Interlinked Model Investigation

SCREENING AND DUAL ASSESSMENT

PROGRESS REPORT / MAY 2021

Contents

1. Executive summary

To achieve EU targets in the most efficient way, it is essential to have a holistic view of the energy system. The Interlinked Model is a key step in this regard, as it aims at ensuring that the impact of gas and electricity sectors on each other is considered when assessing the value of infrastructure projects.

In 2020, ENTSO-E and ENTSOG have joined forces to further test, verify and develop draft project screening and dual assessment methodologies based upon the outcome of the report "Investigation on the interlinkage between gas and electricity scenario and infrastructure projects assessment", produced by Artelys (hereafter Focus Study). The aim has been to test the methodologies, still under development, and to derive a set of recommendations to identify further improvements in view of the next TYNDP editions. Aim of this analysis has not been to perform a full project assessment.
To test and develop the draft methodologies, specific assumptions have been made and data from TYNDP 2020 has been used and adapted. Moreover, in some instances, assumptions have been made to test the limits of the model.
This study has focussed only on specific items related to these methodologies. The presented results should therefore be interpreted in this perspective and not as a full project assessment. The present report highlights the main outcomes of this implementation and the next steps.

The scope of the project was to elaborate on:

- the identified current and future input needed for the Screening phase that verifies when infrastructure projects need a dual assessment
- the assumptions and the results stemming from the application of the Screening Methodology based on Focus Study results and tested on TYNDP 2020 data
- a set of recommendations for the Screening Methodology and to identify possible areas for further improvement in the upcoming TYNDP editions
- the foreseen approach for Dual Assessment, once the Screening Methodology is applied

The main insights are presented below:

1. Current investigation and test phase have confirmed the outcome that many of the elements identified as relevant for interlinkages are defined at scenarios level, as already highlighted in the 2019 Focus Study.
2. Following the used Screening tests (chapter 8):
    a. under significant presence of Gas to Power, the tested screening identified the countries and projects where it is relevant to perform a dual assessment

b. ENTSOG and ENTSO-E have identified which available TYNDP metrics/indicators can be used for the screening and which ones need additional considerations
   c. ENTSOG and ENTSO-E will work further on the homogeneity of modelling assumptions
3. The Dual Assessment tests (chapters 9 and 10) confirm that, under certain conditions:
   a. this method highlights that the identified projects should be considered in a broader perspective by taking into consideration also the interactions with gas and electricity systems
   b. electricity flexibility affects identified gas constraints and gas project values
   c. price-driven P2G conversion facilities affect the value of electricity projects
4. The investigation shows that ENTSO-E and ENTSOG are capable of assessing electricity and gas projects under dual assessment. ENTSO-E and ENTSOG will work on further refining this approach to take into account additional aspects that have not been considered yet to better inform European public and support decision-makers. This is further developed in section 12.

2. Background

According to Article 8(3)(b) of Regulation 714/2009 and Article 8(3)(b) of Regulation 715/2009, ENTSO-E and ENTSOG have to publish on a biennial basis their TYNDPs.

Article 11(8) of Regulation 347/2013 requires ENTSO-E and ENTSOG to jointly submit to the European Commission and ACER a "[...] consistent and interlinked electricity and gas market and network model including both electricity and gas transmission infrastructure as well as storage and LNG facilities [...]".

On 21 December 2016, ENTSO-E and ENTSOG have submitted the required interlinked model to the European Commission and the Agency for the Cooperation of Energy Regulators (ACER) for approval[1]. The key element of the model submitted by ENTSO-E and ENTSOG was the joint development of scenarios that constitute the basis for the cost-benefit analysis of gas and electricity infrastructure projects. Once the scenarios have been commonly established, the submitted model proposed that each of the ENTSO-E and ENTSOG performs the cost-benefit analysis of infrastructure projects based on their specific tools and methodologies.

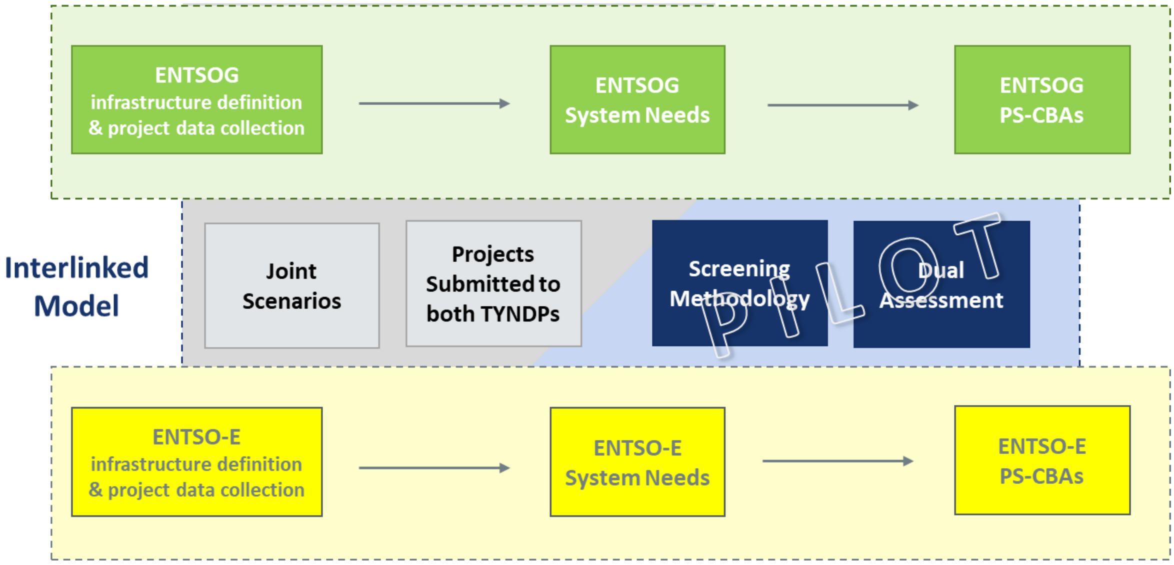
In March 2017, ACER has published its opinion on the ENTSO-E and ENTSOG's draft consistent and interlinked electricity and gas market and network model. ACER was of the view that the level of interlinkage between the modelling of the gas and electricity sectors was insufficient, and that the following phenomena should have been investigated in further details: (1) Interaction of the price formation process for the gas and electricity sectors; (2) Interaction (potential competition and synergies) of electricity and gas infrastructure developments; (3) Cross-sectoral influence of gas and electricity projects.

To meet ACER expectations, in September 2019 the "Investigation on the interlinkage between gas and electricity scenarios and infrastructure projects assessment" commissioned by ENTSO-E and ENTSOG to Artelys, was published[2] (hereafter Focus Study).
Main objective of this Focus Study was to provide ENTSO-E and ENTSOG with the elements allowing them to determine for which kind of projects a more thorough investigation of the impacts of interlinkages should be performed.

[1] ENTSOs consistent and interlinked electricity and gas model in accordance with Article 11(8) of Regulation (EU) No 347/2013 of the European Parliament and of the Council of 17 April 2013 (21 December 2016)

[2] https://www.entsog.eu/sites/default/files/2019-10/ENTSOs%20-%20Interlinkages%20Focus%20Study%20-%20Final%20report_31%20Oct.pdf

In 2020, ENTSO-E and ENTSOG have started jointly working to develop and implement a project screening methodology, taking into account the outcomes of the Focus Study as well as to develop a dual assessment methodology for electricity, gas and hybrid projects for its application as a pilot project on the basis of TYNDP 2020 and as an extensive analysis for the TYNDP 2022 and further.



The outcome of this investigation also provides input to the TYNDP scenarios development process (also part of the overall Interlinked Model).

In accordance with above mentioned Article 11 of Regulation 347/2013, the updated Interlinked Model, once approved by the European Commission, will be included in the CBA Methodologies which shall be applied for the preparation of each subsequent TYNDPs to be developed by ENTSO-E and ENTSOG. The Interlinked Model will be considered as an additional element of the CBA Methodologies, considering the regulatory framework already set for the current or under development methodologies.

3. Role of scenarios in the joint ENTSO-E and ENTSOG interlinked model

Scenarios are at the centre of the joint interlinked model by ENTSO-E and ENTSOG, and their central role was confirmed by Artelys in the study published in 2019.
Since TYNDP 2018, the joint TYNDP scenario building process has ensured wide stakeholder engagement in both ENTSO-E and ENTSOG processes and full consistency between gas and electricity infrastructure modelling.
Furthermore, the Interlinked Model as developed by ENTSO-E and ENTSOG is an original and permanently improving and evolving process, which requires extensive research and innovation with each new TYNDP edition. For TYNDP 2020, the interlinked joint scenarios were developed to an extent never reached by any other existing model, considering a full energy model with country detailed data, based on the European Climate and Energy targets and National Energy and Climate plans, and developed in total transparency with extensive stakeholder involvement. The TYNDP scenario building process ensures full consistency across all energy sectors, including hybrid consumption technologies[3], and produces all the necessary data to perform the relevant regulatory tasks set out in the TEN-E regulation as part of the TYNDP.

4. The Focus Study

The main objective of the Focus Study was to provide the elements allowing ENTSO-E and ENTSOG to determine which kind of projects require additional investigation on the impacts of interlinkages.

The outcome of the application of the Focus Study should be:

- Determine projects that are assessed in a satisfactory manner with the current CBA methodologies, to be treated according to the "usual" ENTSO-E and ENTSOG TYNDPs approaches
- Determine projects for which further interlinkages than those captured in the scenario building phase are important for further investigation

The objective of the Study was to propose recommendations for ENTSO-E and ENTSOG to develop a screening methodology. To achieve this objective, the focus study proceeded the following four tasks: (1) identification of all relevant interlinkages between the gas and electricity sectors; (2) qualitative assessment of the identified interlinkages via the definition and analysis of use-cases; (3) quantitative analysis of the use-cases to detect the cases where

[3] Hybrid technologies are technologies consuming gas and electricity which create a link between the gas and electricity systems that can affect the assessment of infrastructure projects

an additional investigation of gas and electricity interlinkages during the cost-benefit analysis would be valuable; (4) recommendations for a screening process based on the quantitative results obtained in the third step.

The Focus Study confirmed that interactions between current gas and electricity systems are dependent on scenario assumptions and most of the interactions are already considered in the TYNDP scenarios jointly developed by ENTSO-E and ENTSOG. Additionally, the Focus Study has identified two types of interactions:

- indirect interactions[4], captured at scenario level and, once defined, have no impact on (or are not impacted by) new infrastructure (projects)
- direct interactions[5] (gas-to-power, power-to-gas and hybrid technologies), mostly captured in scenarios. However, in some specific configurations, a project can have an impact on (or be impacted by) the other energy system

Based on this work, ENTSO-E and ENTSOG have developed and tested a methodology to further analyse the impacts of interlinkages on the assessment of the projects that have been flagged by our proposed screening process.

5. Scope of the pilot project

Main objectives of the investigation carried by ENTSO-E and ENTSOG were:

- to identify potential interlinkages between electricity and gas sector based on the Focus Study results and on the TYNDP 2020 data and scenarios
- to propose recommendations for a dual assessment methodology to electricity, gas and hybrid projects

The outcome of this investigation also provides input to the TYNDP scenarios development process.

The analysis was based on TYNDP 2020 inputs. When needed, additional assumptions have been made for the purpose of testing the described approach.

The scope of this document is to inform on:

- the identified current and future input needed for the Screening phase

[4] An interaction is said to be indirect if gas and electricity are linked via a third sector. For example, the link between electric vehicles and gas vehicles is an indirect interaction since the electricity and gas are linked via mobility.

[5] An interaction is said to be direct if both electricity and gas are inputs or outputs of the interaction. For example, a CCGT is a direct interaction between the gas and electricity sectors as it consumes gas to generate electricity.

- the assumptions and the results stemming from the application of the Screening Methodology based on Focus Study results and tested on TYNDP 2020 data
- a set of recommendations for the Screening Methodology and to identify possible areas for further improvement in the upcoming TYNDP editions
- the foreseen approach for Dual Assessment, once applied the Screening Methodology

6. Stakeholder engagement

Stakeholder collaboration and feedback represent an important element of the Interlinked Model process and will continue to be in future editions.

In addition to the stakeholder involvement organised as part of the Focus Study development[6] and of the TYNDP 2020 Scenario Report development[7], ENTSOG and ENTSO-E have finalised this Report considering the feedback and recommendations received from:

- Group of External Stakeholders "Prime Movers" (webcos on July 2020 and February 2021)
- The European Commission and ACER (webco on 7th October 2020)
- Madrid Forum (23rd and 24th October 2020)
- Copenhagen Infrastructure Forum (29th October 2020)

[6] For more details please refer to https://www.entsog.eu/events/entsos-investigation-on-the-interlinkage-between-gas-and-electricity-scenarios-and-infrastructure-projects-assessment#welcome

[7] For more details please refer to https://www.entsos-tyndp2020-scenarios.eu/stakeholder-feedback/

7. Input used in the investigation phase

The input used in the investigation phase are described below.

> Electricity and gas demand and supply data

Electricity and gas demand data, as well as electricity installed capacities and gas supply potentials, were taken from TYNDP 2020 scenarios. Since the investigation was carried out in parallel with the ENTSO-E and ENTSOG TYNDP 2020 processes, the screening phase was applied on preliminary scenario data while the dual assessment phase on final scenario data. The investigation has been carried on all three TYNDP 2020 scenarios (National Trends; Distributed Energy; Global Ambition)[8].

> Infrastructures

The selection of the proper level of development of infrastructure is key for the identification of infrastructure gaps (constraints) and for a reliable system and project assessment.
For this investigation ENTSO-E Reference Grid[9] 2025 and all three ENTSOG Infrastructure Levels ("Existing"; "Low"; "Advanced")[10] have been considered. Both ENTSO-E and ENTSOG grids are based on the projects collected in TYNDP 2020.

ENTSOG collects the following project categories: transmission (TRA); underground storages (UGS); regasification terminals (LNG); energy transition projects (ETR) projects. More details can be found in the TYNDP 2020 ENTSOG Practical Implementation Document[11]. Once collected, a draft list of projects is also published by ENTSOG[12].
Similarly, ENTSO-E collects the following project categories: transmission; storage projects. ENTSO-E does not consider electricity generation plants as projects as they are not included in the Regulation (EU) 347/2013. More details can be found in the TYNDP 2020 ENTSO-E "Guidance for applicants - Transmission and Storage Project Promoters"[13]

In terms of maturity status, ENTSOG differs projects by FID projects (projects that have taken the final investment decision before the closure of TYNDP project collection period); advanced projects and less-advanced.

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[8] For more details on TYNDP 2020 joint scenarios please consult the page https://www.entsos-tyndp2020-scenarios.eu/

[9] For more details on ENTSO-E Reference Grid please consult page 52 of the ENTSO-E Identification of System Needs https://eepublicdownloads.azureedge.net/tyndp-documents/IoSN2020/200810_IoSN2020mainreport_beforeconsultation.pdf

[10] For more details on ENTSOG TYNDP 2020 Infrastructure Levels please consult TYNDP 2020 Annex D at https://www.entsog.eu/sites/default/files/2020-12/entsog_TYNDP2020_Annex_D_Methodology_201221.pdf

[11] https://www.entsog.eu/sites/default/files/2019-05/TYNDP%202020_Practical_Implementation_Document_20190502_0.pdf

[12] https://www.entsog.eu/sites/default/files/2019-11/__TYNDP%202020_Annex%20A%20-%20Projects%20Tables.xlsx

[13] Guidance for applicants - Transmission and Storage Project Promoters

ENTSO-E considers the following level of maturity: under consideration (investments in the phase of planning studies and under consideration for inclusion in national plans and Regional/EU-wide Ten Year Network Development Plans, TYNDPs, of ENTSO-E); planned, but not yet in permitting (investments that have been included in the national development plan and have completed the initial studies phase (e.g., completed pre-feasibility or feasibility study), but have not initiated the permitting application yet); permitting (investments for which the project promoters have applied for the first permit required for its implementation and the application is valid); under construction (the investment is in its construction phase); commissioned (investments that have come into first operation); cancelled.

> Timeframe

TYNDP 2020 scenarios focus on the following years: 2020, 2025, 2030, 2040 and 2050 (the latter at European level only).
ENTSOG runs system assessment (i.e. identification of system needs/gaps) and PS-CBAs for all above years but 2050 where only scenarios data at EU level are available. ENTSO-E runs the identification of system needs in National Trends 2030 and 2040. Additionally, in TYNDP 2020 ENTSO-E runs cost benefit analyses for all scenarios for years 2025 and 2030.
To ensure consistency and data availability, the investigation phase has been mainly focusing (but not only) on 2030 as assessment year.

> Indicators

The indicators used by ENTSO-E and ENTSOG are defined in their respective Cost-Benefit Analysis (CBA) Methodology[14].
The ENTSO-E and ENTSOG CBA Methodologies are both based on a multi-criteria analysis that includes both monetary and non-monetary indicators, as well as qualitative assessment.
Both Methodologies apply the same principle (Incremental Approach) by assessing project benefits by comparing an indicator under the situations with/without the concerned project.

> Geographical perimeter

Only the countries included in both ENTSO-E[15] and ENTSOG[16] TYNDP geographical perimeters have been considered for this analysis.

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[14] ENTSOG CBA Methodology: https://www.entsog.eu/methodologies-and-modelling#2nd-cba-methodology; ENTSO-E CBA Methodology https://www.entsoe.eu/Documents/TYNDP%20documents/Cost%20Benefit%20Analysis/2018-10-11-tyndp-cba-20.pdf

[15] ENTSO-E perimeter: https://www.entsoe.eu/about/inside-entsoe/members/

[16] The geographical perimeter of the ENTSOG TYNDP covers the EU-28 countries as well as Switzerland, Bosnia and Herzegovina, Serbia and Republic of North Macedonia.

8. The screening phase

The common scenarios jointly developed by ENTSO-E and ENTSOG represent the first step and a cornerstone of the Interlinked Model.
As part of their TYNDP processes, ENTSO-E and ENTSOG assess submitted projects versus the common demand and supply scenarios. Once the interactions are identified at scenario level, the project assessment is carried out by the two associations separately, by applying the metrics as defined in their respective Cost-Benefit Analysis Methodologies.
For this reason, and for the scope of this document, the assessment of projects under this framework is defined hereafter as "single assessment".

The screening phase is applied after the single assessment of ENTSO-E and ENTSOG TYNDPs and is based on common inputs and common assumptions.

Aim of the screening phase is to identify which are the gas projects and the electricity projects that can be considered relevant for a dual assessment and not only for single assessment (i.e. by considering how gas infrastructures influence electricity infrastructures and vice versa).

The Focus Study has identified three main situations when a project can have an impact on (or be impacted by) the other energy system when looking at the electricity and gas systems:

- significant presence of gas-to-power (condition 1, section 8.1)
- significant presence of power-to-gas (condition 2, section 8.2)
- significant presence of hybrid consumption technologies[17] (condition 3, section 8.3)

For each of these conditions, a set of sub-conditions have been identified and they are presented later in this document.
Once these sub-conditions are all met, interlinkages between electricity and gas can be considered relevant and selected for further investigation.

In the case for example of three sub-conditions, the Screening phase can be generally described by the following steps:

- step 1: check if sub-condition X is verified and identify which countries are impacted by it
- step 2: only for the countries where sub-condition X is met, check if sub-condition Y is verified and identify which countries are impacted by it
- step 3: only for the countries where sub-conditions X and Y are met, check if sub-condition Z is also verified and identify which countries are impacted by it

[17] This refers to technologies that link the electricity and gas sectors, such gas hybrid heat pumps

- step 4: from the countries identified select the projects for the dual assessment phase (for some projects, additional filtering criteria can be applied[18])

A schematic overview of the process following the four steps is displayed in Figure 1.

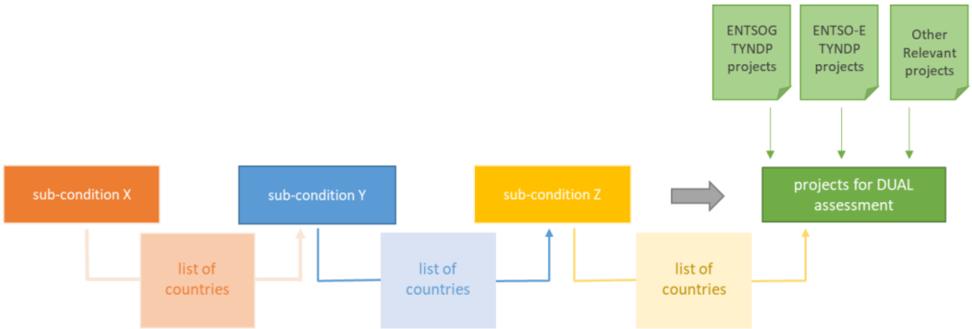

Figure 1 - Screening Methodology general approach

It is important to note that there are projects that, by their nature and definition, need a dual assessment. For example, this is the case for:

- Power-to-Gas projects
- Hybrid projects (e.g., infrastructure projects that enable gas and electricity production whose operation is optimised by looking at both sectors)

These projects are excluded from the application of the Screening phase and qualify automatically for the dual assessment phase.

The Screening and the Dual Assessment phases:

- can be based on the same input used for the single assessment
- can be built and benchmarked with the results from the single assessment

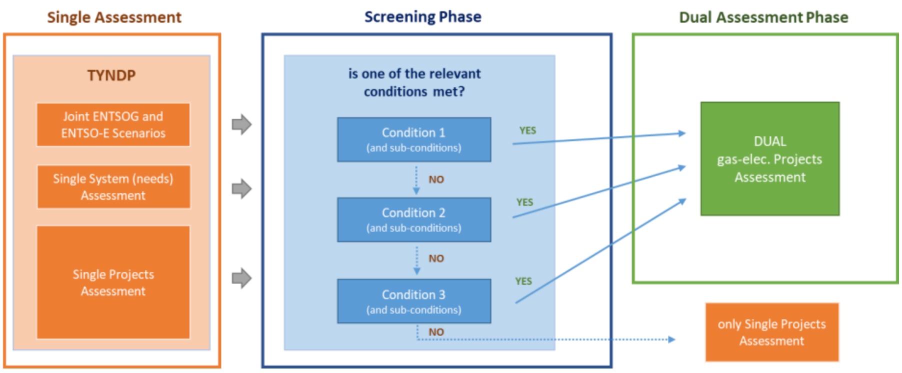

Figure 2 - Application of the Screening phase

[18] For example, a gas metering station project or any project not creating a capacity increment at a given interconnection point will have, most likely, negligible interlinkages impact and could be removed from the projects eligible for dual assessment even if built in a country identified by the screening.

8.1. Condition 1 – Interlinkages in the presence of gas-to-power

There may be some interactions between gas/electricity system and infrastructure projects, in the presence of Gas-to-Power (G2P) and in areas with a high share of G2P if the gas consumption required for electricity purposes creates constraints on the gas system (congestions or security of supply issues).

The Artelys Focus Study has identified the following sub-conditions, as shown in Figure 3, to be followed in order to check whether a dual assessment would be relevant in the presence of gas-to-power.

Figure 3 – Condition 1 and its sub-conditions - Interlinkages in the presence of gas-to-power

If the sub-conditions on the three blocks are satisfied, then there is an interaction between the gas and electricity systems due to the presence of G2P and a dual assessment should be conducted when considering a future gas or electricity infrastructure project.
In the next sections it is further described the above-mentioned sub-conditions.

8.1.1. Sub-condition 1.1 – significant quantity of G2P

G2P interactions between gas and electricity systems that affect gas and electricity infrastructure projects assessment start occurring when the gas consumption due to power conversion creates congestions on the gas network, leading to either security of supply issues or price differences beyond the gas transmission tariffs.
The Focus Study has identified qualitatively that as long as the share of G2P in the gas consumption is below 5% of the total gas consumption, the interactions created by G2P remain limited and do not trigger the need for a dual system assessment.

Sub-condition 1.1 can be derived per scenarios by comparing the level of gas demand for power generation vs the level of total gas demand. The result will be a list of the countries where this sub-condition is verified.

$$\text{G2P YearlyGasConsumption} \geq 5\% \text{ YearlyGasConsumption}.$$

Depending on the scenarios and the year chosen the number of countries might change.

The level of final gas demand is not dependent on the ENTSOG Infrastructure Levels. However, the gas demand dedicated to electricity generation (G2P) can be affected by the interconnection capacities in the Reference Grid, since these have an impact on the generator dispatch and therefore the gas consumption to produce electricity.
Moreover, there are other factors that can influence the level of G2P, such as the maintenance profile, climatic dependent data for variable renewable energy sources and hydropower generation.

Below an example (0 for sub-condition not met / 1 for condition met).

	G2P Yearly Consumption	Gas Final Consumption	G2P Consumption / Total Gas Consumption	Sub-conditions met?
Country 1	12.2	59.8	16.9%	1
Country 2	39.8	133.1	23.0%	1
Country 3	3.5	22.6	13.4%	1
Country 4	0	20.1	0.0%	0
Country 5	10.1	200	4.8%	0
Country 6	259.5	1395.3	15.7%	1
Country 7	4.2	17.6	19.3%	1
Country 8	2	4.4	31.3%	1

Table 1 - Application of sub-condition 1.1 to TYNDP joint scenarios data

As mentioned, the Focus Study has identified qualitatively a threshold of 5%. Cases where gas demand for power generation is lower than 5% of the overall gas demand do not trigger the need for a dual system assessment.

It must also be noted that this sub-condition 1.1. represents only the first of the three verifications carried out to screen countries and projects. Below a graphical representation of the share of gas to power demand in all the considered countries vs the overall gas demand for years 2030 and 2040.

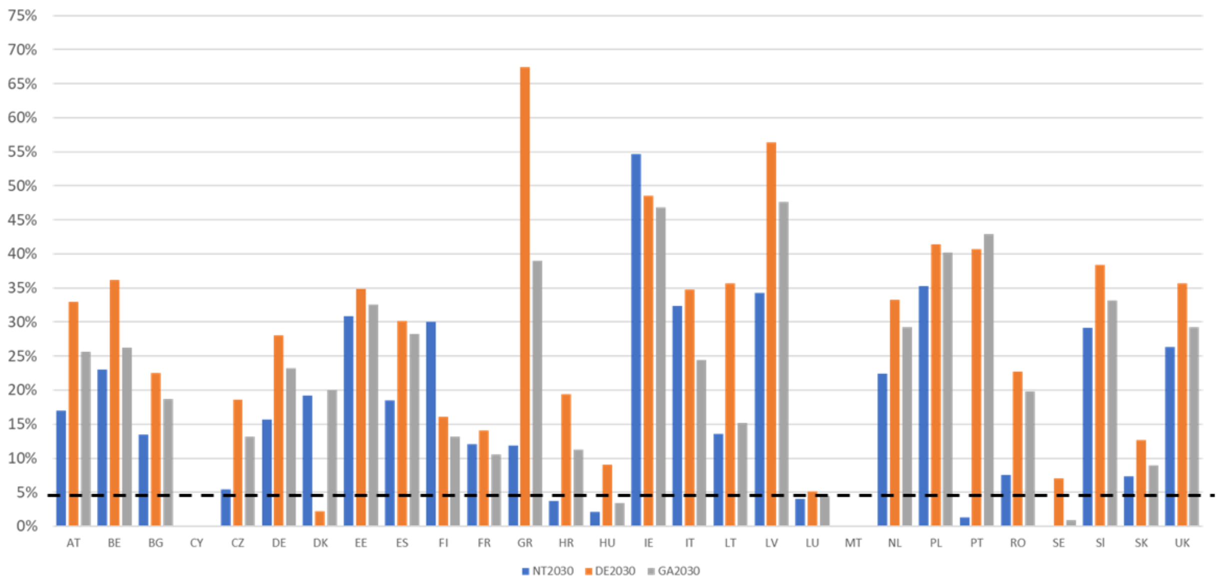

Figure 4 – Percentage of gas demand for power vs overall gas demand (2030)

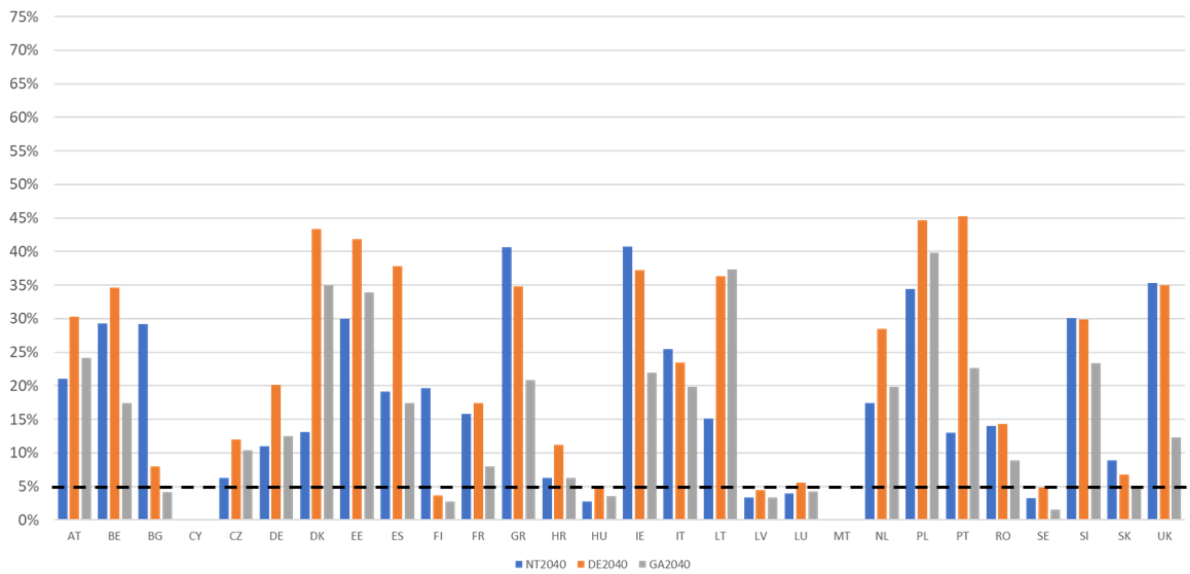

Figure 5 – Percentage of gas demand for power vs overall gas demand (2040)

The number of countries showing gas demand for power lower than 5% of the overall gas demand is limited. Therefore, many countries fulfil the first sub-condition to trigger a dual assessment.

Additionally, if compared with the results of sub-condition 1.2 (8.1.2), it can be observed that in some cases countries show gas constraints even in cases where the G2P share is lower than 5% of the total gas demand. This is the case for Sweden (under curtailed demand indicator) or

Croatia (under the SLID indicator). Such situations should be therefore treated on an individual basis to see whether the threshold should be lowered for a specific country or not.

8.1.2. Sub-condition 1.2 – presence of gas constraints

Based on the Focus Study outcomes, G2P assets can add constraints to the gas system that directly depends on the electricity system. These constraints can take different forms:

- an augmentation of the dependence of the area to a given gas supply source
- when the gas consumption due to power conversion creates congestions on the gas network, leading to either security of supply issues (gas SoS issues due to yearly supply) or price differences beyond the transmission tariffs a constraint on the gas storage level due to the seasonality of the gas demand

This second sub-condition will be applied only to those countries for which also sub-condition 1.1 is verified.
The above constraints can be measured by using different ENTSOG TYNDP indicators or simulations output. Different indicators allow to capture different gas constraints. Below more details.

Independently from the chosen indicator, the same indicators should be used during the Screening and Dual Assessment phase to ensure consistency and comparability of the results.

In this pilot project, ENTSO-E and ENTSOG have investigated the following ENTSOG TYNDP indicators[19] to identify infrastructure gaps:

- Demand Curtailment (CR) and Single Largest Infrastructure Disruption (SLID), both indicators measure the resilience of the European gas system (in terms of curtailed demand) to cope with various stressful events (climatic stress and supply route and infrastructure disruptions)
- Minimum Annual Supply Dependence (MASD), this indicator measures the unreducible share of this source necessary for a country to cover its demand on a yearly basis (i.e. in case of average daily demand)
- Price Convergence, self-explanatory

Current investigation showed that the CR and SLID indicators are suitable for interlinkage applications. a shortage of gas in the power sector doesn't necessarily lead (or not partially) to infrastructure gaps in the gas system if the same electricity could be generated through alternative means.

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[19] For more details please refer to ENTSOG CBA Methodology (https://www.entsog.eu/methodologies-and-modelling#2nd-cba-methodology) and to ENTSOG TYNDP 2020 Annex D at (https://www.entsog.eu/sites/default/files/2020-12/entsog_TYNDP2020_Annex_D_Methodology_201221.pdf)

On the contrary, in ENTSOG MASD indicator, given a certain level of gas demand, determining the level of dependence from a supply source is not straightforward (like in CR and SLID) and an arbitrarily "dependence threshold" has to be chosen (e.g. 25%). This threshold is not automatically related to market situations since a country could aim at increasing its share of dependence from a specific supply source to improve its security supply and its diversification, independently from the price of the supply source itself (price that might also change over the assessment period based on the signed supply contracts). Additionally, even reducing the share of a more expensive supply source without fully replacing it, may not result in a significant change in marginal prices (being the marginal supply source the one setting the marginal price). In such situations where gas demand and/or gas prices do not change, the use of this indicator in the context of Interlinked Model has some intrinsic limitations.

With regards to the Price Convergence indicator, ENTSOG assesses the gas system and projects, considering tariffs (and related sensitivities) that have an impact on gas flows. For the Interlinked Model application, results from simulations without the infrastructure tariffs could be used to better identify countries affected by price differentials due only to infrastructure bottlenecks. While this input is not directly available in TYNDP 2020, it should be considered for the future editions.

Below the results for the CR and SLID indicators for the year 2030[20]. In red are the countries that show gas constraints in terms of risk of demand curtailment.

[20] Result for year 2020, 2025 and 2040 are available in ENTSOG TYNDP 2020.

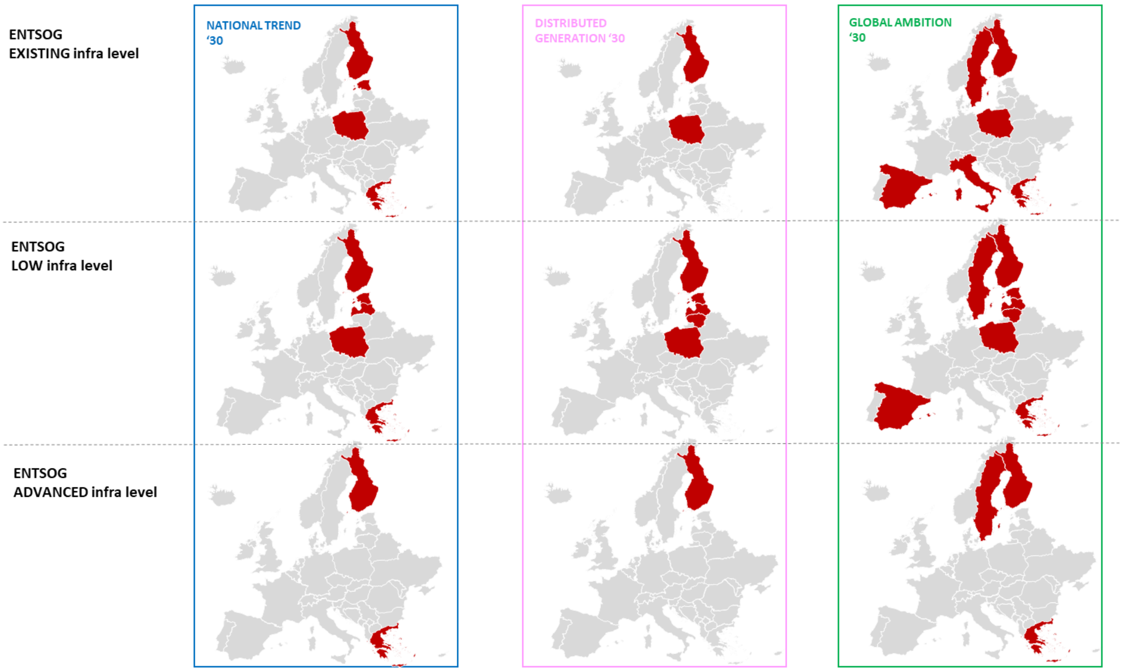


Figure 6 – Countries with gas constraint under Curtailed Rate indicator – CR (2030)

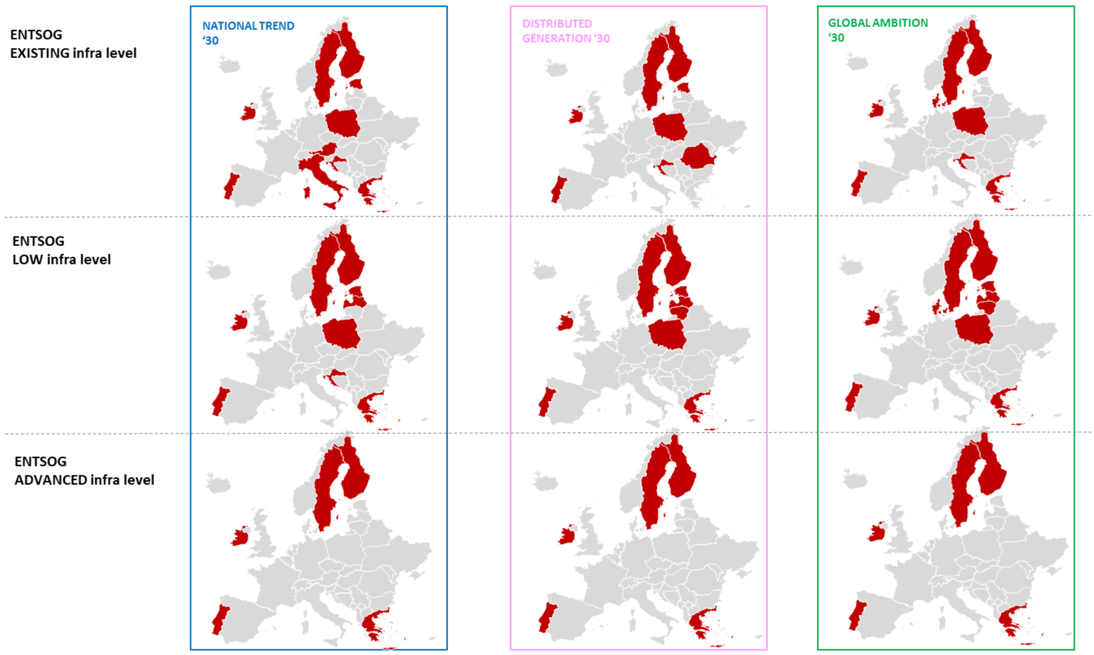


Figure 7 – Countries with gas constraint under Single Largest Infrastructure Disruption indicator – CR (2030)

It can be seen that in some cases when compared to existing infrastructure level, more countries are affected by risk of gas demand curtailment under low or advanced infrastructure levels. Given the same year and the same level of gas demand, this is due to the fact that projects included in the low or advanced infrastructure levels allow more countries to cooperate and share risk of demand curtailment (so overall the gas demand curtailed is reduced by reallocation among more countries). More detailed information can be found in the ENTSOG TYNDP 2020 System Assessment[21].

8.1.3. Sub-condition 1.3 – presence of electricity flexibility

In addition, according to the Focus Study, the interaction between the gas and electricity systems only occur when there is some flexibility on the electricity system side that allows for a reduction of the electricity generation from G2P. These flexibilities could include available capacities of electricity interconnections, electricity storage or generation assets that are more expensive than G2P in a situation where the gas system is not constrained.
Such flexibility is called in this document "capacity margin" [22] and, in the context of the interlinkages, aims at answering the following question: how much generation and interconnection capacity is still available in countries with gas constraints in order to reduce the G2P consumption and (partially) relief the constraints on the gas system?

This third sub-condition will be applied only to the countries for which also sub-condition 1.1 and sub-condition 1.2 are met.

The Focus Study states that LOLE (Loss Of Load Expecation) could be used as a measure for capacity margin.
ENTSO-E and ENTSOG have investigated a different approach since the LOLE computation does not consider the type of fuel of power plants used in the electricity system. The approach proposed aims at quantifying the contribution of interconnectors and power plants that are fuelled by fuels other than gas, under gas constraints.

To answer this question, the following approach is implemented in electricity market tools:

1. Reference case: a market simulation is performed considering 35 climate years using a single maintenance profile for thermal units.
2. Stress case: In this scenario all the gas to power units located in the areas where there are gas constraints (including market participating Other non-RES[23]), are considered totally or partially unavailable during the day of the peak gas demand. In the case a gas power plant does not have any must-run constraints of any nature (e.g., electricity generation, heat needs, balancing reserves, etc.), then it is considered as unavailable. When a gas power plant has must-run constraints, then this power plant only runs at the minimum level to fulfil these constraints. This case is also evaluated whilst running

[21] https://www.entsog.eu/sites/default/files/2021-01/TYNDP2020_System_Assessment_0.pdf

[22] It is important to clarify that in this document the term "capacity margin" has a different meaning compared to the meaning given in the context of adequacy studies in the electricity sector. Therefore, the meaning given to this term in the present document is for its exclusive use in the context of the interlinkages between electricity and gas sectors.

[23] The "Other non-RES" power plants can include CHP (non-renewable), Waste (non-renewable), non-dispatchable thermal generation, among others.

simulations for 35 climate years.

The electricity capacity margin for each country in the context of the gas curtailed demand indicators (CR and SLID) is calculated as follows:

$$ECM\ Country = G2P_{95\%,reference} - G2P_{stress} - \frac{\Delta ENS_{CY}}{\eta}$$

Where

- $G2P_{95\%,reference}$ is the gas consumption in the specific country being analysed, in reference case. The value used corresponds to the one that is greater than 95% of the G2P consumption among all the simulated climate years.
- $G2P_{stress}$ is the gas consumption in the case with the stress for the climate year chosen above, for the country *being analysed*. It basically indicates the minimum gas possible for gas power plants (they will have gas only if they have must-run obligations due to security reasons).
- ΔENS_{CY} is the difference in the annual energy not served (electricity), in the country *under analysis,* between the case with the stress and without it for the climate year chosen above.
- η is an estimation of the efficiency of gas power plants (e.g. 50%).

This expression can be interpreted as a metric of how much the gas consumption for electricity generation can be reduced respecting possible security constraints in which gas power plants are involved. The fact of using the climate year in which the gas consumption for electricity is higher than the 95% percent of the rest of the climate years, is to be consistent with the gas curtailed demand indicator which uses the maximum gas demand that occurs every 20 years (i.e. 1-20). In the same way, the Other non-RES category in the electricity system is always available (with the only exception for the Other non-RES that are market participant) as they are used for other purposes different than electricity generation (e.g. heating) and therefore they cannot be directly replaced by other electricity generator (however this could depend on the reality of each Member State). Finally, this expression considers that the gas consumption can be reduced as far as it does not increase the energy not served in the electricity sector[24]. The reason for this is that the gas curtailment assumed to impact the G2P could occur also in non electricity sectors (for example interruptible industrial gas costumers).

The period for which the capacity margin is computed must be consistent with the period used to identify the constraints on the gas system (daily peak, yearly average).
In cases where the electricity capacity margin is computed for a specific date (for consistency with single day in which the gas constraint is identified) it is recommended to consider a

[24] There is a simplification in this case, since the unavailability of the gas power plants in one country could potentially also generate unserved energy in a neighbouring country

sensitivity on the level of variable RES. This could be done by assessing the gas constraint and the electricity capacity margin under the Kalte Dunkelflaute case or similar cases.

As part of the investigation, ENTSO-E and ENTSOG have also computed the capacity margin when the MASD indicator is used to measure the gas constraints. Given the consideration in section 8.1.2, the capacity margin for the MASD indicator has been only included as part of this document Annex.

8.1.4. The overall process for condition 1

The overall process for screening relevant countries and projects under condition 1 (significant presence of G2P) can be graphically represented as follows.

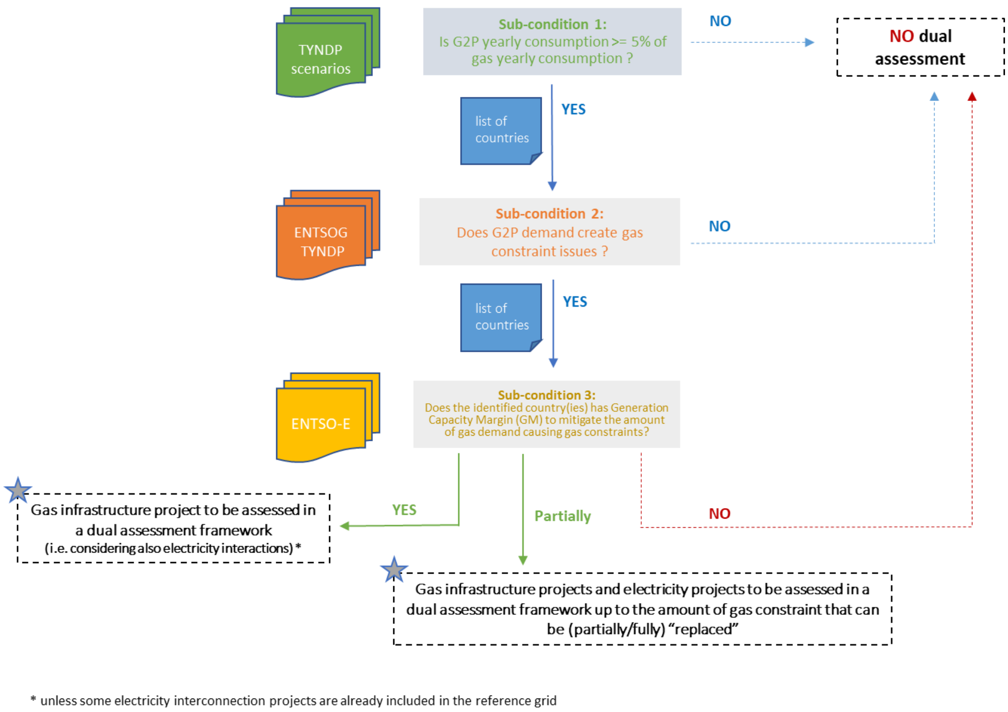


Figure 8 – Screening Methodology Condition 1, overall process

8.1.5. Results

Once implemented, the screening of condition 1 allows for the drafting of a list of countries for which dual assessment should be further investigated.

Which country and their number highly depends on the indicator used to identify the gas constraint and the way the electricity margin is computed.

The choice of the grid has also a significant impact on the identified constraints (the higher the number of projects assumed to be implemented the lower the gas constraint/the higher the electricity capacity margin available).

Below, the results from the application of the Screening Methodology for condition 1.
For curtailed demand indicators (CR and SLI), countries are marked as relevant in the maps below if the Screening Methodology shows results under at least one of the different stressful cases and according to the following criteria:

- green: the electricity capacity margin allows to fully mitigate the gas constraint
- orange: the electricity capacity margin is not enough yet to fully mitigate the gas constraint

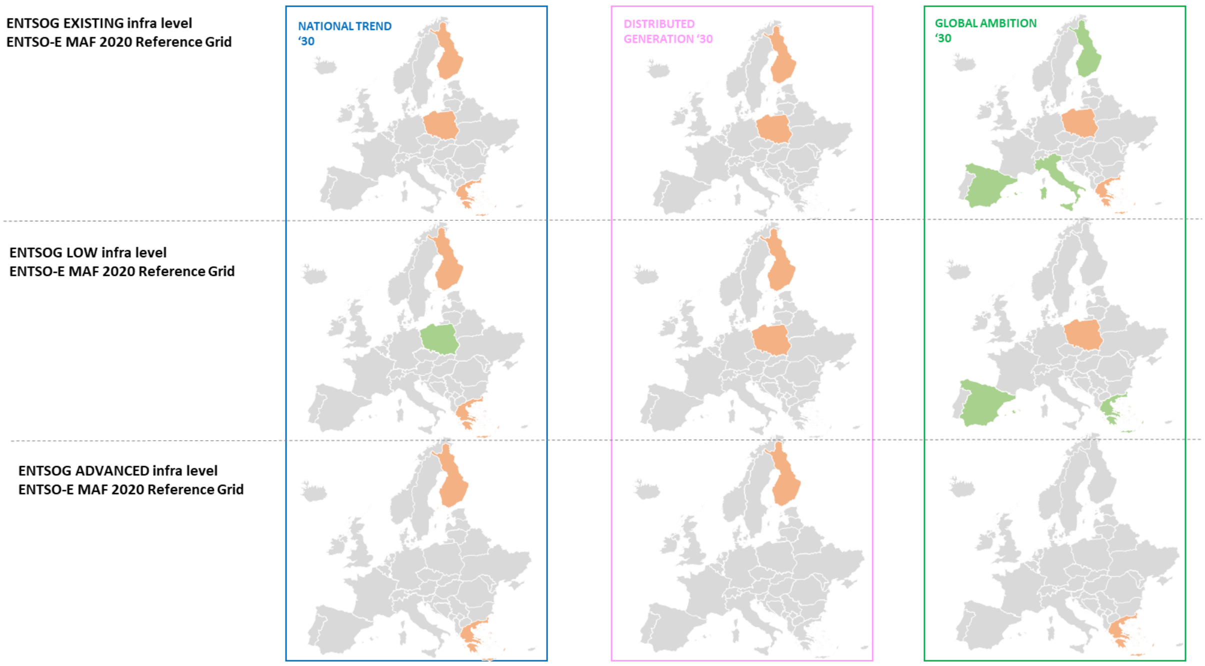


Figure 9 - Under Curtailed Rate indicator – CR (2030)

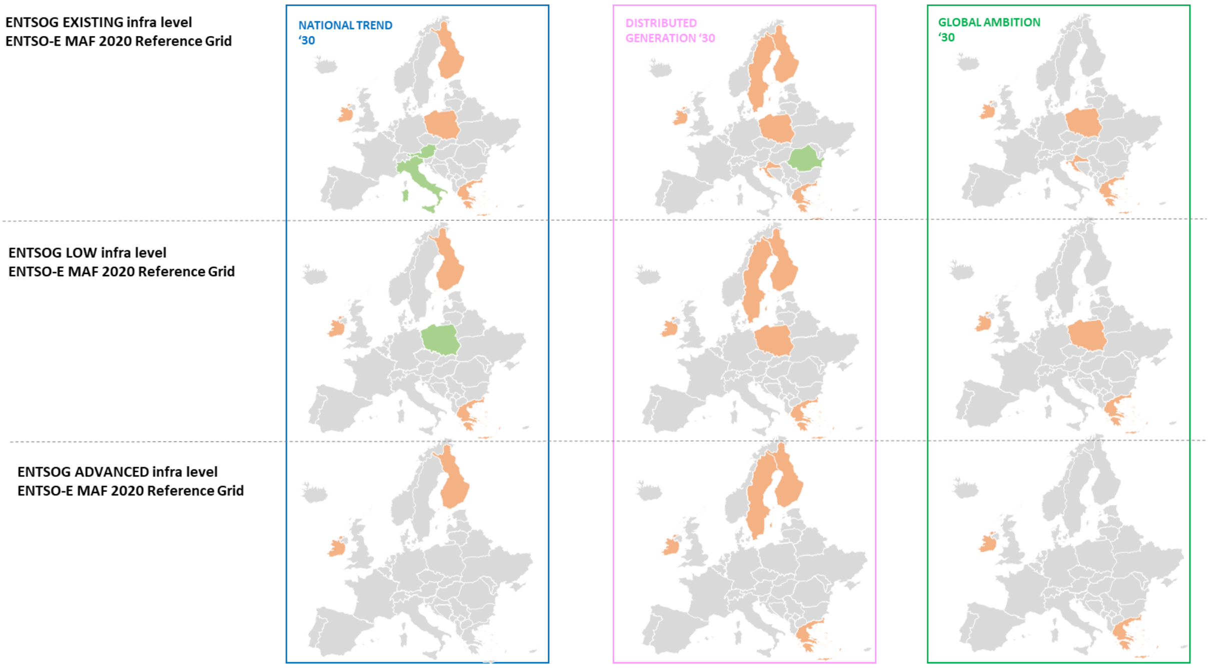


Figure 10 - Under Single Largest Infrastructure Disruption indicator – SLID (2030)

Figure 11 - Under Curtailed Rate indicator – CR (2040)

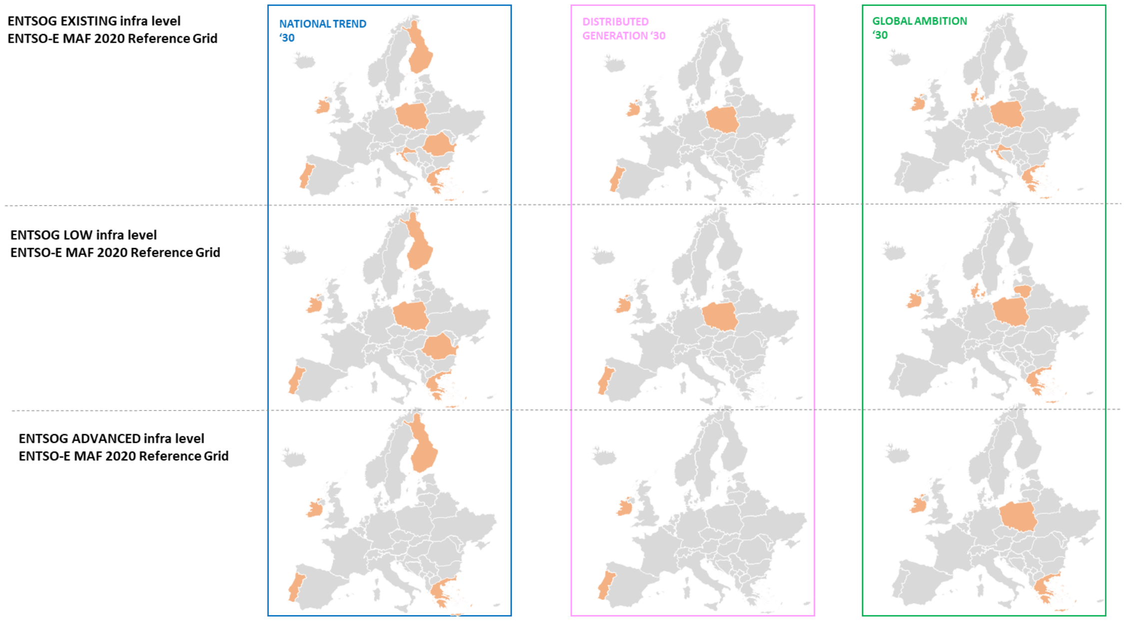


Figure 12 - Under Single Largest Infrastructure Disruption indicator – SLID (2040)

In the case of same countries appearing relevant for dual assessment under more than one indicator (and configurations), these countries should be prioritised when performing the dual assessment.

Results for MASD indicator are included in this document Annex.

The above maps represent the results of the screening phase applied on preliminary scenarios data (see section 7). At the stage of the dual assessment phase, based on the final scenarios data, a consistency check was run and only the countries still resulting impacted by the gas constraint were considered for the dual assessment test.

8.2. Condition 2 – Interlinkages in the presence of power-to-gas

As an electricity-consuming and gas-producing technology, power-to-gas (P2G) creates a link between the gas and electricity systems that can affect the assessment of infrastructure projects.

According to the Focus Study, the characteristics of the interlinkage differ depending on the way power-to-gas assets are operated:

- P2G can be operated with a dedicated electricity generation capacity without connection to the electricity grid or to satisfy a given need of gas (in this case no interlinkage)
- P2G can be operated based on the electricity wholesale market price (or any other relevant price from the markets where it participates) or P2G can be operated based on the system's point of view to solve more constraints[25] on the network (triggering possible interlinkages) or improve balancing. However, there could be P2G facilities which are hybrid with dedicated vRES-e production but also with the possibility of consuming energy from the grid.

The Focus Study has identified the following sub-conditions to be verified in order to check whether dual assessment would be relevant for electricity projects.

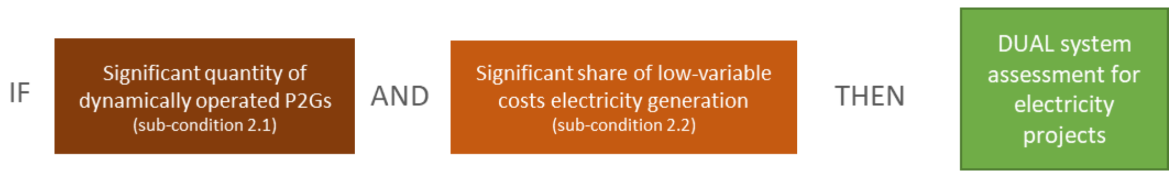


Figure 13 – Condition 2 and its sub-conditions - Interlinkages in the presence of power-to-gas

Sub-condition 2.1 and 2.2 allow to identify dual assessment needs for electricity projects in terms of

- interaction between P2G capacities and electricity interconnectors/storages: P2G consumption can reduce the volume of electricity that is available for exports and increase the local price of electricity thus reducing the depth and value of energy exchanges. This is especially true in areas with high P2G and vRES-e or nuclear capacities (the latter function either in must-run or want to maximize their use). Hence,

[25] In the Focus Study they refer more to "local" constraints, from a systemic point of view, electricity which is suitable for use in electrolysers is described as 'non-integrable green electricity'. This is green electricity that cannot be directly integrated into the electricity system. This can happen for two reasons: (1) there are no recipients for green electricity in the electricity system; (2) the electricity cannot be transported to users for technical reasons. Thus, P2G on a systems point of view is not only related to local constraints in the network.

depending on the consumption profiles, the benefits from interconnection exchanges could be influenced by the presence of price-driven P2G
- synergies between P2G capacities and electricity interconnectors/storages: if the P2G capacities are in an area next to another area with high RES surpluses, a new electricity interconnection could allow to export the cheap electricity to the area with P2G capacities

When both areas have access to cheap electricity generation technologies, both phenomena can appear simultaneously.

If the gas converted from P2G is higher than the local gas consumption, and the existing gas export and storage capacity are saturated, it can increase the value brought by gas interconnection projects. A third sub-condition should therefore be checked.

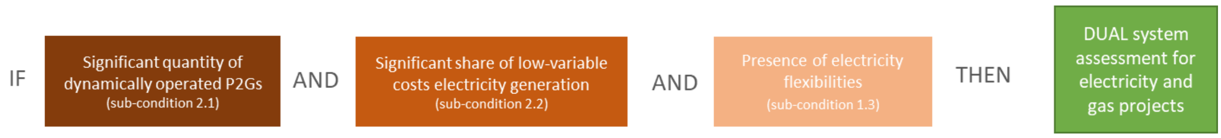


Figure 14 – Condition 2 and its sub-conditions - Interlinkages in the presence of power-to-gas

As mentioned at the beginning of this section, P2G projects (and other hybrid projects) are by default considered eligible for Dual assessment phase. These will be treated directly in the chapters dedicated to the Dual Assessment.

8.2.1. Sub-condition 2.1

The price-driven or system-driven P2G has a significant impact only if it represents a significant part of the electricity system. The Focus Study has assessed that below the following threshold, it is not useful to perform a dual system assessment of electricity and gas infrastructure projects.

$$\mathrm{P2Gcapacity} \geq 5\% \text{ of } (\mathrm{nuclear} + \mathrm{VRESe})\mathrm{capacity}$$

The result will be a list of the countries where this sub-condition is verified.

The amount of P2G capacity is defined as part of scenario process. TYNDP 2020 scenarios do not consider significant price-driven P2G as electrolysers were modelled outside of the market. For this reason, as part of this investigation phase, additional assumptions on the share of price-driven P2G have been made.
In the future, the share of price-driven P2G will be defined during the scenario development process and could also rely on collected information from project promoters.

Below a graphical representation of the share of P2G capacities in all the considered countries vs variable RES capacity + Nuclear capacity, from TYNDP 2020 scenarios data, assuming that 100% of the P2G capacities are in the market (price-driven).

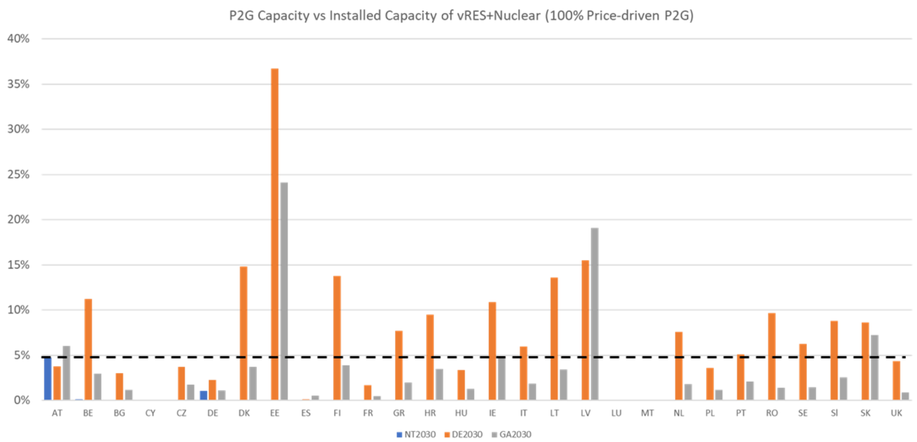


Figure 15 – Percentage of P2G capacity vs variable RES capacity + Nuclear capacity, assuming all P2G capacities in the market for 2030 scenarios

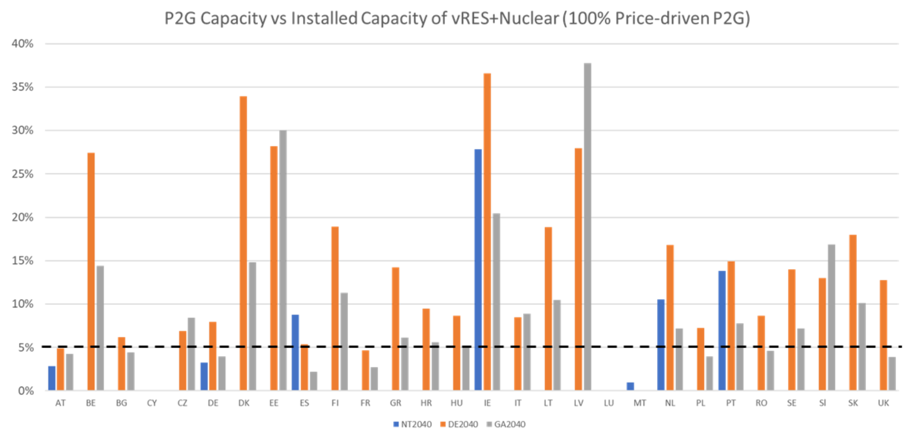


Figure 16: Percentage of P2G capacity vs variable RES capacity + Nuclear capacity, assuming all P2G capacities in the market for 2040 scenarios

8.2.2. Sub-condition 2.2

There is a significant interaction between gas and electricity systems in the presence of P2G as soon as the share of RES and nuclear in the electricity consumption is high and leads to large surpluses of cheap electricity during a significant number of hours.

The presence of pumped hydro storage (or other storage assets[26]), as a competitor of the use of this cheap electricity, increases the share of RES or nuclear admissible in the system before witnessing this interaction.
The simulations performed by Artelys within the Focus Study, have identified the threshold of 60% on the share of low variable costs electricity generation.

$$\frac{\text{vRESe Yearly Generation}^{27} + \text{Nuclear Yearly Generation}}{\text{Electricity Yearly Consumption (incl. pumping)}} \geq 60\%$$

This sub-condition should be checked for countries where sub-condition 2.1 is met but also for its neighbouring countries (independently whether for the neighbouring countries sub-condition 2.1 is met).

- in case the country(ies) identified under sub-condition 2.1 have enough generation from vRES + nuclear to ensure the use of all price-driven P2G capacity, some special situations could be observed. For example, it would be observed the need to assess electricity infrastructure projects in a dual assessment framework since interconnections value could change in the presence of significant P2G when extra generation is used by P2G

The Focus Study considers the consumption from pumped storages in the denominator of sub-condition 2.2, highlighting the fact that pumped storage competes with P2G to exploit the potential surpluses created by the variability of vRES-e generation. However, batteries could also compete for these surpluses.

- in case the country(ies) identified under sub-condition 2.1 does not have enough generation from vRES + nuclear to ensure the use of all price-driven P2G capacity, such electricity could be imported by neighbouring countries. For this reason, also the available import capacity margin within the country(ies) under sub-condition 2.2. and its neighbouring countries should be checked

Based on the current TYNDP scenarios assumptions, the sub-condition mentioned above cannot be checked since P2G capacities in each country are "dedicated" (i.e. there is enough electricity to fully use the assumed P2G capacity in each country). Additionally, even if this

[26] In principle also other flexible technologies, heat pumps, EVs, among others, could be competitors for the use of this cheap electricity.

sub-condition could have been checked, it should always be verified that, before being exported, the electricity surplus is used for the P2G capacities in the neighbouring countries (since presumably cheaper than exporting it to the countries with the constraint).

Below a graphical representation of the share of variable RES generation[28] + Nuclear generation vs overall electricity demand, from TYNDP 2020 data.

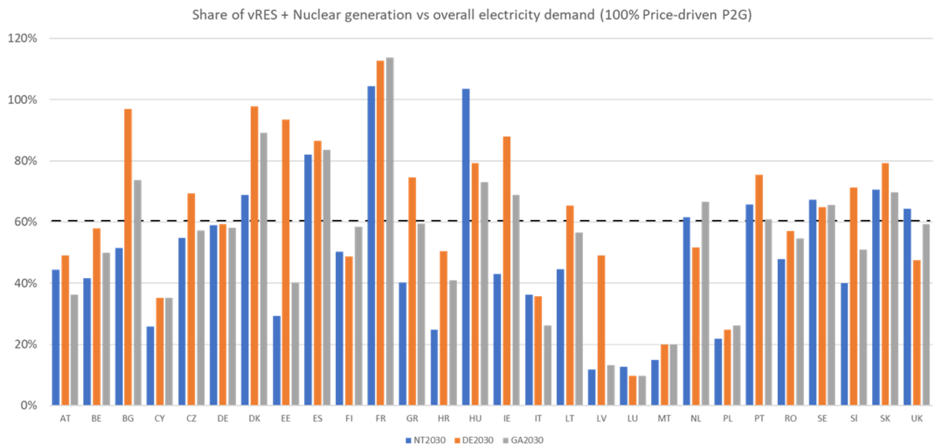


Figure 17 – Percentage of variable RES + Nuclear generation vs overall electricity demand, assuming all P2G capacities in the market for 2030 scenarios

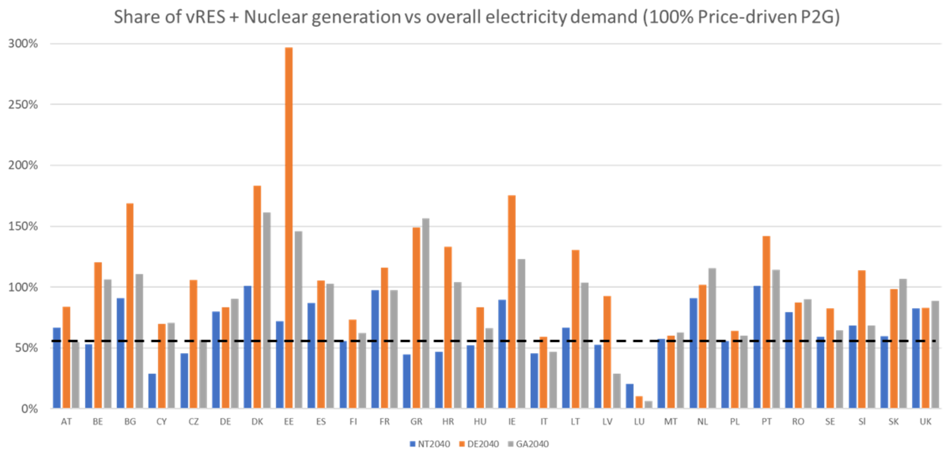


Figure 18: Percentage of variable RES + Nuclear generation vs overall electricity demand, assuming all P2G capacities in the market for 2040 scenarios

28 The generation from the dedicated vRES (used to feed the P2G that is out of the market) is included without discounting the share of it actually curtailed (in the case with 100% price-driven P2G). This curtailment can occur due to operational constraint in the electricity system. In order to discount the contribution of the share of curtailed vRES from the sub-condition 2.2 threshold, such share should be firstly estimated when running the electricity market model simulations.

8.2.3. Sub-condition 2.3

In the single assessment carried out by ENTSOG, given a certain level of conversion of from P2G facilities as defined in the joint scenarios, it is possible to analyse the impact of P2G on infrastructure gaps and PS-CBA: the more national conversion the lower the need for imports. This step therefore does not require an interlinked approach.

However, two other situations could materialise that affect interlinkages electricity-gas:

- electricity projects (for example the ones already included in the electricity reference grid) increase the amount of P2G conversion reducing the need for gas imports and related projects
- the local gas system is such that it cannot make good use of the gas volume converted by P2G facilities and additional export capacity could be increased by gas projects

Both situations will have an impact on gas projects only if the changes in the P2G conversion are relevant.

For the second situation, another condition is necessary to trigger the need for a dual system assessment for gas projects: when the local gas system is such that it cannot make good use of the gas volume produced by P2G. This last condition can be written as:

$$\text{P2G GasConversion } \geq \text{LocalGasDemand} + \text{StorableVolume} + \text{ExportableVolume}$$

If considered under yearly situation, the investigation carried by ENTSO-E and ENTSOG show no “constraints” on the gas side since gas storages run a full cycle without having any increasing impact on the gas amount on a yearly basis.

At the same time, it is important to consider that infrastructure on the gas system is usually sized to cope with a peak situation. Therefore, sub-condition 2.3 should also be verified under certain and more extreme conditions in order to identify cases where the local gas system might not be able to accommodate the total P2G conversion.
This considering some specific assumptions:

- P2G gas conversion, as the daily peak P2G conversion
- local gas demand, as the daily average gas demand
- storable volume, as the storable volume (and consequently injection rate) at the end of September / beginning of October, when the storages are usually at their maximum filling rate before winter)
- exportable volume, daily average cross-border firm export capacity between countries

Similarly, to the case of condition 1, conversion of price-driven P2G facilities depends on the Reference Grid and the projects considered in it.

8.2.4. The overall process for condition 2

The overall process for screening relevant countries and projects under condition 2 (significant presence of P2G) can be graphically represented as follows.

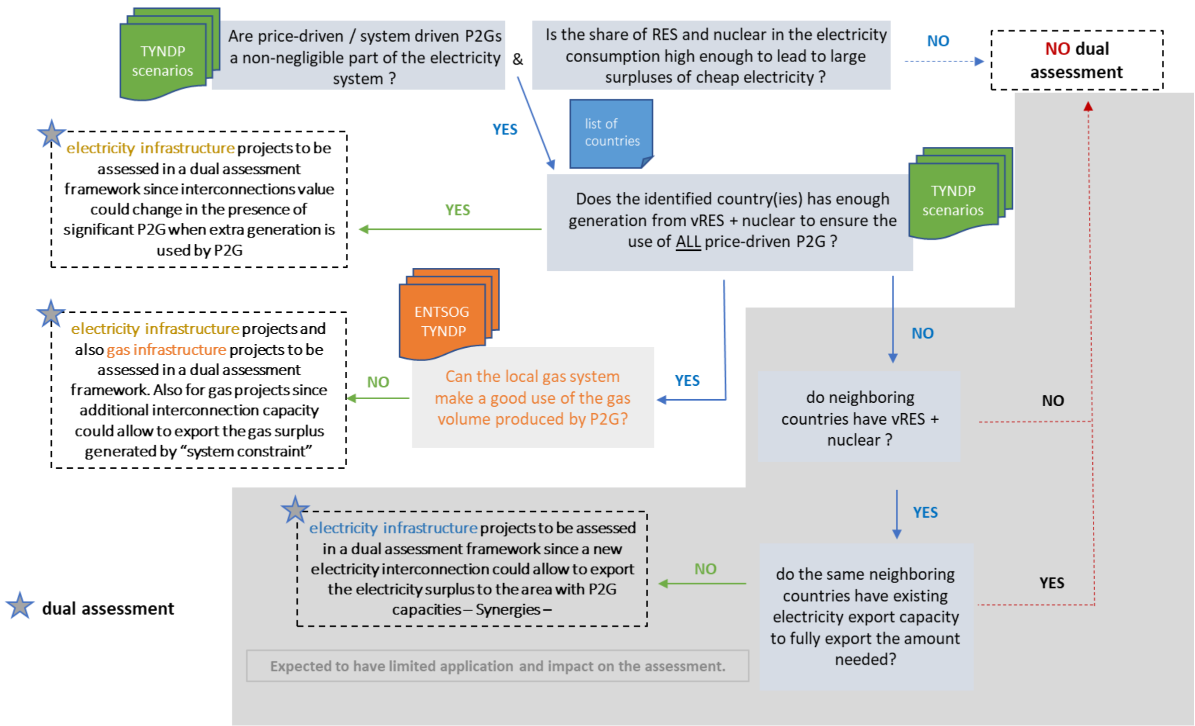


Figure 19 - Screening Methodology Condition 2, overall process

8.2.5. Results

Results are displayed by different level of price-driven P2G penetration and according to the following criteria:

- orange: dual assessment relevant for electricity projects only. The benefits brought by electricity interconnections which export electricity from an area with P2G could be changed by the presence of price-driven P2G
- orange/blue: dual assessment for electricity and gas projects. If the gas conversion from P2G is higher than the local gas consumption, and that the existing gas export and storage capacity are saturated, it can increase the value brought by gas interconnection projects.

In line with the scenario storylines and the foreseen penetration of P2G plants, year 2040 shows a higher number of countries for which dual assessment should be investigated.
The number of concerned countries also depends on the actual share of price-driven P2G capacity.

Only in few cases, the Screening phase results suggest a dual assessment for both electricity and gas projects.

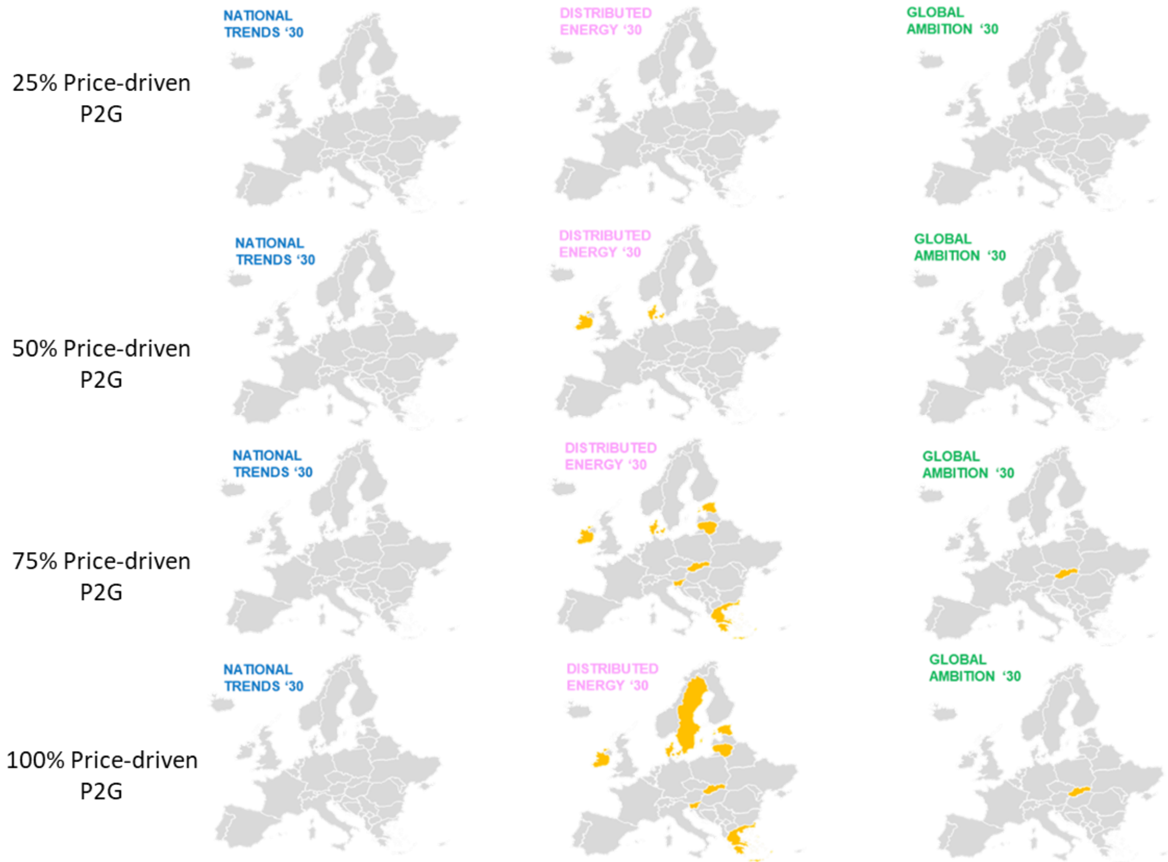


Figure 20 – Year 2030, with different shares (25%/50%/75%/100%) of price-driven P2G

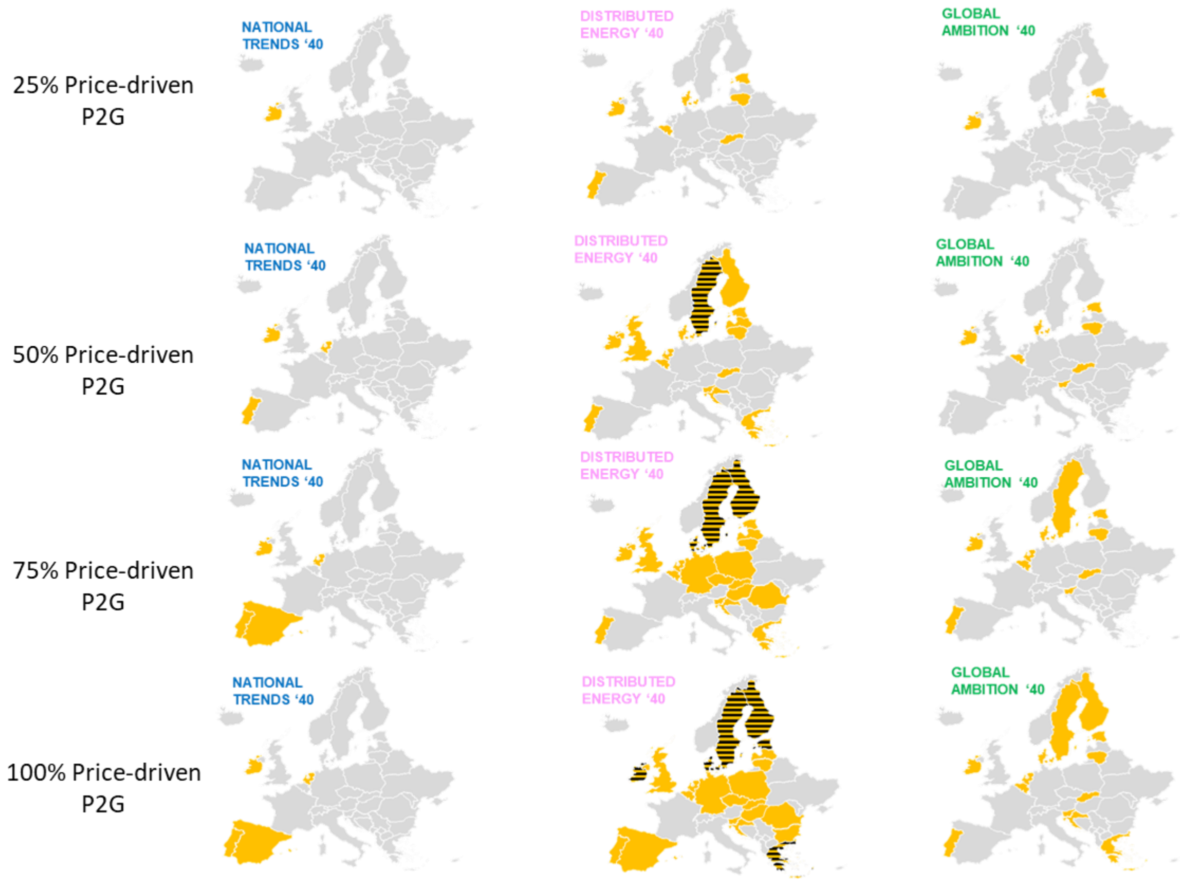


Figure 21 - Year 2040, with different shares (25%/50%/75%/100%) of price-driven P2G

8.3. Condition 3 - Interlinkages in the presence of hybrid consumption technologies

To assess if there is a need for a dual system assessment, when looking at an electricity or gas infrastructure project in the presence of hybrid consumption technologies (hereafter HCTs), two sub-conditions need to be checked:

- Presence of a significant amount of dynamically operated HCT in the electricity and gas systems
- Frequent arbitrage between gas and electricity consumption in the HCT

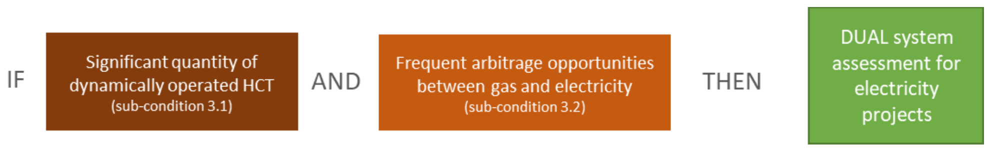


Figure 22 – Condition 3 and its sub-conditions - Interlinkages in the presence of hybrid consumption technologies

8.3.1. Sub-condition 3.1

HCT can create interactions requiring a dual system assessment when studying an electricity or gas infrastructure project when there is a significant share of dynamically operated HCT in the system. The Focus Study has identified that the interaction starts requiring a dual assessment when the capacity of the dynamically operated HCT is above 5% of either the gas or electricity yearly consumption

$$\text{DynamicallyOperated HCT gas consumtpion } \geq 5\% \text{ of total gas consumption}$$

or

$$\text{DynamicallyOperated HCT electricity consumption} \geq 5\% \text{ of total electricity consumption}$$

According to the Focus Study, these constraints should be verifiable at scenario level with the results of the simulations performed. However, given the current and forecasted deployment of hybrid technologies (especially for dynamically operated technologies) the Focus Study anticipated that these constraints will not be met very frequently.

Currently TYNDP 2020 scenarios consider only temperature-driven HCTs. At the stage of the current investigation, sub-condition 3.1 has not been therefore tested and verified.

8.3.2. Sub-Condition 3.2

The interaction created by HCTs occur only if the trade-off between using gas or electricity is a close call.

The interaction thus occurs when, for a given hybrid consumption technology:

$$\frac{\text{GasPrice}}{\text{GasEfficiency}} \sim \frac{\text{ElectricityPrice}}{\text{ElectricityEfficiency}}$$

However, as explained in the Artelys Focus Study, in most cases this is unlikely to happen. Indeed, in the case of hybrid heat pumps, the coefficient of performance of the heat pump component is such that even if it were dynamically optimized versus gas and electricity prices, the heat pump component will be used at its maximum capacity at each hour, the gas boiler being used only as a back-up when the heat pump component is not sufficient to cover the heat consumption.

This represents therefore a very theoretical case, unlikely to happen, and for this reason it was not further investigated. ENTSO-E and ENTSOG should keep monitoring the evolution/change in technologies in order to ensure they will be taken properly into account, when relevant, in other scenarios editions.

8.4. Conclusions and recommendations from the Screening Methodology

This section summarises the main conclusions and recommendations regarding the Screening phase approach.

Section 9 will investigate how much these interactions do change the assessment of projects.

8.4.1. Condition 1

The screening methodology allows for a number of relevant countries and projects to be identified for dual assessment under condition 1.

ENTSOG and ENTSO-E have identified which available TYNDP indicators can be used for the Screening phase and which ones need additional considerations.
The number of countries identified highly depends on the indicator used to identify the gas constraint and the way the electricity margin is computed

- For CR or SLID indicators the it is recommended considering also the case of Kalte Dunkelflaute situation (or similar ones) to measure possible interactions between electricity and gas under a 2-week cold spell and low vRES condition
- MASD indicators shows shortcomings in the interlinked model context and should not be further considered
- Price Convergence indicator should be further refined in order to ensure results compatible with its use within the Interlinked Model.
- Further improvements on the electricity capacity margin should consider that some gas power plants can run using alternative fuels than gas

Other indicators could be tested in the future.

With regards to the input required to implement the Screening phase on condition 1, the carried investigation has shown that all inputs are available through ENTSOG and ENTSO-E TYNDPs and current available metrics and tools:

- Input for sub-condition 1.1 can be entirely derived from ENTSO-E and ENTSOG joint scenarios (gas data).
- Input for sub-condition 1.2 can be entirely derived from ENTSOG TYNDP system assessment results which identify existing and future infrastructure gaps.
- Input for sub-condition 1.3 can be derived from ENTSO-E and ENTSOG joint scenarios and ENTSO-E market model simulations.

Since there are many elements that can have an impact on the input data of the screening methodology, it is recommended to have a consistent approach for its calculation. ENTSOG and ENTSO-E will work further on the homogeneity of modelling assumptions. An example of this is to have consistent criteria for the ENTSO-E reference grid and the ENTSOG infrastructure level definitions.

Results of the tested screening also show that many countries would show remaining gas constraints after having considered electricity capacity margin, indicating potential for “direct” dual assessment (see section 9.2).

8.4.2. Condition 2

Screening methodology allows for a number of relevant countries and projects to be identified for dual assessment under condition 2.
The previous points provide a clear methodology to assess if these interactions are enough to trigger a dual assessment of projects. At the same time, it can be noted that these interactions lead to potential cost and benefits that can be measured and that are not being captured in today’s cost benefit analysis.

With regards to sub-condition 2.1, the carried investigation has considered additional assumptions on the shares of price-driven P2Gs by taking some fixed levels during the screening phase (e.g. 25%, 50%, 75%, 100%). In the future such assumption will be directly included in the scenario development process and could be further supported by information collected during the TYNDP project collections.
Although a limited impact is expected, a possible improvement for condition 2.2 that should be analysed is the inclusion of batteries consumption in the denominator of the considered formula.

Concerning the input required to implement the Screening phase on condition 2, the carried investigation has shown that all inputs are available through ENTSOG and ENTSO-E TYNDPs and current available metrics and tools: input for all conditions (2.1; 2.2 and 2.3) can be derived from TYNDP scenarios and data.

The Focus study focuses on the P2G condition mainly at a yearly granularity. In this time scale no “constraints” will be observed on the gas side since gas storages run a full cycle without having any increasing impact on the gas amount on a yearly basis. The screening should be carried out also on daily basis in order to identify cases where there are gas constraints for some countries in peak situations where the local gas system might not be able to accommodate the total P2G conversion. If this is the case, the impact on the projects should be considered only for that day.

With regards to the number of projects, application of condition 2 identifies a significant number of projects for which dual assessment could be relevant. While for some projects exclusion from dual assessment might be straightforward, this may not be the case for other identified projects. Further strict criteria could be considered during the dual assessment phase (for example based on the level of maturity of projects on both gas and electricity side). Additionally, as already mentioned, ENTSOG and ENTSO-E do not run PS-CBA following the same principles. This should also be considered as part of the dual assessment.

Finally, the impact these interactions have on the assessment of projects should also be investigated. This will be investigated during the dual assessment phase and it can provide valuable information to improve the screening methodology.

8.4.3. Condition 3

During this pilot project, ENTSO-E and ENTSOG have not assessed the need for a dual system assessment when looking at an electricity or gas infrastructure project in the presence of hybrid consumption technologies.
These conditions have not been tested as TYNDP 2020 scenarios data (basis for this analysis) do not include price-driven hybrid consumption technologies but temperature-driven.
As also confirmed by the Focus Study, this represents a very theoretical case that could be applied in the future in case of changes in technology. Such case would be first investigated and defined at scenarios level.

9. Dual Assessment principles

9.1. Project selection for the dual assessment

The ultimate aim of the Screening Methodology is to identify which projects a dual assessment should be carried out on, per condition given a set of assumptions, .
A list of countries can be derived by applying the condition described in section 8. For each country, ENTSO-E and ENTSOG have collected project data as part of their respective TYNDP processes.

Unless justified by technical reasons, the dual assessment will be carried out on all projects (for the type of projects refer to section 7) submitted to ENTSO-E and/or ENTSOG TYNDPs that create new or additional capacity in the identified country. Only gas and electricity projects having similar level of maturity should be however assessed together.

In general, only projects mitigating certain constraints in the ENTSOG or ENTSO-E single assessment should be considered (e.g. if the project is not contributing to the gas constraint in the single assessment, presumably, it will not contribute to it under dual assessment situation either).

The projects considered might differ depending on the condition investigated.

At the same time, there might be projects (or a group of projects) submitted to TYNDP that "clearly" involve interaction between the electricity and gas system but the country in which they are planned to be built was not identified in the screening phase. This could be the case for P2G facilities or for groups of cross-energy system projects (e.g. offshore Wind + P2G + H2 grid conversion).
ENTSO-E and ENTSOG should always screen all the projects submitted to their respective TYNDPs and identify any possible other project for which electricity-gas interaction could be relevant, independently from the outcome of the screening methodology.

Additionally, in case the screening methodology application is based on a (or multiple) infrastructure endowments that already consider the realisation of some projects (e.g. ENTSOG Low infrastructure level or ENTSO-E reference grid), this should be duly taken into account. Projects already part of these grids should also be included in the investigation for relevant interlinkages.

9.2. Type of Dual Assessment

Once relevant projects have been identified, there might be different types of interactions in between infrastructure and energy systems in terms of dual assessment.

Gas and electricity projects dual assessment could be differentiated as follows:

- **direct dual assessment**, as interaction project-project. A gas and an electricity project are assessed together since directly influencing on one another value streams.
- **indirect dual assessment**, as interaction project-energy system. A gas or electricity project is assessed taking into account (in more detail) certain elements from the other energy system otherwise not fully taken into account in a single assessment approach (e.g. existing electricity generation capacity margin availability could influence the value of a gas project)

The above-mentioned approaches are not chosen discretionally but are a consequence of the Screening Methodology results.

For condition 1 (G2P), there is an "indirect" situation where the identified gas constraint (e.g. risk of demand curtailment) can be fully mitigated by a combination of existing generation capacity margin and import capacity margin from the electricity grid (or at least by one of the two), likewise in case1, case2 and case3 in the table below.
For case4 there is a "direct" situation since an increase in the import electricity capacity margin by an interconnector project (eIC) could help to fully mitigate the gas constraint (otherwise mitigated only up to 35 GWh/d).

A	B	C	D	E	F	G
GWh/d	**Gas Constraint**	**Local Generation Margin**	**Neighbouring Generation Margin**	**Import Electricity Margin**	**Total Flexibility** C + min(D:E)	**Type of Dual Assessment**
case 1	50	50	not needed	not needed	50	Indirect *
case 2	50	25	at least 25 available	at least 25 available	50	Indirect *
case 3	50	25	only 10 available	at least 25 available	35	Indirect *
case 4	50	25	at least 30 available	only 10 available	35 + eIC**	Direct

* The ENTSO-E Reference Grid already includes some projects. If one or more electricity project concerning the countries for which the Screening Methodology has identified a need, is already included in the reference grid, the type of dual assessment would be Direct/Indirect. See also section 9.1.

** Electricity interconnector project

For condition 2 (P2G), there is an "indirect" situation where electricity projects are assessed taking into account price-driven P2G (as part of the scenario) while "direct" when both electricity and gas projects are impacted by P2G.

9.3. The cost element

The costs of an infrastructure project (e.g. CAPEX and OPEX), while not directly impacting the gas and electricity systems' operations, are an important factor in the cost-benefit analysis under both single system assessment and dual system assessment.

As described in their respective Methodologies, when applying a Multi Criteria Analysis, ENTSO-E and ENTSOG evaluate the social benefits of the assessed projects by considering also the related costs.

The costs of the assessed projects were not directly considered as part of this investigation. The analysis carried out by ENTSO-E and ENTSOG and described in section 9 and section 10 of this document, focused in fact on how the benefits stemming from the realisation of gas and electricity projects can change under dual system assessment.
Nevertheless, it must be recognised that costs are an important element not to be disregarded and that can be used after benefits are computed:

- to Identify different levels of "social-profitability" by comparing the project analysis of a single to a dual assessment
- to Identify which alternative infrastructure option(s) presents higher "social-profitability"

Additionally, if introduced at screening phase level, project costs (and their magnitude) could also help to select which project can be considered relevant for dual system assessment.

9.4. Indicators for Dual Assessment

Aim of the ENTSO-E and ENTSOG CBA Methodologies is to assess the social benefits (and costs) of a project.

The dual assessment investigation (and the current chapter) should focus on the following main objectives:

- to capture cost and benefits of projects when the interactions between electricity and gas are relevant.
- understand if (some of) the indicators currently included in ENTSO-E and ENTSOG CBA Methodologies can be used to assess the social benefits and costs of gas and electricity within a dual assessment framework

- refine current indicators or create new indicators to better capture some interlinkage situations

Whenever an indicator is already used in the Screening Methodology, this indicator should also be considered in the Dual Assessment phase, to ensure consistency of metrics and results comparability.

All the indicators will be applied based on the Incremental Approach, i.e. comparing the "without project(s)" situation and the "with project(s)" situation. This approach is explained in both ENTSO-E and ENTSOG CBA Methodologies. The "without project" situation can also be called "counterfactual".

9.4.1. Condition 1 – Interlinkages in the presence of gas-to-power (G2P)

In section 8.1 it was seen that different indicators from ENTSOG CBA Methodology can be used to identify certain constraints on the gas side:

- curtailed demand (monetary)
- supply source dependence
- price convergence (monetary)

In a single gas-system analysis, a gas project benefit would be therefore measured through one (or more) of those indicators in terms of its capability to mitigate/solve the gas constraint found in its absence ("without the project" situation). The quantity of gas constraint reduced could be (in some cases) also monetised (given a certain monetary value).
In a dual assessment, however, the presence of gas constraints could also affect the electricity system and other indicators from the ENTSO-E CBA Methodology.

<u>Example</u>: the analysis at system level identifies an infrastructure gap for country2 (C2). Given a certain infrastructure level, country2 is in fact not able to entirely cover its gas demand even in case of infinite availability of gas from the existing supply source. One or more gas projects may therefore help to mitigate or entirely solve the situation (up to 50 GWh/d being the maximum value of the gas constraint). In a single gas-system project assessment, this would represent the maximum benefit a gas project can contribute to, it would be monetised by using a certain cost of disruption of gas value[29] (for the sake of this example let us say 100 EUR/GWh). The maximum benefit stemming from the implementation of the gas project (or multiple projects) in that specific year would then be 50x100=5,000 EUR

[29] In case of ENTSO-G CBA Methodology this monetary value is called Cos of Gas Disruption (CoDG). Please refer to page 44 of ENTSOG CBA Methodology for further details.

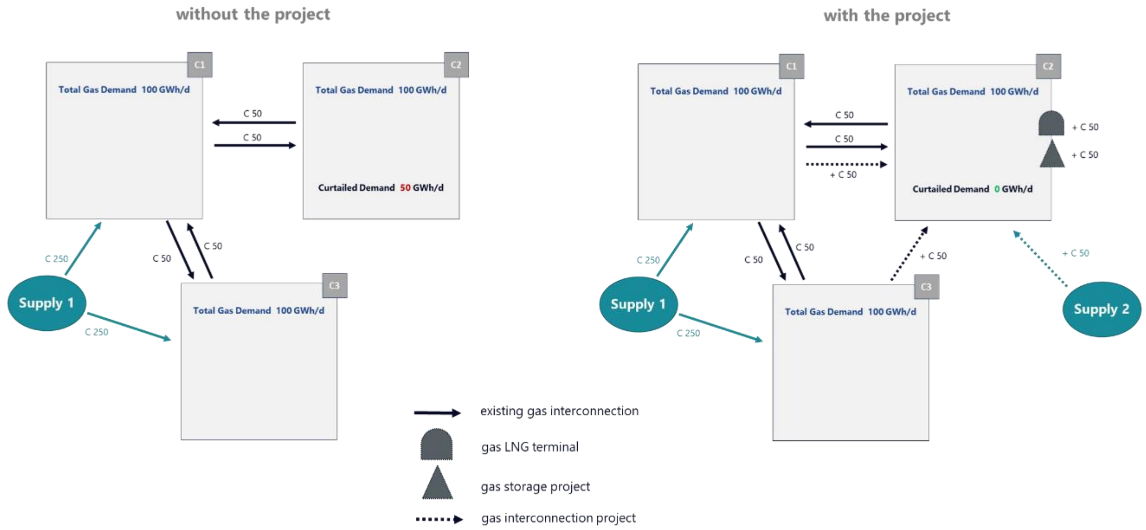


Figure 23 – Example for dual assessment under condition 1 (single assessment)

Let us now assume that, in a dual assessment framework, the gas constraint will be fully mitigated either by existing electricity generation/import margin (indirect dual assessment) or by both electricity generation/import margin and electricity projects (direct dual assessment). In this example, this has a negative effect on the gas project by reducing its benefit in mitigating the gas constraint.

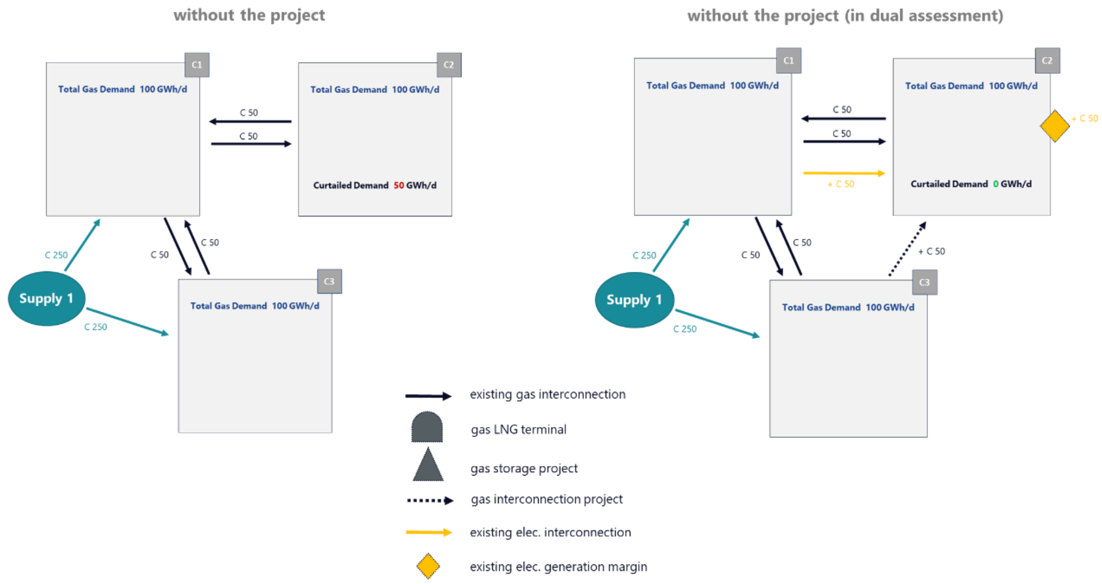


Figure 24 – Example for dual assessment under condition 1 (dual assessment)

This does not prevent the gas project from scoring in other indicators.

But what about the electricity side? This could also have in fact a social impact in terms of

- **Social Economic Welfare (SEW)** by using a different generation mix the cost of generation, start-up costs, demand-side response, among others, will also vary
- **CO2 emissions** by using a different electricity generation mix the level of emissions and the associated costs will vary

For example, if the 50 GWh/d are produced by a light oil power plant instead of an old gas power plant, then the following values can be obtained:

$$\Delta SEW = (81 - 138)\left[\frac{\text{eur}}{\text{MWh elec}}\right] * 50\left[\frac{\text{GWhgas}}{\text{d}}\right] * 40\%\left[\frac{\text{GWh elec}}{\text{GWh gas}}\right] = -1{,}14\left[\frac{\text{Meur}}{\text{d}}\right]$$

$$\Delta CO_2 = (0{,}8 - 0{,}59)\left[\frac{\text{CO2Ton}}{\text{MWhelec}}\right] * 50\left[\frac{\text{GWhgas}}{\text{d}}\right] * 40\%\left[\frac{\text{GWh elec}}{\text{GWh gas}}\right] = 4200\left[\frac{\text{CO2Ton}}{\text{d}}\right]$$

Whether the social impact will only be attributed to the electricity system or also to the electricity projects depends on the type of dual assessment identified (direct vs indirect).

The use of additional electricity generation capacity in neighbouring countries of the one affected by the gas constraint could in turn create constraints in those countries in terms of:

- curtailed demand/reduced remaining flexibility
- increase of supply dependence above the identified threshold limit
- price convergence

The approach described in the example above could be applied with the MASD indicator. This indicator is not monetised.

The dual assessment could also require need for additional convergence between the input used by ENTSO-E and ENTSOG in terms of:

- Cost of Disruption of Gas vs Loss of Load
- Probability of occurrence (ENTSOG considers the CD indicator under a severe probability of occurrence of 1/20 year)
- CO2 emission monetary value and/or Social Cost of Carbon

9.4.2. The overall process

In case of dual assessment under condition 1 (G2P), the process can be generally summarised as follow:

1. Build scenarios and calculate the amount of G2P.
2. Run ENTSOG TYNDP system assessment and identify gas constraints based on ENTSOG CBA Methodology metrics
3. Apply the Screening Methodology
   1. check ILM Screening Methodology sub-conditions
   2. as part of ILM Screening Methodology sub-conditions application, ENTSOE to include gas constraints (identified by ENTSOG) in its electricity reference simulations and check how remaining electricity flexibility can further mitigate/solve gas constraint by generating/importing electricity from non-gas-fired power plants. This assessment should also identify any other impact on SEW and CO2 coming from this alternative solution
   3. based on ILM Screening Methodology, identify list of countries and projects relevant for Dual Assessment (include any other relevant projects not submitted to TYNDP)
4. Dual Assessment
   1. run ENTSOG TYNDP PS-CBAs and ENTSO-E TYNDP PS-CBAs for the identified projects (this is already part of the TYNDP exercise)
   2. ENTSOG to include new gas-to-power demand from ENTSO-E new runs (point 2) in ENTSOG System Assessment and PS-CBAs for projects identified by the screening methodology. The PS-CBAs should also consider any other impact on SEW and CO2 from point 2
   3. Compare results with single-system PS-CBAs.
5. Results from the Dual Assessment to compute the social benefit in dual assessment will consider:
   1. changes in the gas constraints thanks to the implementation of the project(s) in the forms of
      i. reduced curtailed gas demand (monetised)
      ii. reduced supply dependence
      iii. reduced price differentials (monetised)
   2. ΔSEW from re-run ENTSO-E PS-CBAs
   3. ΔCO2 emissions from re-run ENTSO-E PS-CBAs

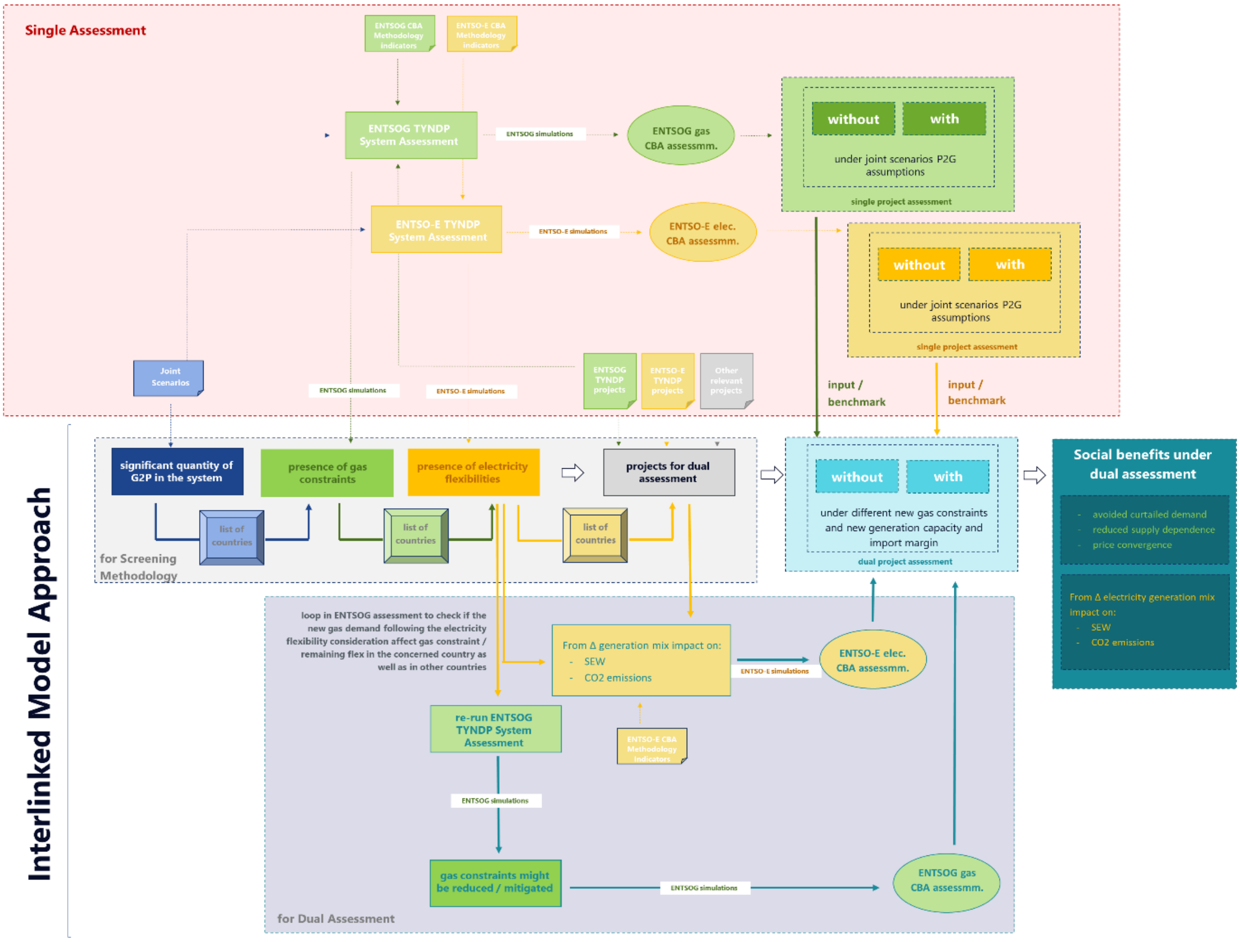


Figure 25 – The overall process: from single assessment to dual assessment under condition 1, significant presence of gas-to-power

9.5. Condition 2 – Interlinkages in the presence of power-to-gas (P2G)

From the Screening Methodology results it is possible to identify countries and projects for which:

- electricity interconnector(s) is assessed taking into account a certain share of price driven P2G capacity (sub-conditions 2.1 and 2.2)
- electricity interconnection and gas projects are assessed together (when including sub-condition 2.3)

9.5.1. Assessing electricity and P2G projects in the presence of price-driven P2G

As mentioned in other sections, price-driven power-to-gas capacities can interact with exports and/or storage for the use of cheap electricity. Indeed, P2G consumption can reduce the volume of electricity that is available for exports and increase the local price of electricity thus reducing the depth and value of exports. This is especially true in areas with high P2G and vRESe or nuclear capacities (that either function in must-run or want to maximize their use).

Hence, the benefits brought by electricity interconnections which export electricity from an area with P2G could be modified by the presence of price-driven P2G. A graphical example is shown in the following figure (values are just referential):

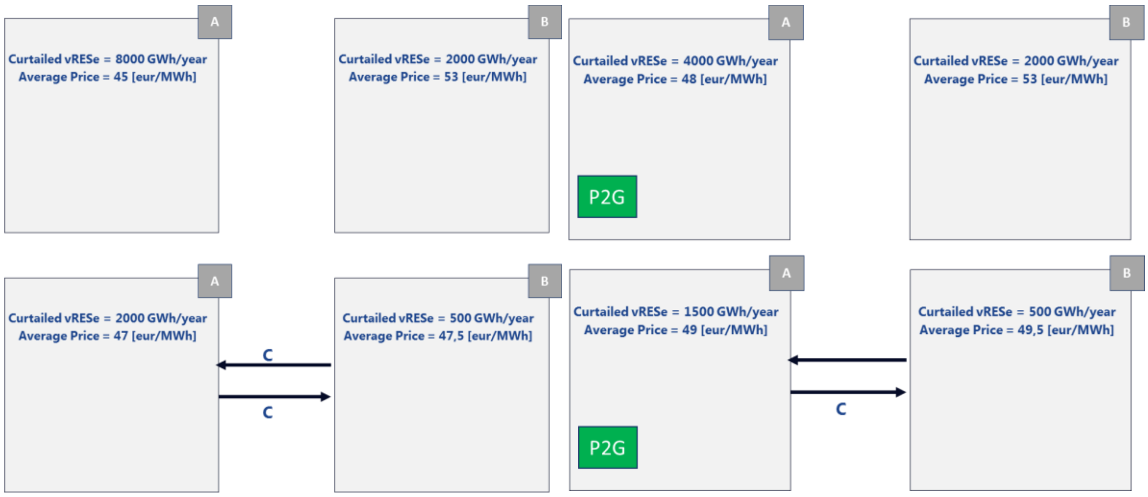


Figure 26 – Example for dual assessment under condition 2

In the figure above it can be noted that the amount of curtailed VRESe decreases under the presence of P2G, therefore the benefits by increasing the transmission capacity between two countries change. At the same time, it can also happen that the P2G facility takes advantage of the capacity increase due to an interconnector project, so it can run with cheaper electricity imported from another country, so in this case there is an effect of "supplying electricity demand" (coming from the P2G facility) at a lower price. There are many elements that can make one effect stronger than another, so it is not possible to say per se how the value of interconnectors is affected.

The electricity projects should be assessed, following the incremental approach, under the following situations:

- "without electricity project" in the presence of price-driven P2G (as defined in the scenarios)

- "with electricity project" in the presence of price-driven P2G (as defined in the scenarios)

By comparing the benefits of the electricity projects in the "without/with situation", it is possible to identify the social impact of assessing this project under single and dual assessments. To do so, the same metrics should be used:

- change in Social Economic Welfare stemming from the changes in the electricity generation merit order
- change in CO2 emissions stemming from the changes in the electricity generation merit order

At the same time, the assumed share(s) of price-driven P2G might have an impact also in terms of produced renewable/decarbonised gas (i.e. hydrogen or synthetic gas) since their utilisation would be different compared to non-price-driven P2G.
Given a certain amount of hydrogen and methane demand defined in the scenarios, a different share of price-driven P2G capacity and strike price could therefore also affect:

- the amount of cross-border flows of hydrogen or methane required to satisfy that demand (for example, in case methane is imported to produce hydrogen through processes like steam methane reforming).
- the value of gas projects that would enable additional import/export or cross-border flows of hydrogen and methane, in terms of utilisation rate and cost of the gas supplied. The value of such project could increase or decrease depending on the changes in the flow's needs.
- the amount of CO2 emissions stemming from locally-produced decarbonised gas being replaced by other imported gas sources.

As done for the electricity projects, in case of additional stress on the gas-system caused by significant presence of price-drive P2G capacities, also the gas projects should be assessed, following the incremental approach, under the following situations:
- "without gas project" in the presence of price-driven P2G (as defined in the scenarios)
- "with gas project" in the presence of price-driven P2G (as defined in the scenarios)

For the purpose of this test phase and in the absence of price-driven P2G shares already defined in the joint scenarios, a sensitivity on the share of price-driven P2G is considered.

9.5.2. Assessing electricity projects and gas projects in the presence of price-driven P2Gs

According to the Focus Study, as a gas source, power-to-gas can reduce the needs for additional import capacities in the area and should be taken into account when assessing gas infrastructure projects (this requires P2G projects of several hundred MW to materialise).

If the gas conversion from P2G is higher than the local gas consumption, and that the existing gas export and storage capacity are saturated, it can increase the value brought by gas interconnection projects or gas underground storages. However, Artelys expects this case to be quite exceptional, for example in the case of large wind farms coupled with electrolysers.

In the Screening Methodology chapters, ENTSO-E and ENTSOG have already identified that this situation should be verified on a daily basis rather than on a yearly basis (for more details see section 8.2.3).

The impact on gas infrastructures could be measured by ENTSOG by using the same metrics described in section 9.5.1. However, this would be relevant only for the single day assessed, with presumably limited impact on the social economic welfare.

9.5.3. The overall process

In case of dual assessment under condition 2 (P2G), with regards to the sub-conditions 2.1 and 2.2, the process can be generally summarised as follow:

1. Apply the Screening Methodology
    1. based on joint scenarios check for which countries there is a significant quantity of dynamically operated P2Gs
    2. for the identified countries check, always based on joint scenarios data, if there is significant share of low-variable costs electricity generation
    3. based on ILM Screening Methodology, identify list of countries and projects relevant for Dual Assessment (include any other relevant projects not submitted to TYNDP)
2. Dual Assessment
    1. run ENTSOG TYNDP PS-CBAs and ENTSO-E TYNDP PS-CBAs for the identified projects (this is already part of the traditional TYNDP exercise)
    2. run PS-CBAs on electricity and gas projects identified by the screening methodology application
3. Results from the Dual Assessment to compute the social benefit in dual assessment
    1. ΔSEW from re-run ENTSO-E PS-CBAs and from changes in gas supply mix due to changes in the amount of decarbonised gas produced by P2Gs
    2. ΔCO2 emissions from re-run ENTSO-E PS-CBAs
    3. ΔCO2 emissions from changes in gas supply mix due to changes in the amount of decarbonised gas produced by P2Gs
    4. variations in the utilisation rate of gas project and Δcost of gas supply thank to its implementation

The below picture represents the process implemented, as part of this investigation, for condition 2. However, some of the steps followed, will not be required in the future (e.g. the share of price-driven P2G will be already defined at scenarios level).

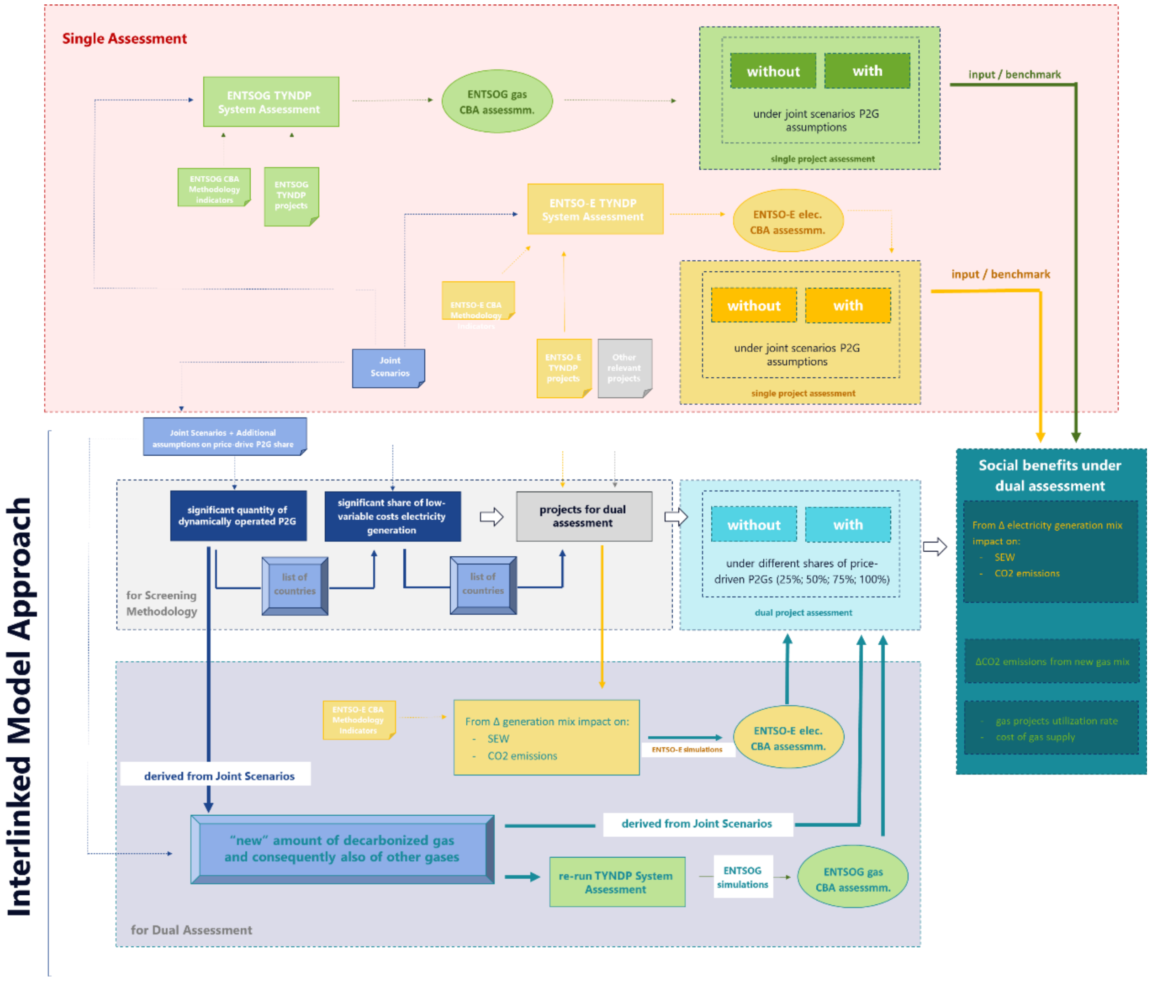


Figure 27 – The overall process: from single assessment to dual assessment under condition 2, significant presence of power-to-gas

9.5.4. P2G projects and "hybrid projects"

ENTSOG, in TYNDP 2020, has collected P2G projects (under ETR project category). ENTSO-E has also received projects that include electrolysers as part of its TYNDP 2020.
However, no information was collected with regards whether those projects are actually price-driven or not.

There must be market-driven P2G in the scenario to have interactions for electricity and gas projects under the presence of P2G. In the future, the amount of price-driven P2G capacity could be directly defined as part of the scenarios development process and could be supported by the project data collected in the ENTSO-E and ENTSOG TYNDPs.

The follow approach could be used:

- scenarios define a certain share of P2G capacity (e.g. 1000 MW) in line with the identified storylines
- the same capacity is considered available in the System Assessment Need phase
- Each P2G project (e.g. 10 MW) can be assessed by removing/adding the P2G facility (with the Take Out One at the Time - TOOT method or Put in one at the Time – PINT method) from the overall capacity included in the System Assessment, by both ENTSO-E and ENTSOG

Not only P2G projects. Other type of infrastructure projects that enable gas and electricity conversion whose operation is optimised by looking at both sectors could be also collected in future TYNDP editions. These projects, depending on their specificities could also be considered as natural candidate for dual assessment.

9.6. Condition 3 – Interlinkages in the presence of hybrid consumption technologies (HCT)

Not considered for the test under TYNDP 2020.

10. Dual Assessment: application and test phase results

In the previous section, a first proposal for a dual assessment methodology has been proposed. In the following section, this methodology is applied and tested on TYNDP 2020 projects from the countries identified by using the screening methodology.

While the screening phase was implemented for both years 2030 and 2040, the dual assessment was tested only on year 2030. Such choice is justified by the fact that, in TYNDP 2020 ENTSO-E has carried PS-CBAs (single assessment) only for year 2030. Therefore, comparison between single and dual assessment could be done only in 2030.

10.1. Condition 1 – Presence of relevant G2P

10.1.1. Scope

The aim of the tests was to assess how the interactions between the electricity and gas affect the projects assessment and their contribution towards gas constraints.

More in detail:

- to check if and how the flexibility margin reduces the level of gas constraints (and by this way affect the value of gas projects when there is relevant presence of G2P)
- to quantify how the difference on gas constraints could affect the contribution of ENTSOG gas infrastructure levels to their relief
- to measure how the difference in gas constraints affects contribution of specific projects to their relief
- to calculate the impact of the analysis on the EU Social Economic Welfare (no projects costs were considered in this part of the test).

10.1.2. Indicators used

For condition 1, the CR indicator was selected for testing the dual assessment methodology. The main reason behind is that both CR and SLID indicators measure gas demand that is not served, although in different conditions. Nevertheless, the interactions between electricity and gas are the same for both indicators, and therefore, the conclusions obtained by analysing one indicator, can be extended to the second one.

10.1.3. Assumptions

The tests for the CR indicator are based on the following input:

- Scenarios: National Trends 2030 / Distributed Energy 2030 / Global Ambition 2030
- Demand situation: daily peak without infrastructure disruption

- Infrastructures:
  - ENTSOG Infrastructure Levels (Existing / Low / Advanced)
  - MAF reference grid for electricity
  - 5 gas projects from the gas TYNDP 2020 covering all type of projects (transmission, LNG and underground storage)
  - 4 electricity projects (including interconnection and storage)
- Focus on 2 countries (based on screening phase outcome)
  - Countries C1 and C2
- Electricity flexibility margin:
  - based on ENTSO-E MAF reference grid
  - calculated considering gas constraint in C1 and C2

More details on how the dual assessment is applied under relevant G2P can be found in the section 9.4.2.

10.1.4. Results

The following table summarises the results of the tests on dual assessment for condition 1.

Global Ambition			Distributed Energy			National Trends		
Impact on gas constraint?	Impact on gas infra contribution to the		Impact on gas constraint?	Impact on gas infra contribution to the		Impact on gas constraint?	Impact on gas infra contribution to the	
	Infrastructure considered	Condition met		Infrastructure considered	Condition met		Infrastructure considered	Condition met
v	infrastructure level	vv	v	infrastructure level	vv	-	infrastructure level	-
v	transmission (C1)	vv	v	transmission (C1)	vv	-	transmission (C1)	-
v	LNG (C1)	x	v	LNG (C1)	vv	-	LNG (C1)	-
v	UGS (C2)	x	-	UGS (C2)	x	-	UGS (C2)	-
v	LNG (C2)	x	-	LNG (C2)	-	-	LNG (C2)	-
v	transmission (C2)	vv	-	transmission (C2)	-	-	transmission (C2)	-

v	the electricty capacity margin reduces the gas constraints
vv	the electricty capacity margin reduces the gas infrastructure contributions to the gas constraints
x	the electricty capacity margin has no impact on the gas constraints
-	no gas constraint identified and situation not further assessed

Table 2 - Summary of the results from test on condition 1

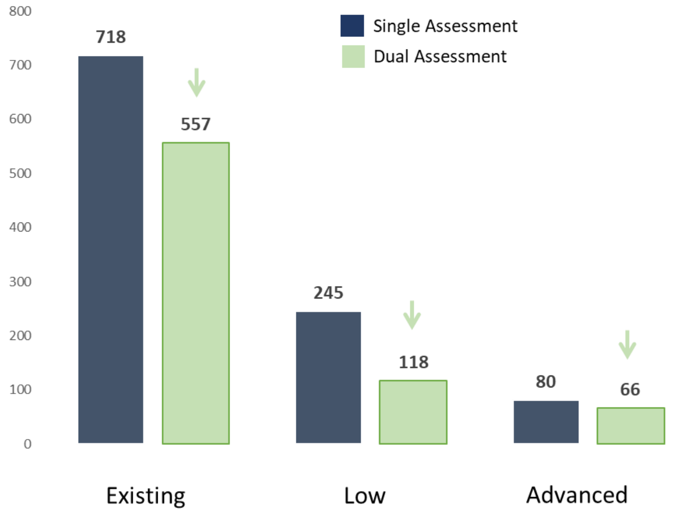
For each scenario, it was tested whether the available flexibility on the electricity system (capacity margin) has an impact:
- on the gas constraints (first column for each scenario)
- on the gas infrastructure contribution in reducing the identified gas constraint (second and third columns for each scenario)

As displayed in the table, in all the situations assessed, the available flexibility on the electricity side always reduces the identified gas constraint and the impact of gas infrastructures when aggregated at infrastructure level (based on the same maturity status). At the same time, the reduction of the overall gas constraint does not always affect the contribution (and therefore the benefits) of each single gas project.

With regards to the underground gas storage the tests carried do not show significant impact. However, this can be at least partially explained by the fact that the tests were based on a daily peak demand situation (without infrastructure disruption) while the role of underground storage can be captured more when considering other demand cases such as 2-weeks cold spell or 2-weeks cold spell and Dunkeflaute. This should also be considered in the future.

In the following pages the results for two projects are presented in more details.

Figure 28 and Figure 29 – Gas curtailed demand (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030 show the gas curtailed demand under single assessment (i.e. from ENTSOG TYNDP 2020 System Assessment analysis) and the gas curtailed demand obtained when considering the electricity flexibility margin for the scenarios Global Ambition 2030 and Distributed Energy 2030, respectively. Results are displayed for all three ENTSOG gas infrastructure levels.

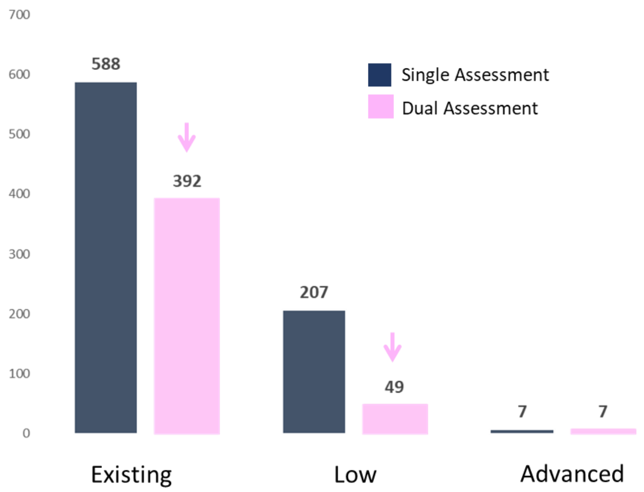


SINGLE

gGWh/d	Existing	Low	Advanced
Country 1	443	123	0
Country 2	92	5	18
Rest of EU	183	117	62

DUAL

gGWh/d	Existing	Low	Advanced
Country 1	296	0	0
Country 2	78	0	5
Rest of EU	183	118	62



SINGLE

gGWh/d	Existing	Low	Advanced
Country 1	479	159	0
Country 2	0	0	0
Rest of EU	109	48	7

DUAL

gGWh/d	Existing	Low	Advanced
Country 1	284	0	0
Country 2	0	0	0
Rest of EU	109	49	7

Figure 28 and Figure 29 – Gas curtailed demand (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030

Figure 28 and Figure 29 – Gas curtailed demand (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030show that for the three gas infrastructure levels, the gas curtailed demand obtained when performing a dual assessment is lower or equal to the case when a single assessment is performed. The explanation for this result is that when performing a dual assessment, the electricity flexibility margin is used to reduce the G2P demand, and in this way, decreasing the gas curtailed demand. This has the effect that the electricity system uses more expensive power plants compared to the gas power plants, since the latter are not fully available due to constraints on the gas system. The previous could be located internally, in the same country having gas curtailed demand, or in neighbouring countries, whose generation is then imported through electricity interconnectors (existing or included as projects in the reference grid).

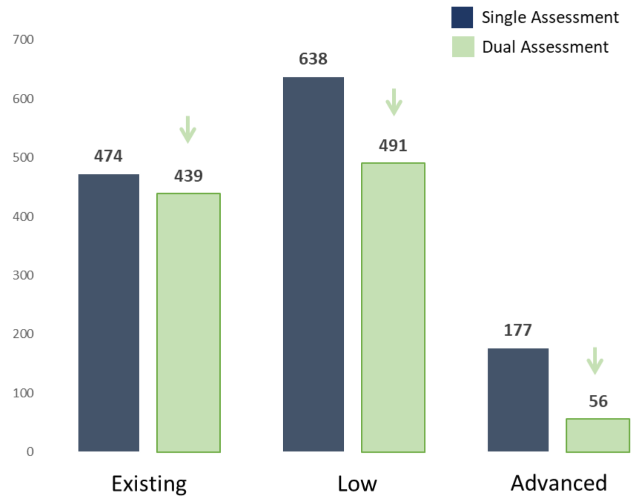
In the same figures, it can be observed that for Distributed Energy 2030, advanced infrastructure level on the gas side, the single assessment and the dual assessment show the same amount of gas curtailed demand. The reason for this situation is that the gas curtailed demand in countries C1 and C2 is already mitigated by projects included in such infrastructure level while the residual constraints occur in other countries of Europe different to the ones analysed.

It is important to note that not all gas curtailed demand comes necessarily from the G2P demand, and that not all G2P demand can be decreased (due to security constraints on the electricity system), therefore, there can be situations in which the electricity capacity margin doesn't impact the gas curtailed demand.

Through this approach is also possible to verify how the contribution of more projects with the same maturity status (gathered under the same ENTSOG infrastructure level) is affected by the electricity capacity margin.

Figure 30 and Figure 31 – Contribution of the gas infrastructure levels to gas curtailed demand (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030show the difference on the results in terms of contribution to the mitigation of gas curtailed demand for the different infrastructure levels and for the scenarios Global Ambition 2030 and Distributed Energy 2030, respectively.

It is also important to remember that the capacity margin is identified based on ENTSO-E's Reference Grid that is also composed by a certain number of projects with a certain level of maturity.

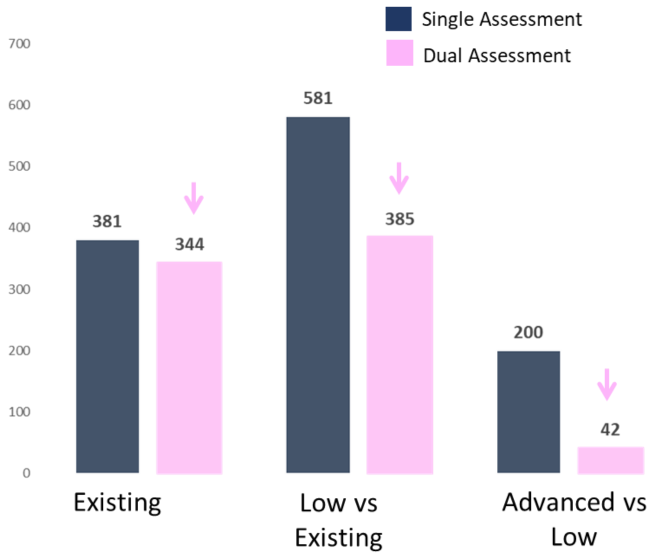


SINGLE

gGWh/d	Existing	Low	Advanced
Country 1	321	443	123
Country 2	87	74	0
Rest of EU	66	121	55

DUAL

gGWh/d	Existing	Low	Advanced
Country 1	296	296	0
Country 2	78	73	0
Rest of EU	65	121	56



SINGLE

gGWh/d	Existing	Low vs Existing	Advanced vs Low
Country 1	321	479	159
Country 2	0	0	0
Rest of EU	60	102	42

DUAL

gGWh/d	Existing	Low vs Existing	Advanced vs Low
Country 1	284	284	0
Country 2	0	0	0
Rest of EU	60	102	42

Figure 30 and Figure 31 – Contribution of the gas infrastructure levels to gas curtailed demand (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030

Tests showed relevant results only for Global Ambition and Distributed Energy scenarios.

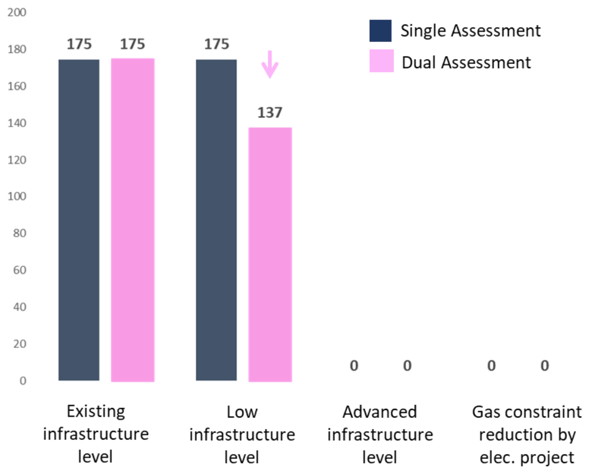
From Figure 28 and Figure 29 – Gas curtailed demand (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030 it is possible to observe that, for example in Global Ambition 2030, the gas constraint is 718 GWh/d under existing infrastructure level and 245 GWh/d under low infrastructure level. In case of dual assessment, the same constraints would be reduced to 557 GWh/d and 118 GWh/d, respectively.

Figures 31 and Figure 32 show how each gas infrastructure level can contribute to the reduction of the identified gas constraints and in the following situations:

- low vs existing, shows how all projects with FID status contribute to the gas constraint identified in case only currently existing infrastructure
- advanced vs existing, shows how all projects with FID and the ones with advanced status can contribute to the gas constraint identified in case only currently existing infrastructure
- advanced vs low, shows how all projects with advanced status can contribute to the remaining gas constraint after the FID projects are considered implemented.

Figures 18 and 19 show that the contribution of each infrastructure level to the gas constraint mitigation is potentially reduced under dual assessment. Clearly, the decrease in their contribution will differ depending on the infrastructure level considered.

It must also be noted that, while in the gas side three infrastructure levels were considered, on the electricity side the flexibility margin was assessed always using the same reference grid (i.e. the infrastructure composition affecting the gas constraint and the infrastructure level contribution does not change).



SINGLE

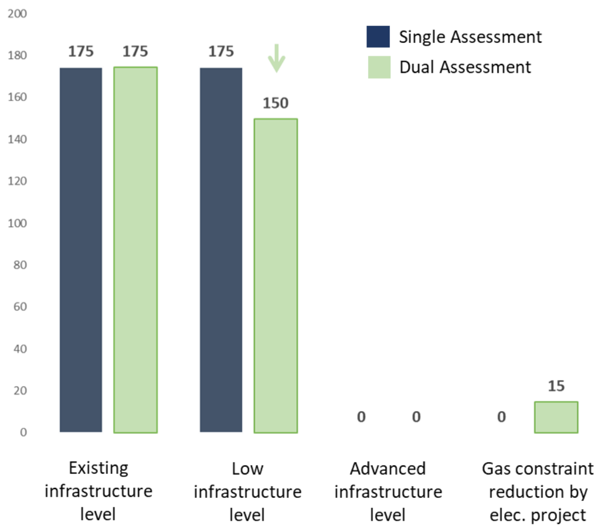
gGWh/d	Existing	Low	Advanced
Gas constraint	1,068	715	7
Gas project impact	175	175	0
Elec. project impact	0	0	0

DUAL

gGWh/d	Existing	Low	Advanced
Gas constraint	676	323	7
Gas project impact	175	137	0
Elec. project impact	0	0	0

Figure 32 and Figure 33 show the contribution of a single gas project “Project 1” and an electricity project “A” to the identified gas constraint in Global Ambition 2030 and Distributed Energy 2030 scenarios, respectively, and under single and dual assessment.

In line with the other figures, results are presented for each gas infrastructure level since the contribution of a project will also depend on the level of infrastructure considered (and number of projects included in it).

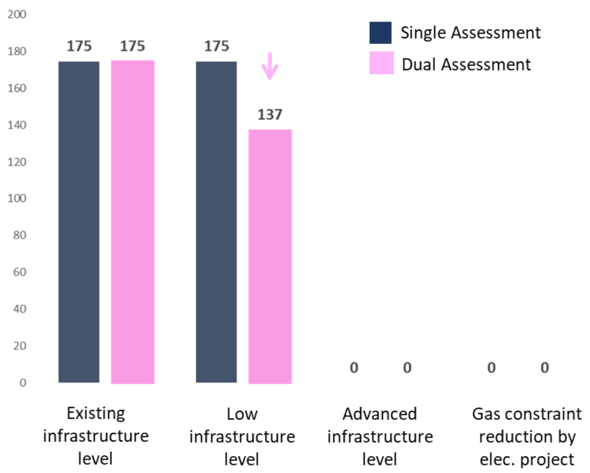


SINGLE

gGWh/d	Existing	Low	Advanced
Gas constraint	1,162	716	80
Gas project impact	175	175	0
Elec. project impact	0	0	0

DUAL

gGWh/d	Existing	Low	Advanced
Gas constraint	853	417	66
Gas project impact	175	150	0
Elec. project impact	15	15	15



SINGLE

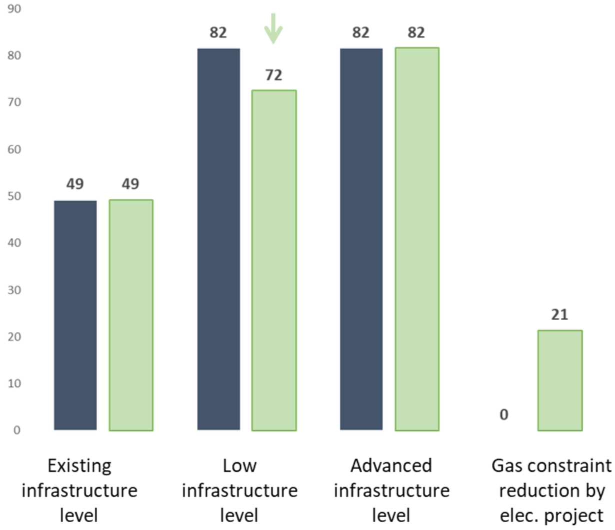
gGWh/d	Existing	Low	Advanced
Gas constraint	1,068	715	7
Gas project impact	175	175	0
Elec. project impact	0	0	0

DUAL

gGWh/d	Existing	Low	Advanced
Gas constraint	676	323	7
Gas project impact	175	137	0
Elec. project impact	0	0	0

Figure 32 and Figure 33 – Contribution of gas Project 1 and Electricity Project A to the gas constraint (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030

It can be observed that, in some cases, the project contribution to gas curtailed demand is reduced in dual assessment. Despite the decrease in the gas curtailed demand due to the influence of the electricity flexibility margin (see Figure 28 and Figure 29 – Gas curtailed demand (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030), the contribution of "Project 1" in decreasing the gas curtailed demand of the scenarios does not necessarily decrease in all situations. The main reason for this behaviour is that the amount of gas curtailed demand, after considering the contribution of electricity flexibility margin, is still high enough for the project to contribute with its total capacity in decreasing the gas curtailed demand (when needed). The figures above also show the contribution of the tested electricity “Project A” to the gas constraint:



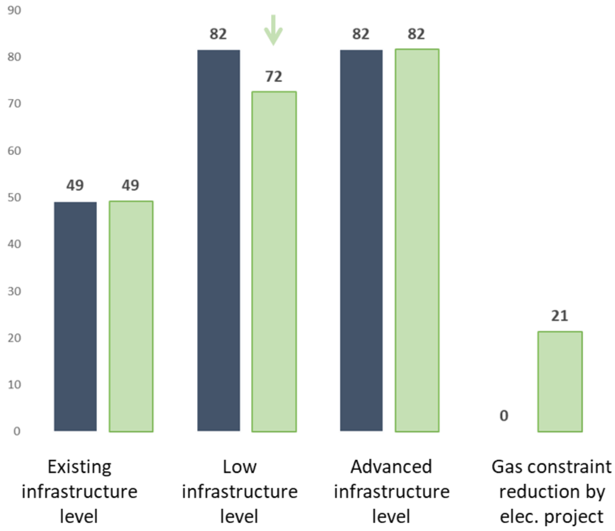
SINGLE

gGWh/d	Existing	Low	Advanced
Gas constraint	811	399	256
Gas project impact	49	82	82
Elec. project impact	0	0	0

DUAL

gGWh/d	Existing	Low	Advanced
Gas constraint	635	263	229
Gas project impact	49	72	82
Elec. project impact	21	21	21

Figure 34 - Contribution of Project 2 to the gas constraint (in GWh/d) in Global Ambition 2030



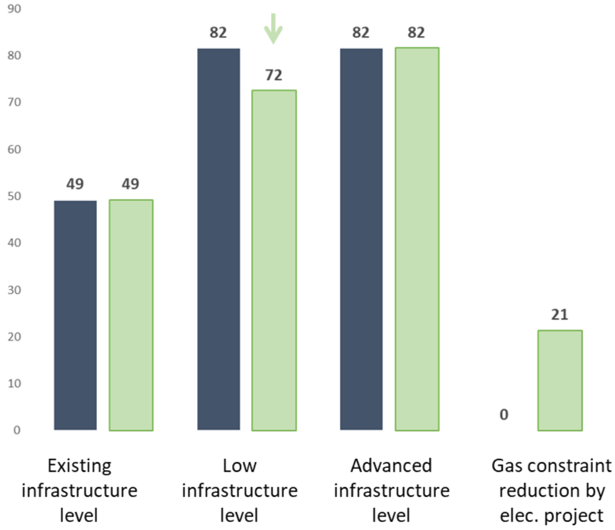
SINGLE

gGWh/d	Existing	Low	Advanced
Gas constraint	811	399	256
Gas project impact	49	82	82
Elec. project impact	0	0	0

DUAL

gGWh/d	Existing	Low	Advanced
Gas constraint	635	263	229
Gas project impact	49	72	82
Elec. project impact	21	21	21

Figure 34 shows the contribution of “Project 2” in decreasing the gas curtailed demand in Global Ambition 2030. No contribution is observed in Distributed Energy 2030 and National Trends 2030.



SINGLE

gGWh/d	Existing	Low	Advanced
Gas constraint	811	399	256
Gas project impact	49	82	82
Elec. project impact	0	0	0

DUAL

gGWh/d	Existing	Low	Advanced
Gas constraint	635	263	229
Gas project impact	49	72	82
Elec. project impact	21	21	21

Figure 34 shows a similar behaviour to the one observed in Figure 32 and Figure 33 – Contribution of gas Project 1 and Electricity Project A to the gas constraint (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030. Despite the decrease on the gas curtailed demand due to the electricity flexibility contribution, the impact of the projects in decreasing the gas curtailed demand is not necessarily reduced.
Generally, the contribution of a project to the gas constraint decreases the more infrastructure are considered already implemented. However, there might be cases when a project fully unleashes its potential only thanks to the implementation of complementary projects. This explains why “Project 2” has a higher impact in the assessment under low existing infrastructure level than under existing infrastructure level.

Finally, it is important to analyse how the monetisation of the benefits of the gas projects related to reduction of gas curtailed demand can change when considering the contribution from the electricity flexibility margin.
The following section shows an attempt of monetisation from the Social Economic Welfare perspective of the situations described in Figure 30 and Figure 31 – Contribution of the gas infrastructure levels to gas curtailed demand (in GWh/d) in Global Ambition 2030 and Distributed Energy 2030, under single and dual assessment. At this stage of investigation, the monetisation has been calculated at “grid” level (i.e. considering overall contributions of gas infrastructure levels and electricity reference grid rather than focusing on single projects).

To have a clearer view of the benefits of projects, a sample graph is provided in Figure 35, where all the different quantities are expressed in millions of Euro on a time-horizon of 25 years (not discounted). The interpretation of each pair of columns is as follows:

1. Benefits of the gas infrastructure levels in reducing gas constraint under single and dual assessment (monetized using ENTSOG Cost of Disruption of gas of 600 EUR/MWh and probability of occurrence of 1/20 years).

2. Benefits from electricity flexibility margin in reducing gas constraints under single and dual assessment (monetized using ENTSOG Cost of Disruption of gas of 600 EUR/MWh and probability of occurrence of 1/20 years).

3. Additional cost for the system due to the use of the electricity flexibility margin for reducing gas constraint under single and dual assessment. This additional cost is measured in terms of reduction in electricity Social-Economic Welfare and in terms of increase in CO_2 emissions.

Range of max and min benefits

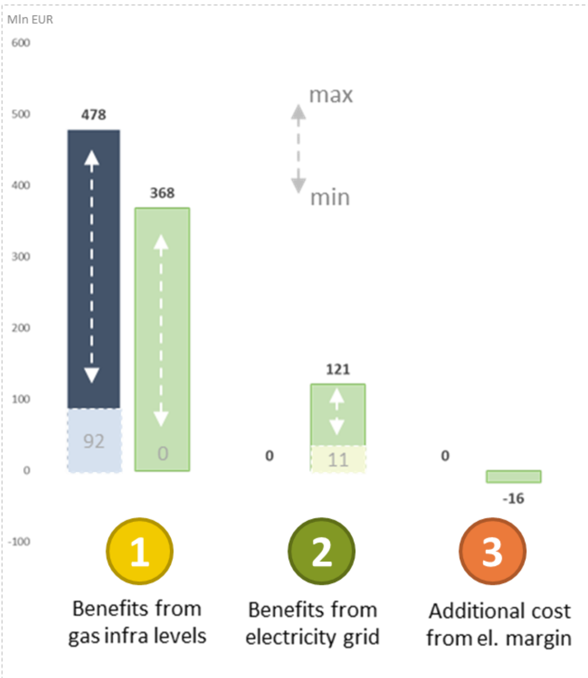


Figure 35 - Sample graph representing the results monetised benefits of projects

The minimum and maximum ranges represent the benefits under different infrastructure level assessment, with higher benefits that can be associated to the situations where low or advanced infrastructure levels are assessed against the existing infrastructure level.

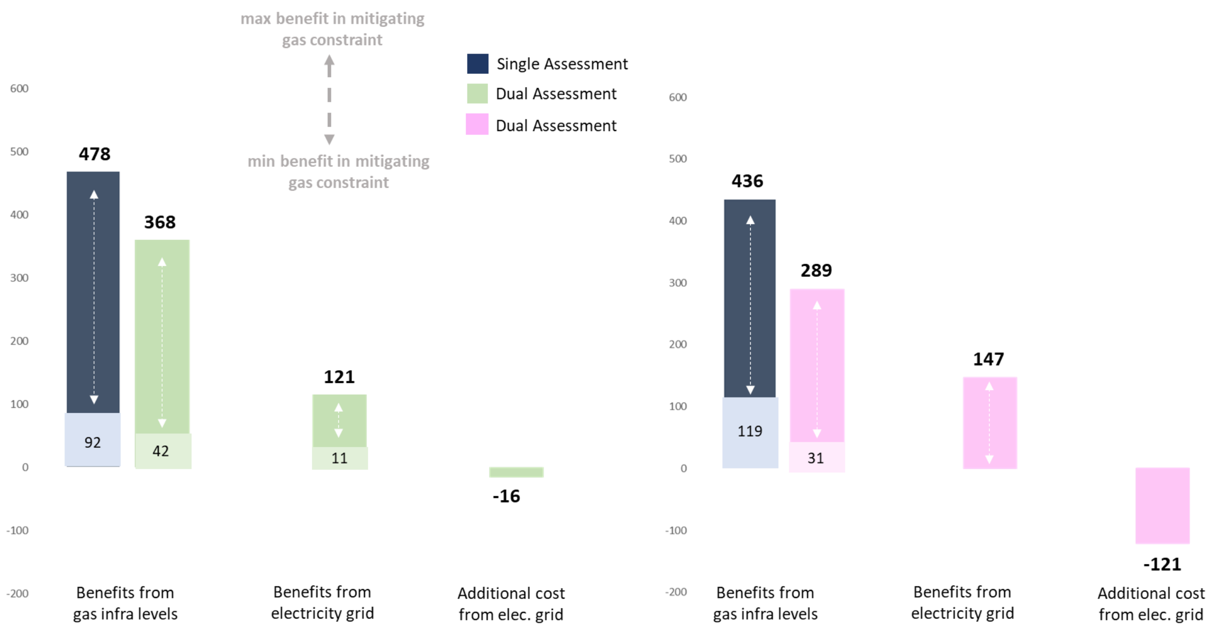


Figure 36 and Figure 37 – Social Economic Welfare impact in Global Ambition 2030 (left) and Distributed Energy 2030 (right).

There is one single value for the additional cost from the electricity margin. The reason behind is that the electricity margin was calculated only for one level of stress for each scenario. If more levels of stress would have been used, then different additional costs might have been obtained.

The above calculation refers only to the constraint where interlinkages are relevant. This does not exclude that infrastructures could still bring benefits in other indicators that do not affect interlinkages between electricity and gas. Also, for this reason, results should be interpreted cautiously.

10.2. Condition 2 – Presence of relevant P2G

In the previous section, a first draft for the dual assessment methodology was tested under situations with relevant G2P. In the following section, the dual assessment methodology under relevant P2G is applied and tested on some projects from TYNDP 2020.

Since the screening methodology did not identify any countries in which projects would need a dual assessment, the scenario assumptions on price-driven P2G capacities were substantially modified, with the sole purpose of testing and developing a dual assessment methodology for electricity infrastructure projects, considering relevant price-driven P2G. Therefore, the results obtained in this test, cannot be compared to the results obtained in the context of the electricity TYNDP.

10.2.1. Indicators used

For this test, two indicators were analysed: the Social-Economic Welfare (SEW) and the CO2 emissions, both looking at the electricity and gas systems.

10.2.2. Assumptions

The tests are based on the following input:

- Scenarios: Distributed Energy 2030
- 1 climate year: 1984
- P2G facilities are used to supply green hydrogen as the final product
- P2G facilities do not have operational restrictions (e.g.: switching constraints)
- scenario dependent, Fixed hydrogen price
- Infrastructure:
    - Electricity TYNDP reference grid
- Focus on:
    - 2 countries identified by screening methodology
    - 3 countries not identified by the screening methodology (to also confirm the validity of the screening methodology)
- It is assumed two different shares of P2G, one of them is the share as given in the TYNDP 2020 scenarios and the other one is 100% of the P2G from the scenarios is connected to the grid for all countries where the scenarios assume presence of P2G capacity. Their dedicated RES is also considered (flow only from the grid to P2G). This means that for all countries from the TYNDP 2020 scenarios in which there were P2G facilities not connected to the grid, they are assumed to be connected to the grid. However dedicated RES in a country can feed only the P2G facility associated to that node. RES flow from the P2G facility to the electricity grid is not allowed. P2G facilities are assumed to be profitable in this configuration.

The climate year 1984 is used since it is considered as one of the representative climate years used in the electricity TYNDP, and also corresponds to an average hydro year in Europe.
For the purpose of this test, electrolysers were modelled as price-sensitive demand that have their own dedicated RES facilities and that on top of that, can consume electricity if the electricity marginal price is lower than 15 EUR/MWh. The reason to set the strike price to 15 EUR/MWh is to ensure that P2G facilities contribute to decarbonising the European economy, by consuming CO2 free electricity. Moreover, the cap price of 15 EUR/MWh is set

since the marginal cost of nuclear units is 14.3 EUR/MWh, therefore P2G facilities run when the marginal units are nuclear power plants, or whenever there is curtailment of RES (which would set the marginal price to zero). In this way, the strike price of 15 EUR/MWh ensures that P2G facilities only run with CO2-free electricity.

Figure 38 shows the elements used to model P2G as a price-sensitive demand with the behaviour described in the previous paragraph. In every market node that has P2G, a dedicated node is created (e.g. P2G FR00, P2G DE00, etc.). Then, the power flow is constrained so it can only go from the grid to the P2G nodes. At the same time, the dedicated RES that feeds the P2G facilities are connected to the respective P2G node. The most important part is how to model P2G as price-sensitive demand. For this purpose, a flat demand is added to the respective P2G node. The magnitude of this load is the same magnitude of capacity of P2G in that node. Then, a generator with a variable cost of 15 EUR/MWh is connected to the respective P2G node as well. The installed capacity of this generator corresponds to the value of P2G capacity. It is important that this generator is added just for modelling purposes and its cost is not considered in the project assessment phase. The reason to exclude the cost of these generators is because in reality they don't represent a cost for the electricity system and therefore, they shouldn't be considered in the calculation of the social-economic welfare.

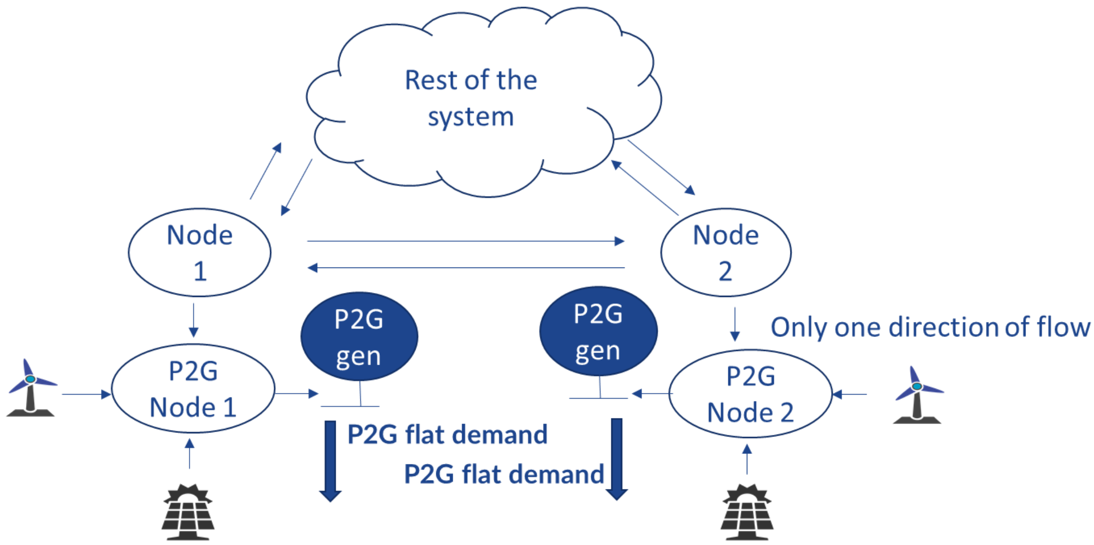


Figure 38 - Simplified diagram of P2G modelling

In this way, whenever there is not enough dedicated RES, and the electricity marginal price from the system is lower than 15 EUR/MWh, the fictitious P2G generator will not run, and therefore, there will be only demand in the P2G node. Then, if the electricity marginal price would be higher than 15 EUR/MWh, the fictitious P2G generator would run, and since it has an installed capacity of the same value as the flat P2G demand, the net sum between both is equal to zero, which is equivalent to have no P2G demand for those specific hours.

The aims of this test was to analyse results of the proposed dual assessment methodology under presence of relevant price-driven P2G, to check how the P2G conversion is affected during the project assessment and to check how the assumption of 100% price-driven P2G affects indicators of electricity projects when performing a single and a dual assessment. Then when having both results, it is possible to compare results of a single assessment versus a dual assessment.

It is important to clarify the difference in the behaviour of P2G between the single assessment and the dual assessment in the electricity market models.

ENTSO-E models P2G as a price-sensitive demand. P2G facilities take electricity from the grid when the marginal price in the node where the P2G facility is connected is lower than a strike price. However, marginal prices are dependent on the electricity grid (e.g.: more interconnection capacity could allow to bring cheaper electricity from neighbouring countries)
In the project assessment phase, when adding or removing a project to the electricity grid, electricity marginal prices change. Since the electricity marginal prices change, the load pattern of P2G facilities changes.
The change on the load pattern of P2G facilities can trigger that different amount of "gas" coming from P2G is produced. The previous point would mean that when comparing two different projects on the same border, they would be assessed under a different total electricity demand, making comparison of projects more difficult.
As solution for this, ENTSO-E calculates the load pattern of P2G facilities of the system with the reference grid. Then this load pattern remains fixed for the project assessment.
ENTSO-E calculates all the indicators under fixed load pattern of P2G facilities. This is a single assessment.
In the case of the dual assessment, the load pattern is not fixed and P2G facilities can have a dynamic load pattern, that changes when an electricity project is included or removed from the grid. Then, the benefits due to changes on the conversion from P2G facilities are quantified.

Single assessment:

- P2G demand profiles are calculated for the electricity reference grid and then fixed
- ΔSEW is measured through the difference in the total generation cost
- ΔCO2 is measured on the electricity system only

Dual assessment:

- P2G demand profiles calculated in every simulation

- ΔSEW is measured through the difference in the total generation cost in the electricity system minus avoided cost by supplying hydrogen/natural gas demand with P2G facilities
- ΔCO2 is measured in the electricity and gas systems

10.2.3. Methodology description and impacts on results

In order to evaluate different projects, the reference case simulation was fixed.
The model minimises the total cost of the energy system, respecting a strike price of 15 EUR/MWh for P2G conversion facilities, to ensure that only power from CO2-free sources is converted into gas.

For the reference case simulation, see table below, there is a large amount of P2G converted by dedicated RES facilities (190 TWh) and only less than 10% generated by the rest of the electricity system (18.7 TWh).

Country	Energy From Dedicated RES [GWh]	Energy from the grid [GWh]	Electricity Consumption of P2G [GWh]	Load factor
AT00	2588	324	2912	33%
BE00	14750	1642	16392	59%
BG00	764	213	977	27%
CZ00	2126	167	2293	38%
DE00	29538	1937	31475	69%
DKW1	14395	934	15329	64%
EE00	5044	274	5318	46%
ES00	660	200	860	69%
FI00	7112	723	7835	44%
FR00	14217	3451	17668	78%
GR00	12444	449	12893	70%
HR00	2013	30	2043	54%
HU00	2459	72	2531	53%
IE00	6386	2158	8543	64%
ITCS	15551	738	16288	41%
LT00	2361	112	2472	57%
LV00	1659	76	1735	57%
NL00	12222	1156	13377	61%
PL00	4375	121	4496	56%
PT00	6873	1891	8764	83%
RO00	2601	452	3054	30%
SE04	10422	691	11112	65%
SI00	1421	43	1464	42%
SK00	2235	62	2297	56%
UK00	16094	849	16943	53%
TOTAL	190307	18764	209071	57%

Table 3 - Reference case results of P2G in MWh, with a strike price of 15 €/MWh

Error! Reference source not found. shows the results for the reference case from which, Social Economic Welfare and CO2 emissions for different electricity projects are compared through single assessment and dual assessment methodologies.

For the single assessment methodology, interactions between the electricity and gas system are neglected, so P2G conversion is not affected by the electricity projects. As a matter of fact, for these simulations, this conversion is fixed to the hourly results obtained from the reference case, which is used to fix the flow that goes from the electricity grid to the P2G facilities.
In order to have a global view of how this flow is fixed, area by area, three indicators are calculated: the number of hours in which there is flow from the grid to the P2G facilities, the average value of these flows (excluding zero values) and their maximum value. These results are shown in **Error! Reference source not found.**.

Country	Numbers of hours in which there is flow from grid to P2G	Average P2G consumption from the grid, excluding zero values (MW)	P2G peak consumption from the grid (MW)
AT00	474	437	860
BE00	434	1307	3158
BG00	907	152	410
CZ00	404	203	491
DE00	168	2071	5006
DKW1	410	779	2626
EE00	102	427	1138
ES00	2924	85	141
FI00	147	643	1894
FR00	2526	1099	2318
GR00	368	578	1420
HR00	74	88	261
HU00	269	155	411
IE00	1472	362	1253
ITCS	499	1197	3993
LT00	102	96	441
LV00	21	60	155
NL00	266	773	2463
PL00	55	184	450
PT00	4137	460	1209
RO00	780	484	1045
SE04	210	621	1795
SI00	147	93	283
SK00	206	129	318
UK00	180	806	2391

Table 4 - Indicators associated to the flows from the electricity to P2G facilities

As dedicated RES contribute largely to P2G conversion, the flow from the grid to P2G facilities has values higher than zero for a limited number of hours, except for Spain, France, Ireland,

and Portugal where there are flows of more than 2000 hours a year. For the other areas the flow from the grid to P2G facilities has a value higher than zero for less than 1200 hours.
The average of the flow, when this flow excluding zero values was calculated, is close to half of the max of the flow, indicating that the distribution of values should be relatively regular.
Finally, it is possible to check that max values are lower but close to capacity values of P2G facilities. This means, at the hour when each max value occurs, that cheap electricity from the grid is available, whereas dedicated RES generation is very low.
The indicators in Table 5 give a Gross Social Economic Welfare of 78.7 billion €, corresponding to the operational costs of the whole electricity system, for the simulated year.
However, the transfer of value from the electricity system to the gas system through the quantity of P2G converted should be also considered. The valorisation of this transfer is done using the hydrogen prices, which considering the losses of electrolysers, gives a benefit of 0.032 M€/GWh$_{electricity}$, and this gives a transfer value of €6.8 billion. Finally, the Net Social Economic Welfare is estimated at €71.9 billion.

Likewise, for CO2 emissions, the first amount calculated of 534 Mtons corresponds to the "gross" CO2 emissions from the electricity system. However, as hydrogen has been generated through P2G facilities, powered by 209 TWh, there is also a transfer of emission reductions from the electricity system to the gas system. Doing some calculations, it is determined that 1 MWh of power transformed in hydrogen will avoid 0.1833 ton of CO2 emissions, in substitution of natural gas used for steam methane reforming[30]. Using these values, the net CO2 emissions amount is 495 Mtons.

Reference Case	
Operational Costs (M€)	78,737
CO2 emissions from Power grid (ktons)	533,795
Flow from Power grid to P2G (GWh)	209,071
Value of P2G generated at H2 price (M€)	6,858
Net Social Economic Welfare (M€)	71,880
CO2 emissions avoided at H2 rate (ktons)	38,323
Net CO2 emissions (ktons)	495,472

Table 5 - Indicators for reference case to compare with projects

[30] It is assumed that the difference on the conversion of power to hydrogen is the opposite of the difference on the hydrogen production from steam methane reforming. So, if hydrogen from P2G varies in +x GWh in a year, then the hydrogen production from steam methane reforming varies -x GWh in a year.

After having fixed the reference case, the dual and single methodologies are applied to 8 electricity interconnectors. The results for the assessment of these projects are presented in the next section.
All these projects give added value to the electricity system, as each of them increases flow capacity between 2 countries.

There are 2 ways to evaluate these 8 projects, depending if the project is included or not in the reference grid.

For the "PINT" projects, the project is not included in the reference case. Simulations done to evaluate the project add the project in the model and run it again. For the single assessment method, the flow from the electricity grid to P2G facilities is fixed hourly at the flow level obtained from reference case simulation, whereas for dual assessment this flow is free and part of the optimisation.

For the "TOOT" projects, the project is included in the reference case. Simulations done to evaluate the project will subtract the project in the model and run it again. For the single assessment method, the flow from the electricity grid to P2G facilities is fixed hourly at the flow level obtained from reference case simulation, whereas for dual assessment this flow is free and optimised.

10.2.3.1. Assessment of 8 electricity interconnector projects

The following 8 electricity interconnector projects have been evaluated through both methodologies:

- Project 1 (TOOT): electricity interconnection project giving 500 MW of additional transfer capacity between two countries identified by the screening methodology;
- Project 2 (TOOT): electricity interconnection project giving 950/900 MW of additional transfer capacity between two countries identified by the screening methodology;
- Project 3 (PINT): electricity interconnection project giving 700 MW of transfer capacity between two countries identified by the screening methodology;
- Project 4 (PINT): electricity interconnection project giving 900/800 MW of additional transfer capacity between two countries identified by the screening methodology;
- Project 5 (TOOT): electricity interconnection project giving 600 MW of additional transfer capacity between two countries not identified by the screening methodology;
- Project 6 (PINT): upgrading of existing electricity interconnection between two countries not identified by the screening methodology;
- Project 7 (PINT): electricity interconnection project giving 600 MW of additional transfer capacity between two countries not identified by the screening methodology;
- Project 8 (PINT): electricity interconnection project giving 1117/685 MW of additional transfer capacity between two countries not identified by the screening methodology.

The results of the annual simulations concerning these projects have been summarized in Figure 39, where the social economic welfare indicator is calculated for single and dual assessments. Additionally, the percentage of increase or decrease of the dual assessment results, compared to the single assessment results is also shown. PINT projects have been added to the grid in the simulations for their respective assessment, and TOOT projects have been removed from the grid in the simulations for their respective assessment.

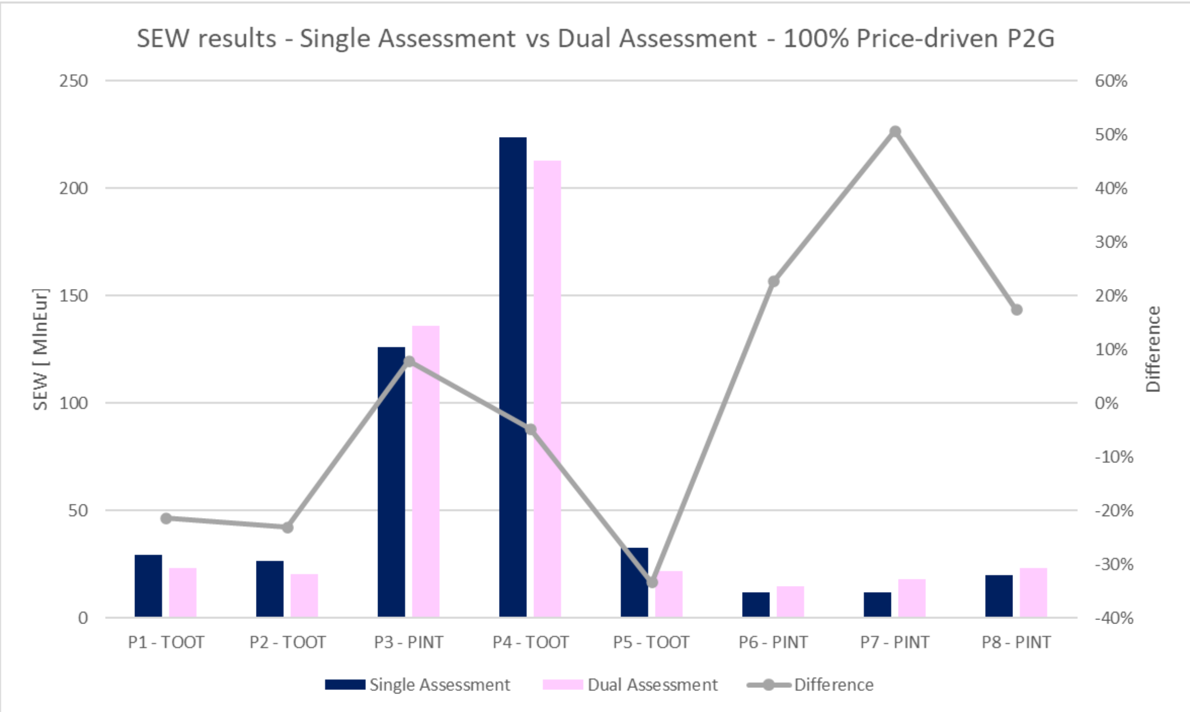


Figure 39: SEW indicator for the 8 projects with single and dual assessment methodologies

From the previous Figure, it is possible to see that the social economic welfare of projects follows the following relation:

SEW TOOT-Single assessment > SEW TOOT-Dual assessment > SEW PINT-Single assessment > SEW PINT-Dual assessment

The magnitude of results between the simulations does not differ significantly and the next table with differential values is more convenient for analysis. This difference is calculated as “project – ref. case” for PINT projects and “ref. case – project” for TOOT projects.

As the amount of P2G converted is the same for single assessment simulations and for the reference case, the differences in Gross SEW and Net SEW are identical for these simulations.

The increase or decrease in the P2G conversion in the dual assessment simulations, is not large (less than 150 GWh) and generates a correction between Gross SEW and Net SEW.
However, the additional value for the dual assessment methodology compared to single assessment methodology is much higher, with a gain for PINT or a loss for TOOT, from 2.7 to 10.9 M€.
This result can be explained by the fact that for some hours, the optimal use of a project can lead to an increase in the use of P2G facilities and for some hours to a decrease, effects only captured by the dual assessment methodology. The temporal and spatial netting effects of these increases and decreases, lead to a gap on the annual P2G conversion compared to the reference case.

Additionally, difference in losses from electrolysers are calculated and shown in Figure 40.

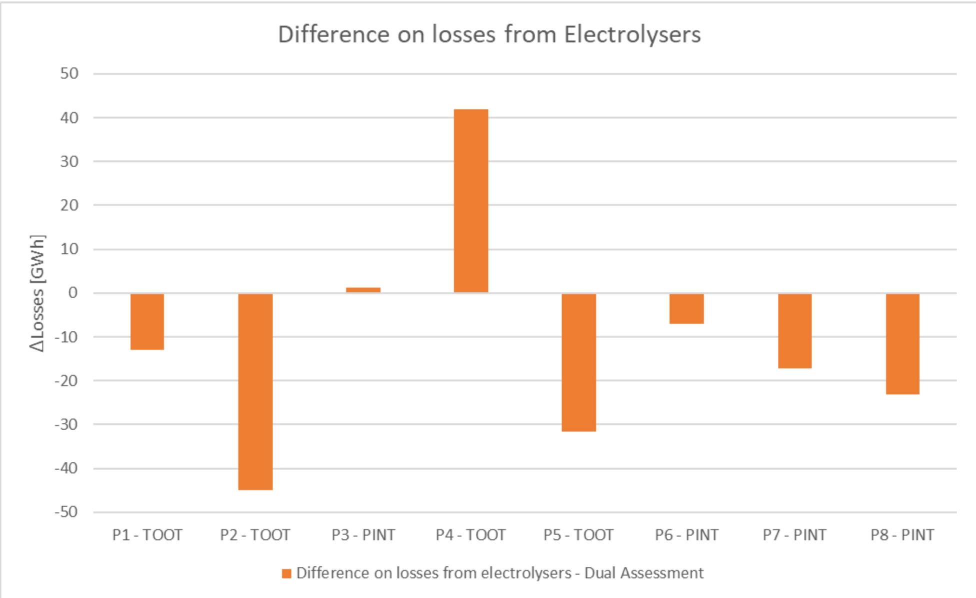


Figure 40: Difference on the losses from electrolysers

Electrolysers losses can come from the electrochemical process carried out in electrolysers, or from the resistivity of the components of electrolysers, among others. Figure 40 shows the differences in the losses from electrolysers, when having the different projects in the grid. So, for example, when the project P1 is in the grid, then losses in electrolysers decrease by around 10 GWh in a year. The reason behind this is that when having the project in the grid, there is less hydrogen being converted by P2G facilities, and therefore, the electrolyser losses are also lower. The changes in hydrogen production could be explained by the fact that when removing a project from the grid, two effects take place depending on the location of electrolysers. On the one hand, the excess of cheap electricity (e.g.: renewables) might not be able to be imported by electrolysers due to the lower transmission capacity, reducing the conversion of electricity into hydrogen. On the other hand, with lower transmission capacity there might be an increase in the curtailed energy (e.g.: renewables) in the node where electrolysers are connected making more electricity available to be converted into hydrogen. The prevailing impact of removing an electricity project from the grid will depend on different factors, such as the countries involved, and the scenario of the assessment.

Additionally, losses from the electricity transmission system have not been calculated, nevertheless, currently their magnitude is around 0.8-3% of the injected energy[31].

10.2.4. Dual assessment of projects with the share of price-driven P2G as given in current TYNDP 2020 scenarios

In the previous sub-section, it was seen that the results of the project assessment differ depending on whether the single assessment or dual assessment methodology was used. Moreover, the differences observed applied not only to projects identified by the screening methodology but also to projects that were not identified in the screening step. Nevertheless, it is important to highlight that the previous results were obtained under the assumption of having all the P2G from the scenarios connected to the market. In other words, a share of 100% price-driven P2G was assumed and also the inclusion of dedicated RES.

As a next step, in order to further challenge the screening methodology, the results of the assessment methodologies were compared, but this time considering current TYNDP 2020 scenarios as they are.

TYNDP 2020 scenarios only consider certain level of price-driven P2G in Germany (2000 MW), in Austria (1000 MW) and in Belgium (25 MW). Additionally, no dedicated RES is considered.

The results obtained when assessing projects using both, the single and dual assessment methodologies, are shown in Figure 41. Additionally, the percentage of increase or decrease of the dual assessment results, compared to the single assessment results is also shown.

[31] CEER Report on Power Losses (2020)

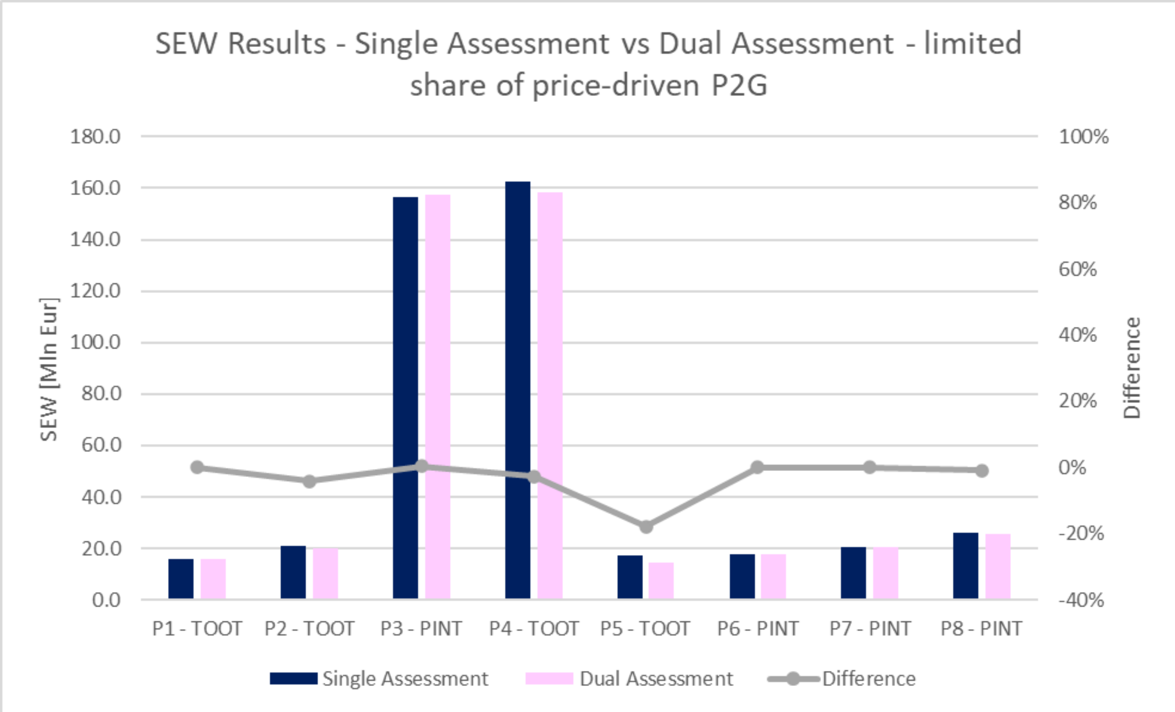


Figure 41: SEW under single and dual assessment methodologies - share of price-driven P2G as given in the TYNDP2020 scenarios

In Figure 41, it can be seen that there are minor differences in the results obtained through the dual assessment methodologies when the share of price-driven P2G is the one given by the scenarios. **Therefore, for the share of price-driven P2G from the scenarios of TYNDP2020, using the single assessment methodology is as accurate as using the dual assessment methodology**. The main reason behind is that since under these circumstances, the amount of price-driven P2G in Europe is relatively small compared to the size of the European electricity market, the interactions between electricity projects and P2G facilities are relatively small.

Figure 42 shows a comparison of the percentage of increase or decrease of the dual assessment results, compared to the single assessment results, under different shares of price-driven P2G. These results suggest that the higher the installed capacity of price-driven P2G, the higher the interactions between electricity projects and the P2G facilities in the system, and therefore, the higher the differences between the single and the dual assessment methodologies.

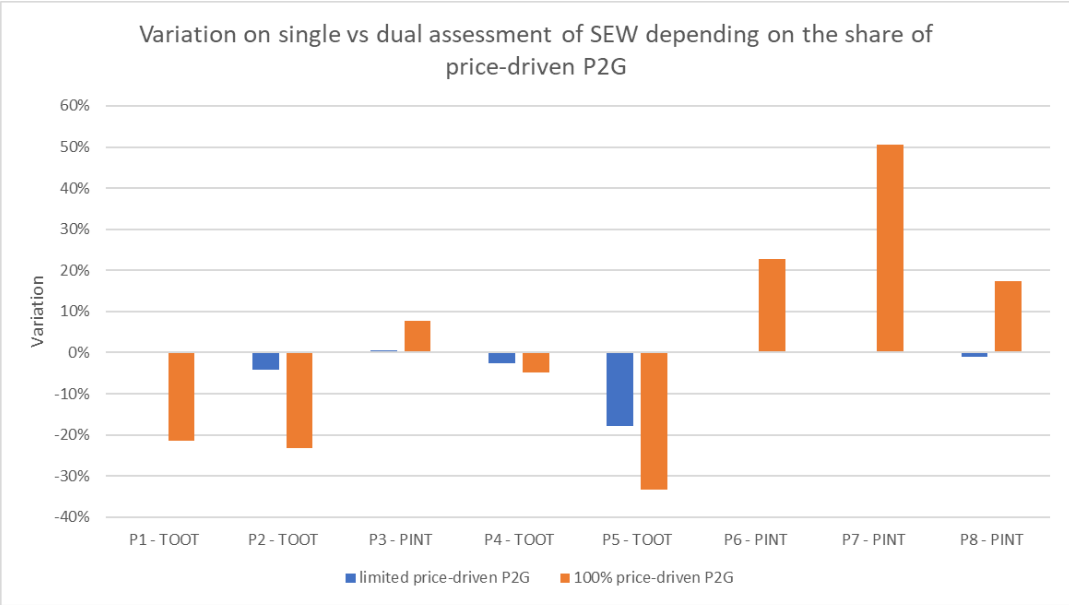


Figure 42: Variation on dual assessment of SEW depending on the share of price-driven P2G

10.2.4.1. Distribution of P2G when performing the dual assessment

Error! Reference source not found. shows the distribution of deviations in the electricity consumption of P2G facilities, when performing the dual assessment in comparison to the reference case.

The deviations are split in 2 amounts, a positive amount for which all additional P2G conversion given by the dual assessment calculation is summed up and a negative amount for which all the reduction of P2G conversion is summed up.

Finally, it is also shown the net value of these 2 amounts with the correct sign depending if it is a PINT or a TOOT approach.

The reason of this decomposition is that from the first results of the dual assessment for condition 2 can be noted that very often the total amount of P2G converted during the year does not differ significantly between single and dual assessment. However, for some projects, there is a significant impact in terms of SEW, that means that the distribution over the year of P2G converted can affect more than the overall amount.

Actually, in the results obtained, it is possible to confirm that very often positive and negative deviations have similar level of magnitude and the net value of these 2 amounts can be low.

Project 3, for instance, has at least a very little impact in terms of net difference of P2G (only 4 GWh). However, for this project the positive deviation (and negative deviation) is over 430 GWh, confirming that the distortion in the distribution is much more significant than a shift in the total amount.

When looking at the deviations obtained for Project 3, it is possible to see that some of these deviations are distributed all over the 25 areas where P2G facilities are modelled. This means that an interconnector project, for instance Project 2, with additional transfer capacity between two countries, can impact the P2G distribution in a different country (e.g. a project North-Sea countries could impact the P2G distribution in Central South Italy). This effect is due to the complexity of the electricity system with many different characteristics and also because the scale of the electricity market is European, so changes on demand patterns affect the P2G conversion across Europe. So, just by modifying a link somewhere in Europe, it can happen that it makes the model reacting differently across Europe.

This qualitative result is important and should be considered in the dual assessment methodology. As a matter of fact, the selection of specific areas induced by the screening methodology must be reviewed.

Country	Reference Case	Dual assessment Project 1 - TOOT			Dual assessment Project 2 - TOOT			Dual assessment Project 3 - PINT		
	P2G Electricity Consumption (MWh)	Sum of positive hourly differences (MWh)	Sum of negative hourly differences (MWh)	Net Difference (MWh)	Sum of positive hourly differences (MWh)	Sum of negative hourly differences (MWh)	Net Difference (MWh)	Sum of positive hourly differences (MWh)	Sum of negative hourly differences (MWh)	Net Difference (MWh)
AT00	2,912,239	1,010	-510	-500	28	-71	43	3,119	-544	-2,575
BE00	16,391,886	17,291	-15,975	-1,316	14,738	-14,307	-431	41,737	-24,378	-17,359
BG00	976,744	1,333	-1,333	0	1,030	-1,351	321	4,118	-828	-3,290
CZ00	2,292,637	1,599	-696	-903	613	-516	-97	1,297	-991	-306
DE00	31,474,939	13,897	-10,913	-2,984	10,744	-12,733	1,989	20,722	-12,217	-8,505
DKW1	15,328,508	3,059	-2,865	-194	3,691	-3,471	-220	10,503	-7,036	-3,467
EE00	5,318,099	14,982	-28,981	13,999	3,451	-3,511	60	5,357	-2,600	-2,757
ES00	859,690	0	-305	305	0	0	0	1,771	-4,925	3,154
FI00	7,834,942	14,847	-8,163	-6,684	2,620	-3,193	573	3,437	-3,333	-104
FR00	17,668,353	16,202	-16,347	145	14,227	-13,282	-945	61,905	-110,647	48,742
GR00	12,892,896	7,232	-7,114	-118	8,157	-8,881	724	11,171	-5,511	-5,660
HR00	2,043,044	921	-921	0	1,156	-956	-200	3,415	0	-3,415
HU00	2,530,935	731	-732	1	647	-466	-181	2,153	-98	-2,055
IE00	8,543,322	25,830	-25,475	-355	174,086	-22,587	-151,499	163,590	-144,419	-19,171
ITCS	16,288,298	25,852	-24,903	-949	29,165	-29,614	449	31,319	-32,655	1,336
LT00	2,472,426	16,831	-205	-16,626	899	-899	0	2,103	-707	-1,396
LV00	1,734,829	17,603	-638	-16,965	315	-314	-1	249	-248	-1
NL00	13,377,313	1,589	-916	-673	983	-809	-174	7,442	-5,182	-2,260
PL00	4,496,033	968	-190	-778	507	-133	-374	78	-425	347
PT00	8,763,602	9,215	-9,215	0	11,020	-11,015	-5	14,990	-46,717	31,727
RO00	3,053,807	4,566	-4,559	-7	6,495	-7,330	835	9,302	-5,645	-3,657
SE04	11,112,274	13,833	-6,671	-7,162	6,646	-6,157	-489	9,187	-7,094	-2,093
SI00	1,463,875	123	-123	0	17	-17	0	1,035	-69	-966
SK00	2,296,731	276	-127	-149	321	-127	-194	390	-127	-263
UK00	16,943,415	15,761	-14,760	-1,001	12,797	-13,220	423	24,410	-14,291	-10,119
TOTAL	**209,070,837**	**225,551**	**-182,637**	**-42,914**	**304,353**	**-154,960**	**-149,393**	**434,800**	**-430,687**	**-4,113**

Table 6: Differential P2G conversion with dual assessment methodology for 3 electricity projects

10.3. Hybrid Projects

There are projects in which there is no need to apply a screening methodology to detect the need for a dual assessment.

A clear example of this kind of projects are price-driven P2G projects, which are connected to the electricity grid, interacting with the electricity system, and at the same time, they influence the gas system as well.

Therefore, projects directly linking electricity and gas systems can be automatically considered eligible for dual assessment. In the case of projects that include electrolysers, they are assessed in the same way as condition 2.

As part of this investigation, the dual assessment methodology was applied to two projects collected in TYNDP 2020.

Hybrid projects submitted to the future TYNDPs might not always have the same characteristics of the ones tested as part of this investigation. It is therefore difficult to define ex-ante a standard approach for these types of projects.

Ad hoc assessment will have to be carried by ENTSO-E and ENTSOG to ensure that all relevant interlinkages are duly considered.

The aim of the test of hybrid projects assessment test was to demonstrate that ENTSO-E and ENTSOG are capable of assessing these projects as part of their TYNDP.

10.3.1. Indicator used

As per the assessment of condition 2, for this test, two indicators were analysed: Social-Economic welfare (SEW) and CO2 emissions, both looking at the electricity and gas systems.

10.3.2. Assumptions for Hybrid Projects

Tests based on the following input

- Scenarios: National Trends 2030 / Distributed Energy 2030 / Global Ambition 2030
- 1 climate year: 1984
- Installed capacity of price-driven P2G as given in the scenarios
- Infrastructure:
  - Electricity TYNDP reference grid
  - No modelling of the gas grid
- Two projects assessed
  - Hybrid project 1

- Hybrid project 2

The climate year 1984 is used since it is considered as one of the representative climate years used in the electricity TYNDP, and also corresponds to an average hydro year in Europe.
As a simplification, it is assumed that there are no constraints on the gas grid, so all the hydrogen produced can be either consumed or allocated in the gas system.
The aim of this test was to analyse results of the dual assessment methodology when applied to these projects and compare the results obtained by performing a single assessment versus a dual assessment.

10.3.3. Hybrid Project 1

Hybrid Project 1 which combines electricity interconnectors, electrolysers and gas pipelines, to help develop a cluster of offshore wind parks with a capacity of several gigawatts.

10.3.3.1. Results

This project was assessed in two different ways. When assessing the project using the single assessment methodology, the electrolysers of the projects were not considered. The only electrolysers that present in the electricity system are the ones from the respective scenario in which the project is being assessed. In this last situation, the P2G demand profiles are fixed, so they do not vary when modifying the grid capacities for the assessment of the project.
In the case of the dual assessment, the electrolysers of the project were included in the simulations, and at the same time, the P2G profiles were not fixed, so they could vary when modifying the capacities of the grid for the assessment of the project.

Figure 43 shows the results obtained for the social-economic welfare indicator.

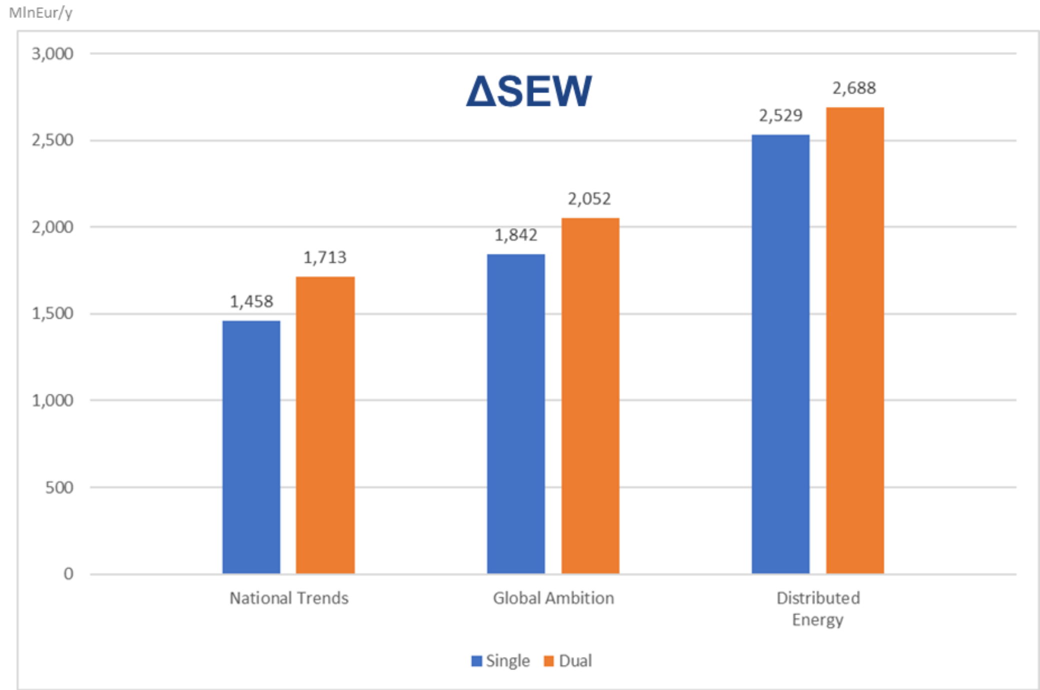


Figure 43 – Results of single and dual assessment for the social-economic welfare indicator for Hybrid Project 1 in 2030

2030 Scenario	Single	Dual
National Trends	1,458	1,713
Global Ambition	1,842	2,052
Distributed Energy	2,529	2,688

Table 7 - Results of single and dual assessment for the social-economic welfare indicator for Hybrid Project 1 in 2030

Figure 30 shows the results obtained for the CO_2 emissions indicator.

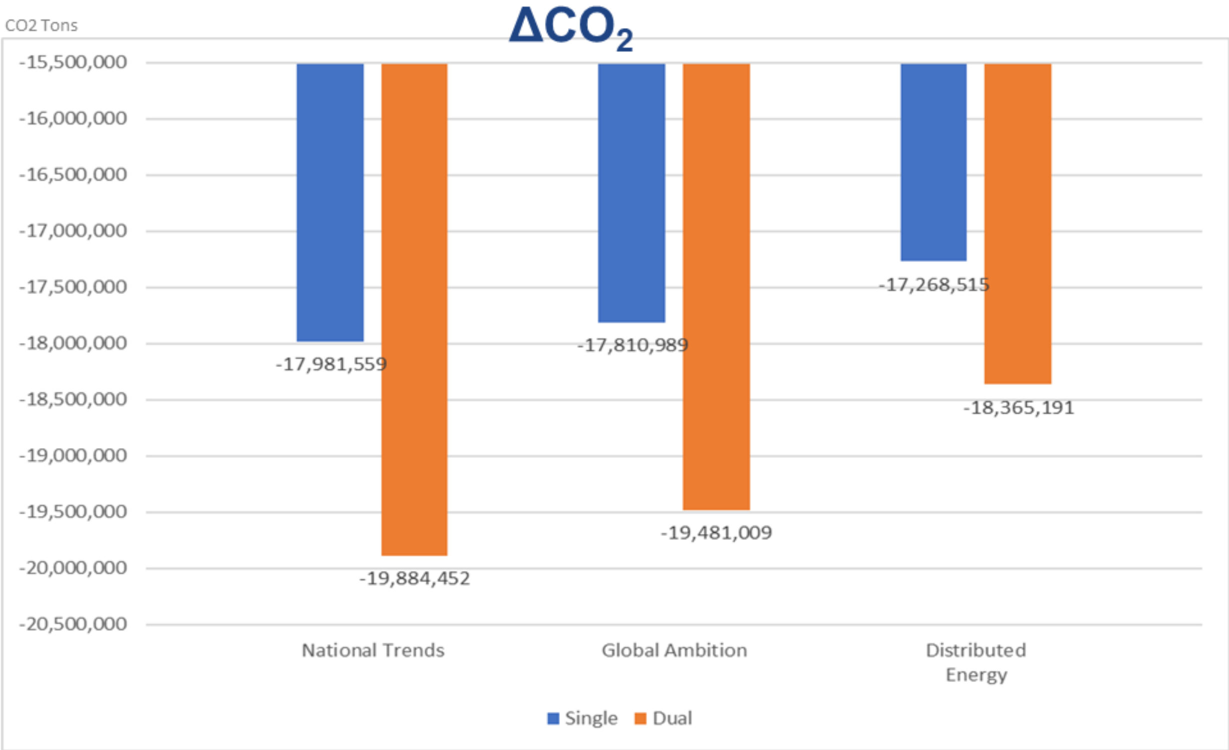


Figure 44 - Results of single and dual assessment for the CO_2 emissions indicator for the North Sea Wind Power Hub Project in 2030

2030 Scenario	Single	Dual
National Trends	-17,981,559	-19,884,452
Global Ambition	-17,810,989	-19,481,009
Distributed Energy	-17,268,515	-18,365,191

Table 8 - Results of single and dual assessment for the CO_2 emissions indicator for the North Sea Wind Power Hub Project in 2030

In Figure 43 it can be observed that the social-economic welfare of the project, increases when assessing it using the proposed dual assessment methodology. The main reason behind, is that the project now includes electrolysers, which contributes with an additional degree of flexibility to the power system. This flexibility allows renewable electricity that was being curtailed even when considering the additional electricity interconnectors from the project, to be used for hydrogen conversion through electrolysers. Thus, increasing the social-economic welfare.

In Figure 44 it can be observed that the CO_2 emissions indicator decreases when the project is assessed with the dual assessment methodology, meaning that the project is able to decrease CO2 emissions of the gas and electricity systems even further compared to the case of the single assessment. This situation is explained, in a similar way as described in the previous paragraph, due to the additional electrolysers that are considered in the project. The hydrogen produced by these electrolysers, especially the one being produced from renewables that were being curtailed, contributes to decrease the emissions of the energy system even further.

10.3.4. Hybrid Project 2

Hybrid Project 2 is a project that combines Compressed Air Energy Storage (CAES) and Underground Hydrogen Storage. The project is planned to be located close to existing electricity and gas transmission, underground gas storage and offshore wind resources.
According to the project description, the first consumer of hydrogen will be the CAES. The green hydrogen will also be used to produce green transportation fuels (e-fuel) and as a feedstock for industrial processes.

10.3.4.1. Specific Assumptions

This project produces hydrogen that can be processed and sold as a different product, or as a feedstock. At the same time, during the air compression phase, there is heat produced that could be sold in a heating market. However, for the purpose of this test, only the phases shown in Figure 45 are modelled in the dual assessment phase.

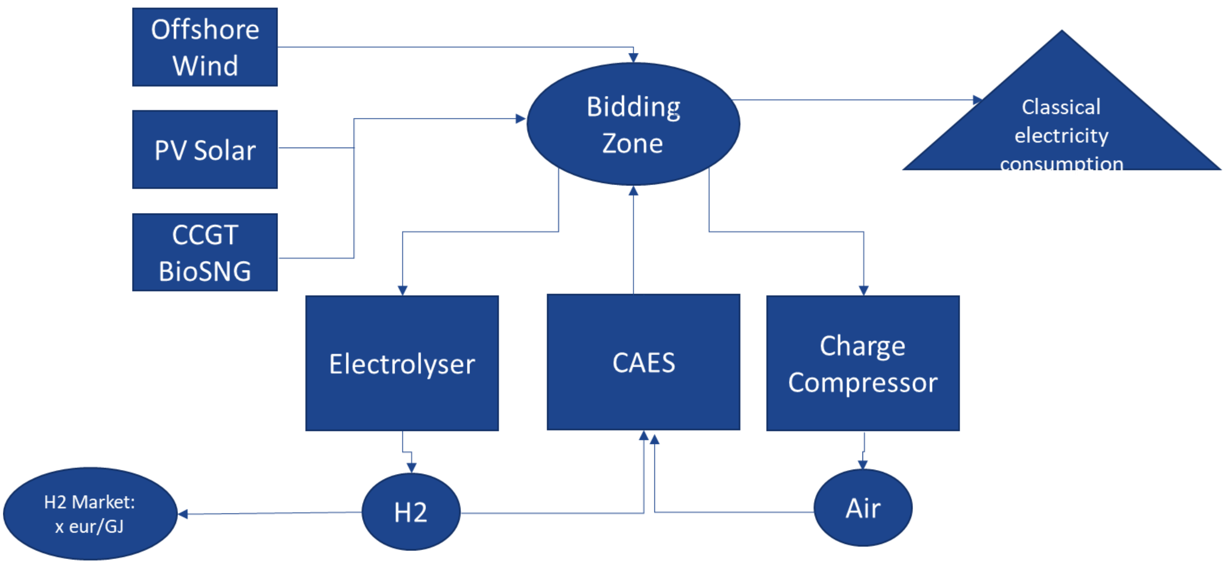


Figure 45 - Simplified diagram of the Hybrid Project 2

Similarly, to the case of Hybrid project 1, in the case of single assessment, the electrolyser of the project is not modelled and the CAES unit consumes hydrogen from the hydrogen market which has a fixed scenario-dependent price. Therefore, when no electrolyser is modelled, the project can use electricity for compressing air only, and not to produce hydrogen that could be used to feed the CAES or sold in the hydrogen market. On the other hand, when performing a dual assessment for the Green Hydrogen Hub project, the electrolyser of the project is modelled (using PLEXOS Gas) and therefore, electricity from the grid can be used for air compression, or to produce hydrogen. In this last situation, there is an additional degree of freedom for the system to use electricity, for example curtailed electricity, to minimise the overall system cost. An important remark is that, due to the nature of CAES projects, the power output of the CAES unit depends on both, the amount of hydrogen that is used for the heating process, and the amount of compressed air.

The assumptions of hydrogen prices are shown in Table 9

	NT2030	DE2030	GA2030
Hydrogen Price for Power Market Modelling [eur/GJ]	€ 12.10	€ 13.01	€ 12.35

Table 9 – Hydrogen prices (Calculation based on fuel prices and efficiencies from TYNDP2020)

These prices are used to monetise the hydrogen bought/sold from/to the hydrogen market.

10.3.4.2. Results

Figure 46 shows the results obtained for the social-economic welfare indicator when assessing this project using single and dual assessment methodologies.

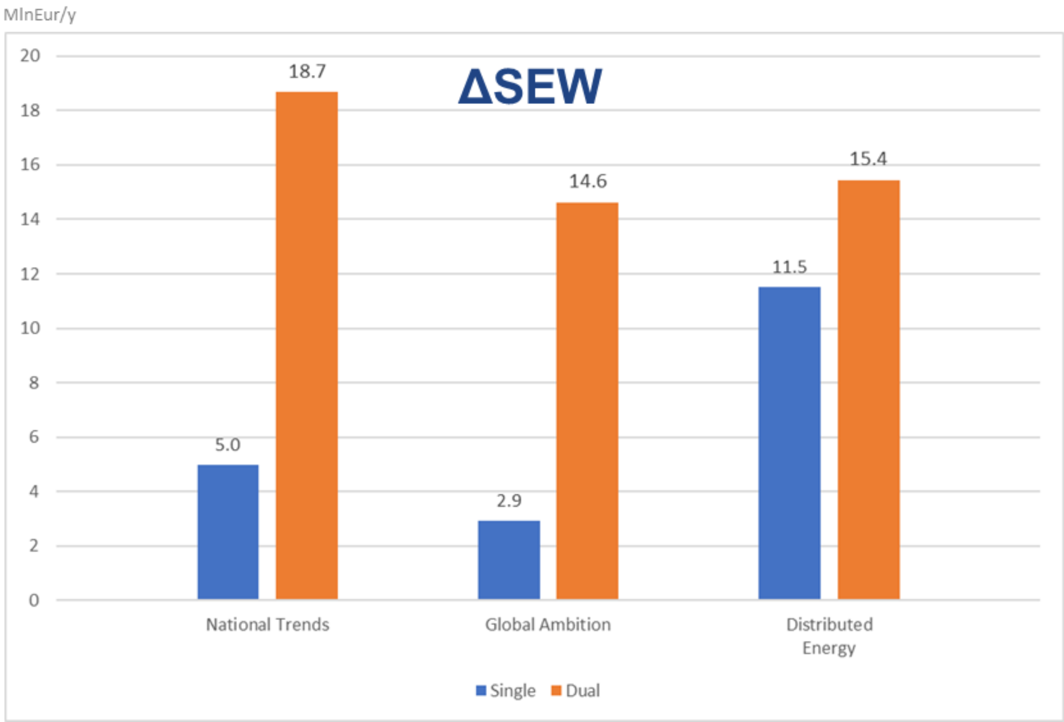


Figure 46 - Results of single and dual assessment for the social-economic welfare indicator for the Green Hydrogen Hub project in 2030

Figure 47 shows the results obtained for the CO_2 indicator when assessing this project using single and dual assessment methodologies.

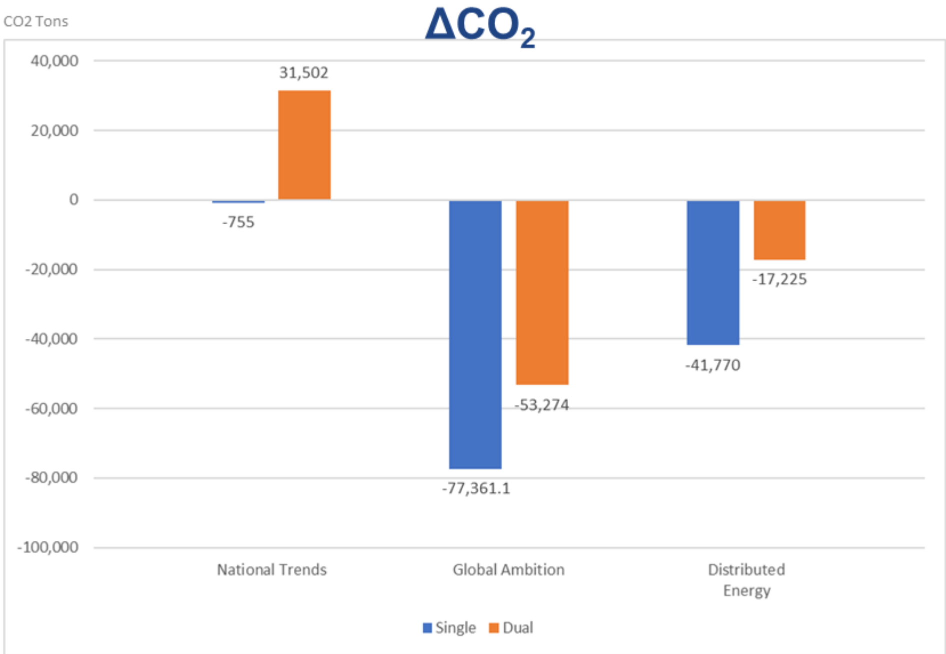


Figure 47 - Results of single and dual assessment for the CO2 emissions indicator for the Green Hydrogen Hub project in 2030

In Figure 46 it can be observed that the social-economic welfare indicator of this project is higher when assessing the project using the proposed dual assessment methodology.
The explanation for this situation can be found in the fact that the project was considered as a "trader" which basically can produce hydrogen that could be sold as a feedstock or processed (through the CAES unit) to be sold as electricity. If the hydrogen prices are expressed in EUR/MWh, they have a value near 40 EUR/MWh, while electricity prices can go much higher in periods of high demand and low generation from renewables. Since the project also includes hydrogen storage in caverns, this is quite relevant, considering that the project can store energy for a long period in a cost-efficient way, having the characteristics of seasonal storage.

In Figure 47 it can be observed the CO_2 emissions indicator for this project is lower when assessing this project using the proposed dual assessment methodology (the negative values in Figure 47 indicate that the project contributes to reduce CO_2 emissions). The main reason behind this situation is that when assessing this project with the single assessment, it is assumed that unlimited "CO2-free" hydrogen (the CO2 emissions for hydrogen conversion occur in the gas system and not in the electricity system) is available for this project, so all surplus of RES can be used for air compression. On the opposite, when modelling the hydrogen market and electrolyser, as part of the dual assessment, the CO2-free hydrogen supply is not unlimited anymore. The surplus of RES from the system must be shared for air compression and hydrogen conversion. Since the surplus of RES is limited, there is a decrease on the amount of generation with which the CAES unit can contribute to lower CO_2 emissions in the electricity system.

10.4. Conclusions and recommendations from the Dual Assessment

While opportunities have been identified, the scope of the current tested ILM method, and the limited number of projects tested, doesn't take into account every aspect for a final decision. ENTSO-E and ENTSOG will further work on those aspects.

10.4.1. Condition 1, significant presence of G2P

The following main conclusions can be drawn from the test carried for condition 1 (significant presence of G2P) on 5 gas projects and 4 electricity projects:
- available flexibility on the electricity system (so called capacity margin) can reduce the gas constraint identified in the gas system assessment
- consequently, available flexibility on the electricity system can reduces (accordingly) the contribution of gas infrastructures
- there are cases when gas projects still bring full contribution, even after a gas constraint reduction by the available flexibility margin
- the cost associated to the electricity flexibility margin should be considered as part of the assessment (at least in terms of changes in SEW and CO2 emission)
- for gas underground gas storages projects could be more relevant to consider 2-weeks and Dunkeflaute demand cases, or any similar stressful situation
- additional electricity projects can reduce the cost of using the electricity flexibility margin and in some cases reduce the gas constraint

10.4.2. Condition 2, significant presence of P2G

The following main conclusions can be drawn from the test carried for condition 2 (significant presence of P2G):
- the share of price-driven P2G in the scenarios has an impact on the benefits of electricity projects
- the conversion of price-driven P2G facilities is impacted by the composition of the electricity grid, however these impacts are not relevant to trigger a dual assessment on the gas system
- the differences on the P2G conversion do not seem to be relevant on a yearly basis, however the interactions on an hourly basis are relevant
- the results obtained showed that the SEW indicator for TOOT projects is higher when calculated using the single assessment methodology compared to the dual assessment. For PINT projects is the opposite, the single assessment methodology shows lower results compared to the dual assessment. The reason for this is that by fixing the P2G time-series, there is less flexibility for the energy system to decide when to convert electricity into gas,

increasing therefore the operational costs of the energy system. Then, depending if the project being assessed is PINT or TOOT, this increases or decreases the social-economic welfare indicator in the single assessment, compared to the dual assessment.

- price-driven P2G has always an effect on the tested electricity projects. The magnitude of this change depends on the amount of price-driven P2G, which will be defined in the future in the scenario building process
  - flexibility on operation of P2G is relevant to properly quantify the overall benefits of electricity projects, including the interactions under the presence of relevant P2G
  - changes on the exchange capacity in one border has an impact on the dispatch of generators around Europe, confirming that the electricity market has a European scale
  - changes on the exchange capacity in one border has a spatial and temporal impact on the P2G conversion
- the tests showed that the current screening methodology does not capture all project potentially impacted by price-driven P2G. However, this will not require a review of the screening methodology if the price-driven P2G and related assumptions will be integral part of the system assessment

10.4.3. Hybrid Projects

The following main conclusions can be drawn from the test carried for hybrid projects:

- assumptions had to be made in order to correctly quantify the benefits of these projects. Some of these assumptions should be already defined in the scenario building phase to ensure consistency in the project assessment phase
- different results in the project assessment are obtained depending if a single or dual assessment methodology is used
- the dual assessment methodology allows to better capture the benefits of hybrid projects in the electricity and gas sectors
- in the cases analysed, the ΔSEW indicator obtained when applying a dual assessment methodology is higher compared to the obtained using a single assessment methodology
- in the cases analysed, the ΔCO_2 indicator obtained when applying a dual assessment methodology is lower (i.e. lower CO_2 emissions) compared to the obtained using a single assessment methodology
- the cases analysed demonstrate that ENTSO-E and ENTSOG are capable of assessing hybrid projects collected as part of their TYNDP
- hybrid projects might have different characteristics and configurations. Ad hoc assessment will have to be carried by ENTSO-E and ENTSOG to ensure that all relevant interlinkages are always duly considered

11. Final Conclusions

The approach adopted during the project implementation phase can be summarised through the following steps:

- identification of ENTSO-E and ENTSOG TYNDP 2020 input and identification of ENTSO-E and ENTSOG TYNDP 2020 indicators that are relevant for the screening phase and for the dual assessment phase
- testing of a screening methodology (for the screening phase) under the situation of significant presence of gas-to-power and under significant presence of power-to-gas
- testing of a dual assessment methodology (for the dual assessment phase) on selected projects from the list of projects resulting from the screening phase
- testing of a dual assessment methodology (for dual assessment phase) on projects initially not identified as relevant by the implemented screening methodology

The investigation has addressed two different main conditions where a project can have an impact on (or be impacted by) the other energy system when looking at the electricity and gas systems:

- in the significant presence of gas-to-power (condition 1)
- in the significant presence of power-to-gas (condition 2)

As part of this pilot project, ENTSO-E and ENTSOG have not assessed the need for a dual system assessment when looking at an electricity or gas infrastructure project in the presence of hybrid consumption technologies. These conditions have not been tested since TYNDP 2020 scenarios data (basis for this analysis) do not include price-driven hybrid consumption technologies but temperature-driven. This however represents a very theoretical case that could be applied in the future in case of change in technology. Such case would be first investigated and defined at scenarios level.

As confirmed by chapter 8 ("The Screening Phase") ENTSOG and ENTSO-E have identified which currently **available TYNDP indicators** can be used in the Screening phase and which ones need additional considerations. Among the indicators tested, the indicators CR (Curtailment Rate) and SLID (Single Largest Infrastructure Disruption), measuring the amount of gas demand curtailment a country could face, seem to be the most appropriate to capture situations where significant gas-to-power demand generates constraints (condition 1) that could be mitigated by further considering flexibility on the electricity side. Also, the Price Convergence Indicator should be further refined in order to ensure results compatible with its possible use within the Interlinked Model.

With regards to the **input required** to implement the Screening phase on condition 1 and condition 2, the carried investigation has shown that all inputs can be available through ENTSOG and ENTSO-E joint scenarios as well as through TYNDPs analysis, metrics and tools. It is recommended to have a consistent approach in the definition of the input used within the screening phase.

With regards to condition 1 (significant presence of gas-to-power demand), **the number of countries** identified by the screening (section 8.1) highly depends on the indicator used to identify the gas constraint and the way the electricity margin is computed. Further improvements on the electricity capacity margin should consider that some gas power plants can run using alternative fuels than gas.

Results of the dual assessment test for condition 1 (section 10.1) carried on 5 gas projects and 4 electricity projects confirm that: (1) the available flexibility on the electricity system can reduce the gas constraint identified in the gas system assessment and consequently reduce the contribution of gas infrastructures; (2) there are cases when gas projects still bring full contribution, even after a gas constraint reduction by the available flexibility margin; (3) impact on the gas constraint from gas and electricity projects can be measured in terms of changes in the avoided curtailed demand, in the electricity social economic welfare and in the CO2 emissions.

It must also be noted that ENTSOG TYNDP 2020 assessment demonstrates that the current infrastructure and gas projects expected to be commissioned no later than 2025 already achieve most of the aims of the internal energy market, with some exceptions in specific areas. In the future, situations where gas constraints under condition 1 will be observed would be therefore quite limited.

With regards to condition 2 (significant presence of price-driven P2G), as for condition 1, the screening phase (section 8.2) allows for a number of relevant countries and projects to be identified for dual assessment under condition 2. The tests carried within the dual assessment phase on electricity projects under modified TYNDP 2020 scenarios, has shown that under specific situations with very large amounts of price-driven P2G, the tested screening methodology does not capture all project potentially impacted by price-driven P2G. This does not necessarily require a review of the screening methodology if the price-driven P2G and related assumptions are integral part of the system assessment. All collected electricity projects could be in fact assessed by default under a situation that already considers the presence of price-driven P2G. In the dual assessment phase, ENTSOG and ENTSO-E will still have to check if changes in price-driven power-to-gas capacities driven by electricity projects are significant enough to also influence the gas import or export needs and related gas projects.

Results of the dual assessment test for condition 2 (section 10.2) on 8 electricity projects confirm that under different share of price-driven P2G capacities: (1) the share of price-driven P2G in the scenarios has an impact on the benefits of electricity projects and the magnitude of this change depends on the amount of price-driven P2G, which will be defined in the future in the scenario building process; (2) the power to gas conversion of price-driven P2G facilities is impacted by the composition of the electricity grid, however these impacts are not relevant to trigger a dual assessment on the gas system since no gas constraints were identified.

As part of this project investigation, ENTSOG and ENTSO-E have also verified their capabilities to assess **hybrid projects**. A clear example of this kind of projects are price driven power-to-gas projects, which are connected to the electricity grid, interacting with the electricity system, and at the same time, they influence the gas system. Hybrid projects can also be more complex merging different technology solutions and energies (e.g. offshore wind hubs + electricity/gas interconnection + P2G facilities). These are projects in which there is no need to apply a screening methodology to detect the need for a dual assessment and, by directly linking electricity and gas systems, can be automatically considered eligible for dual assessment.
For the purpose of this analysis, the dual assessment methodology was applied to two projects collected in TYNDP 2020.

The following **main conclusions** can be drawn from the test carried out on hybrid projects dual assessment: (1) some additional assumptions had to be made in order to correctly quantify the benefits of these projects. Some of these assumptions should be already defined in the scenario building phase to ensure consistency in the project assessment phase and should be checked with the concerned promoters; (2) the dual assessment methodology allows to better capture the benefits of hybrid projects in the electricity and gas sectors in terms of changes in the electricity social economic welfare and CO2 emissions.
Additionally, hybrid projects submitted to future TYNDPs might not always have the same characteristics of the ones tested as part of this investigation. It is therefore difficult to define, ex-ante, a standard approach for this project category. Once a hybrid project is collected, an **ad hoc assessment** should be carried by ENTSO-E and ENTSOG to ensure that all relevant interlinkages are always duly considered.

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12. Next Steps

Current investigation and test phase have confirmed the outcome of the 2019 Focus Study that many of the elements identified as relevant for interlinkages are defined at scenarios level.

The investigation has also shown that ENTSO-E and ENTSOG are capable of assessing electricity and gas projects under dual assessment. However, while opportunities have been identified, the scope of the current tested dual assessment method does not take into account every aspect yet.

ENTSO-E and ENTSOG will consider that future improvements on the interlinked model will have to be compatible with new TEN-E regulation, whose draft requires ENTSO-E and ENTSOG to jointly submit by 31 December 2023 to the Commission and the Agency a consistent and interlinked energy market and network model including electricity, gas and hydrogen transmission infrastructure as well as storage, LNG and electrolysers, covering the energy infrastructure priority corridors and the areas drawn up in line with the principles laid down in Annex V of the new TEN-E regulation.

In addition, ENTSO-E and ENTSOG have already identified some aspects to further work on in the next months and in view of TYNDP 2022 and future editions.

- ENTSOG and ENTSO-E will work further on the homogeneity of modelling assumptions.
- As part of scenario development and scenario storylines, the share of price-driven power-to-gas will be defined. This represents a crucial element for the application of condition 2 of the interlinked approach.
- ENTSO-E and ENTSOG will develop coordinated project data collection guidelines when drafting future TYNDP to ensure that projects that interlink the gas and electricity sectors, are duly considered in TYNDP 2022 and onward.

13. Annex I – Other Indicators

13.1. Indicators for identification of gas constraints for condition 1 (significant G2P).

Below a description of the indicators considered during this investigation phase.

Ind. 1. Curtailment Rate indicator (CR)
This indicator measures the resilience (SOS) of the European gas system (in terms of curtailed demand) to cope with various stressful events (climatic stress and supply route and infrastructure disruptions).

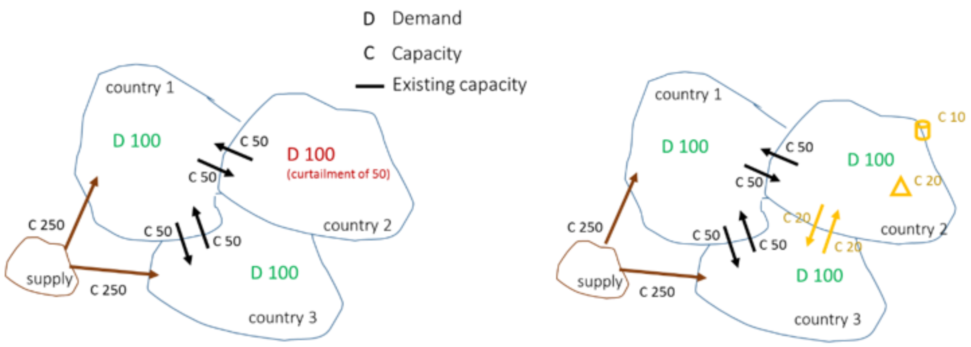
The indicator is computed by ENTSOG under the following different stressful climatic situations (i.e. under higher temperature):

- daily peak gas demand
- 2-weeks cold spell
- 2-weeks cold spell – Dunkelflaute

And under different infrastructure disruptions:

- supply route disruption (sudden/unexpected disruption of a supply route)
- country single largest infrastructure disruption (N-1). This is indicator is called SLI.

<u>Example 1</u>[32]: the analysis at system level identifies an infrastructure gap for country 2. Given a certain infrastructure level, country 2 is in fact not able to entirely cover its gas demand even in case of infinite availability of gas from the existing supply source. One or more projects (in yellow) may therefore help to mitigate or entirely solve the situation (up to 50 GWh/d being the maximum value of the gas constraint).



[32] From ENTSOG 2nd CBA Methodology (https://www.entsog.eu/methodologies-and-modelling#2nd-cba-methodology)

The indicator shows the quantity (GWh/d) and the percentage (%) of gas demand that risk to be curtailed in a specific country if no additional infrastructure(s) is built. The curtailment is measured on the overall gas demand and there is no distinction between sectors.

The CR results are affected by both a given scenario (different gas demand levels) and infrastructure level (the more infrastructure assumed to be in place the lower the amount of gas demand that risks curtailment).

ENTSOG does not consider gas demand sectorial breakdown when measuring CR. To know how much of G2P demand would be curtailed compared to the other sectors, two approaches can be implemented:

- share the CR among all the sectors pro-rata, based on their gas demand
- consider as all the CR is happening first in G2P by taking the min(CR; G2P demand)

The second approach represents a more conservative solution while potentially overestimate the gas constraint on the G2P side. However, it is fair to assume that the residential sector, being the sector more temperature-driven, will be the last to be curtailed ("protected customers"). The second approach represents therefore the solution adopted in this investigation.

Ind. 2. Minimum Annual Supply Dependence (MASD)

This indicator measures the unreducible share of this source necessary for a country to cover its demand on a yearly basis (i.e. in case of average daily demand).

Under cooperative behaviour, countries will align their dependence level if infrastructures allow for it. Non-alignment between countries indicates an infrastructure bottleneck that could be mitigated by building new gas infrastructures between two (or more) countries or to connect the concerned country directly to alternative sources.

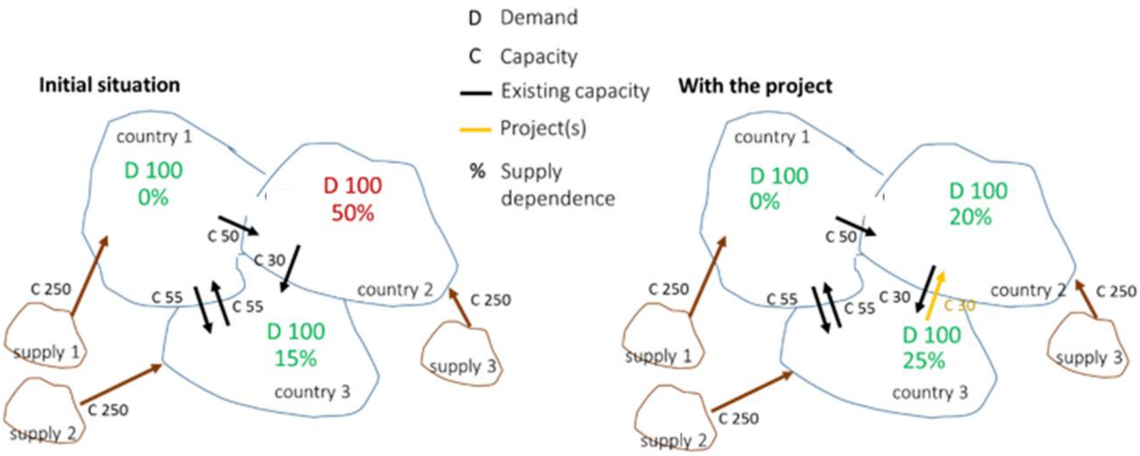
Differently from the CR indicator, the level of dependence from a supply source is not straightforward and an arbitrarily "*dependence threshold*" has to be chosen.

During the last PCI selection processes (3rd and 4th PCI selections) a 25% threshold was used by European Commission: above such threshold there would be therefore a gas constraint.

Example 2[33]: the analysis at system level identifies that in the initial situation (given a certain infrastructure level) without the project, country 1 and country 3 are quite well diversified in terms of access to supply sources, as they are directly, or indirectly, connected to two supply

[33] From ENTSOG 2nd CBA Methodology (https://www.entsog.eu/methodologies-and-modelling#2nd-cba-methodology)

sources (S1 and S2) and to the rest of Europe. Those countries present a maximum dependence supply source S3 not higher than 15%. On the other hand, country 2 can only import gas from country 1 and directly from one of the available supply sources (S3). This results in country 2 being more dependent to supply 3 with an irreducible share of gas coming from that source (S3) of 50%.



Assuming a threshold of supply dependence of 25%, country 2 shows an infrastructure gap. With the realisation of a new capacity between country 2 and country 3 (the project would presumably be initiated by country 2 which is the one with the worst starting situation), country 2 increases its access to sources 1 and 2 allowing to reduce the share of dependence from source 3 to 20%. According to the communicating vessels theory, country 3 sees its source dependence increasing since now it is fully interconnected with country 2. Overall, the dependence of Europe is however reduced.

The gas constraint relieved by increasing the MASD of sources 1 and 2 could represent the following two situations:

- the supply source(s) whose share is reduced is not the most expensive, but the country does not want to rely intensively on that supply source(s) to ensure adequate levels of security of supply and/or supply source diversification
- the supply source(s) to which the country is heavily dependent is also the most expensive and by increasing the share of cheaper sources it is possible to reduce the overall gas bill

As for the CR indicator, also the MASD results are influenced by both scenarios (different gas demand levels) and infrastructure levels (the more infrastructure assumed to be in place the more countries can cooperate sharing their dependence).

As per the CR indicator, ENTSOG does not consider gas demand sectorial breakdown when measuring the MASD. In a situation where, given a 25% threshold, the MASD indicator indicates that 35% of gas demand is dependent from a source S, the following approaches could be implemented:

- share the delta (10%) between the MASD percentage and the threshold among all the sectors by multiplying the delta by the G2P demand
- consider as all the delta (10%) is linked to G2P

For the MASD indicator, the first approach represents the solution adopted in this investigation.

Ind. 3. Price convergence

The system assessment carried on by ENTSOG in TYNDP and the resulting gas flows are impacted by the different input used. The Network Model tool balances the energy supply and demand at the cheapest transport cost for EU considering technical and commercial constraints (e.g. supply potential, capacities, gas price, etc.).

The Focus Study has identified that G2P interactions between gas and electricity systems that affect gas and electricity infrastructure projects assessment start occurring when the G2P consumption creates congestions on the gas network, leading also to price differences beyond the transmission tariffs. Infrastructure tariffs represent an input in the ENTSOG TYNDP simulations.

Infrastructure tariffs correspond to charges paid by users to the operators of infrastructure such as transmission networks, storage facilities, and LNG regasification facilities, for the right to use (i.e. "capacity charges") and the actual utilisation of such infrastructure (i.e. "commodity charges"). For more details on how infrastructure tariffs can be included in ENTSOG TYNDP, please refer to Annex I of ENTSOG CBA Methodology.

The inclusion of market elements such as infrastructure tariffs in ENTSOG assessment represent an additional layer of complexity. Infrastructure costs will inevitably influence gas marginal price paid in a specific country. In some cases, a price difference between two countries could be therefore justified by the presence of infrastructure tariffs.
TYNDP 2020 System Assessment was run with infrastructure tariffs.

13.2. Capacity margin for MASD indicator for condition 1 (significant G2P).

The electricity capacity margin for each country, in the context of the gas MASD indicators has been calculated as follows:

$$ECM\ Country\ \ SSD = \frac{\sum_i (G2P_i - G2P_{stress,i} - \frac{\Delta ENS_{CY,i}}{\eta})}{number\ of\ climate\ years}$$

Where

- $G2P_i$ is the gas consumption in the reference case for the climate year “i”, for the country under analysis.
- $G2P_{stress,i}$ is the gas consumption in the case with the stress for the climate year “i”, for the country under analysis.
- $\Delta ENS_{CY,i}$ is the difference in the annual energy not served (electricity) in the country under analysis, between the case with the stress and without it for the climate year chosen above.
- η is an estimation of the efficiency of gas power plants (e.g. 50%).

13.3. Capacity margin for MASD indicator for condition 1 (significant G2P).

Below the results from the application of MASD indicator in the screening Methodology.
The analysis was based on TYNDP 2020 data.

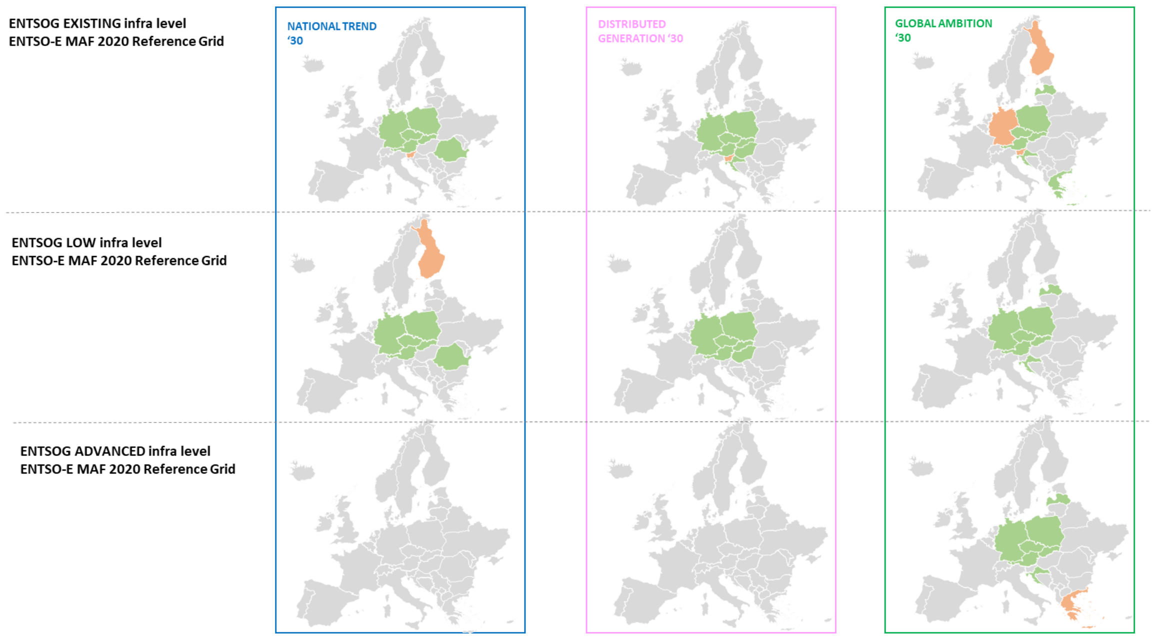


Figure 48 - Under Supply Dependence (2030)

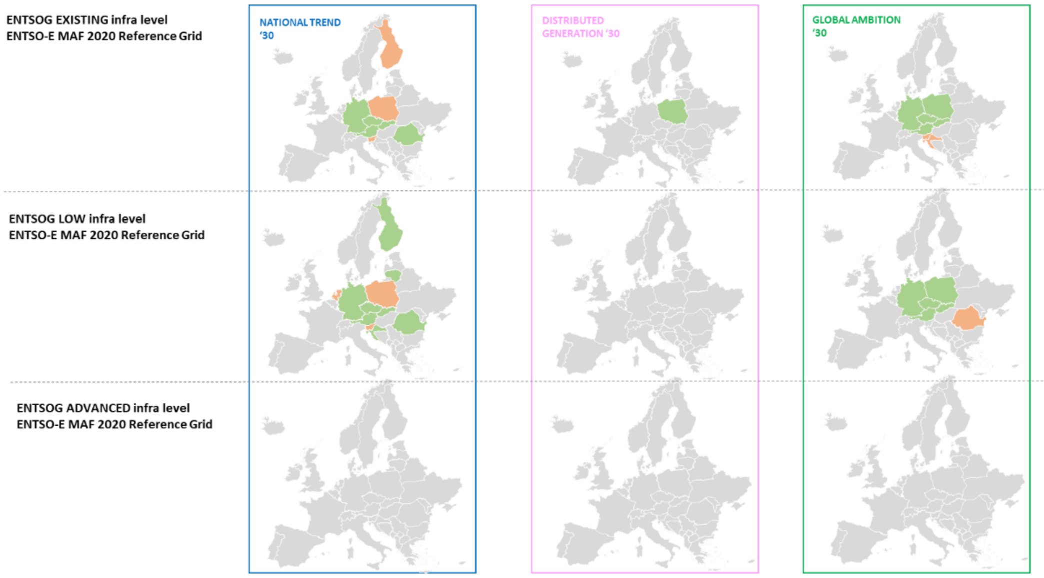


Figure 49 - Under Supply Source Dependence (2040)

14. Annex II – Prime Movers Feedback

This section summarises the feedback received by the Prime Movers on the document which was shared in advance with. The section also includes ENTSOG reaction.

Feedback 1: "*The results of the Interlinked Model investigation could hint towards solutions that may violate the basic unbundling principles, the importance of which has been reiterated under the recast Electricity Directive (2019/944). ENTSO-E and ENTSOG explain that P2G technologies are factored in the analysis as infrastructure, since the development of such projects has already been reported to them. While we recognize the justification and while electrolysers can be presented as infrastructure with some similarities in terms of design of products that can be made available to third parties, they are also simultaneously competing with other electricity sinks and with other hydrogen production activities: they do not operate exclusively in the domain of essential facilities. Designing P2G as infrastructure implies a set of conditions that need to be factored in so that TSOs operating these assets do not step outside their role as regulated entities. More importantly, we note that ENTSO-E and ENTSOG investigation refers specifically to "green" hydrogen production. While we understand that the infrastructure applying for financing under TEN-E needs to pass a sustainability test, this assumption raises a number of important questions that need to be answered before any derogation is granted and public money is allocated to an investment.*"

P2G technologies play an important role in the ENTSO- E and ENTSOG TYNDPs, both at scenarios and project levels. At scenario level it is important to consider P2Gs since they will contribute, together with other technologies and other fuels, to the general energy balance and to reach the environmental targets. Different TYNDP scenarios assess different possible evolutions. At project level, it is important to consider P2G technologies under dual assessment condition since they could have interactions with electricity projects, gas projects as well as with future potential hydrogen import projects.

ENTSO-E and ENTSOG do not make assumptions in their TYNDPs on the ownership and operation of P2G facilities. P2G projects could be submitted by any third-party promoter to the respective TYNDPs.

TYNDP 2020 joint scenarios consider different hydrogen production technologies and not only green-H2 technologies. By focusing on the interaction between gas and electricity, the 2020 investigation addressed by this document has looked into the share of P2G that will use CO_2-free energy sources (renewables and nuclear) to produce green-H2, being the ones with more significant interaction with the electricity system. Such approach will not prevent future TYNDP editions to consider other hydrogen production technologies. Such approach will not prevent any promoter to submit hydrogen production facilities different from green-H2 production facilities.

<u>Feedback 2</u>: "*We further note that the quality of results delivered by the Interlinked Model investigation might be questioned. Under condition 1, the study identifies potential congestion on the gas side e.g. in Poland, where multiple gas network projects are under development and the current share of gas in the energy mix is under 9%. The study then points to the flexibility on the power side, whereas the problem of unscheduled loop flows on the borders with neighbouring countries remains unresolved for years.*"

Regarding condition 1, current ENTSOG TYNDP 2020 shows, in its system assessment analysis, potential gas constraints in specific countries. The same gas constraints have been used as input to the 2020 ILM investigation. ENTSOG assesses the gas constraints under different infrastructure levels (existing, low, advanced) composed by different set of projects and based on their maturity status of development. Therefore, the identified gas constraints must be interpreted accordingly: in cases where current infrastructures (i.e. existing) and FID infrastructures are not enough to fully mitigate the identified constraints, some projects with advanced status would also be needed to be implemented. Checking for gas constraints represent sub-condition 1.2 (while sub-condition 1.1 is met when in a country, gas demand for power represents at least 5% of total gas consumption). The loop flows in the core region are expected to be mitigated with the introduction of the flow-based approach into the electricity market. The Core FB MC go-live date has been updated to February 2022[34]. In this context, future developments of the market models could consider the flow-based approach for long-term modelling as well, reflecting the mitigation on the loop flows due to the implementation of the flow-based market.

<u>Feedback 3</u>: "*The results of the assessment are further undermined by the fact that under Condition 2 ENTSOs note that the predefined sub-conditions do not properly filter the projects that should undergo a dual-assessment and that they will not be applied at all.*"

Regarding condition 2, indeed, the carried investigation has shown that the screening methodology proposed in the 2019 Focus Study for condition 2 does not allow to capture all the situations where significant price-driven P2G capacities could have an impact on electricity projects. The 2020 investigation carried out by ENTSO-E and ENTSOG has shown that all tested electricity projects (including the ones not initially identified by the screening phase) were influenced by the presence of price-driven P2Gs, although with the levels of price-driven P2G in the TYNDP 2020 scenarios the influence was neglectable. As explained in Chapter 11, this does not necessarily require a review of the screening methodology if the price-driven P2G and related assumptions are integral part of the system assessment.

[34] https://www.pse.pl/documents/20182/51490/Core+FBMC_MM_Publication.pdf/

Feedback 4: "*I understood this is a screening exercise to identify where there could be an interest in adding power lines instead of gas assets. By benefits, the only retained criteria is based on short term dispatch of power plants, both in terms of CO_2 and short-term marginal price. This represents a biased approach since it means that all the real costs of electrification are hidden in the fixed terms of the scenarios. Additionally, condition 1 shows a rather limited impact in terms of output and impacted countries. While time and resources should be allocated to more significant elements (such as sensitivity analysis).*"

As outcome of the 2019 Focus Study, with regards to condition 1, given a certain gas constraint, ENTSO-E and ENTSOG have tested what happens when considering further flexibility on the electricity generation side (if for example the gas curtailment is reduced by producing more electricity by oil rather than by gas) and/or by electricity infrastructures included in the ENTSO-E reference grid. The analysis shows that there are cases where additional flexibility from electricity generation side and/or from electricity projects in the electricity reference grid allow to mitigate gas constraints. Results also show that the mitigation offered by the electricity has a lower magnitude compared to the one provided by gas infrastructure projects (in most of the assessed cases gas projects are still needed to fully mitigate the identified constraint).
It must also be noted that ENTSOG TYNDP 2020 assessment demonstrates that the current infrastructure and gas projects expected to be commissioned no later than 2025 already achieve most of the aims of the internal energy market, with some exceptions in specific areas. In the future, situations where gas constraints under condition 1 will be observed would be therefore quite limited. Additionally, it must be remarked that, as explained in section 9.3, the costs of the assessed projects, while not directly considered as part of this investigation, represent a fundamental element to be considered as part of the overall dual assessment when comparing cases of alternative solutions.

Feedback 5: "*Such investigation might miss the point of P2G technologies: P2G main role is not to absorb curtailed electricity. It is to supply in a decarbonized way gas demand. When there is a massive electrification of demand, is it required that this additional demand is supplied only by RES electricity on a short-term marginal dispatch approach? No, then it is perfectly valid to build additional power plants for which the costs are not considered but are part of the scenario input hypothesis (including CCGTs). When we try to supply additional gas demand (be it H2 or CH4 in case of P2G), then one of the main supply options has to demonstrate its additionality. Considered fixed other elements (such as gas demand and biomethane production), a sensitivity analysis should be made on P2G capacities.*"

The task of the scenarios (first and very important step of an Interlinked Model approach) is to draw different possible European energy futures and to show the results of these pathways in terms of demand and supply. The scenarios have in common to meet EU climate targets and the COP21 agreement objective of keeping temperature rise below 1.5°C. To differentiate the scenarios, storylines were developed to describe the differentiation of the main drivers, e.g. imports vs self-sufficiency, the degree of electrification, on the role of CCS, etc. This differentiation is necessary to provide the value of the scenarios: to show the results of these different pathways without favouring one over another. If and to what degree a reduction of the final gas demand is feasible and beneficial, is carefully examined during developing the scenarios. The scenarios consider the following options to decarbonise the gas supply necessary to meet the demand: biomethane, P2H2, P2CH4, SMR+CSS, imports (Methane and/or H2). The pathway to decarbonise the gas supply will be scenario dependent as demand of the different energy carrier is depending on the scenario as well. The role of P2G is to provide the necessary amount of H2 in an efficient way; neither it solely absorbs curtailed electricity, nor it supplies the gas grid without any constraints. Flexibility on the supply will be provided by P2H2, P2CH4, SMR+CCS and methane/H2 storages. The 2020 investigation, by focusing on the interaction between gas and electricity has also focused on the share of P2G that will use/absorb curtailed RES.

Feedback 6: "*We believe that more discussion is needed around the application of the interlinked model and how it can support cost-efficient development of the electricity and gas infrastructure across Europe.*"

As described in the "Next Steps" section, ENTSO-E and ENTSOG will work on the already identified elements to be improved.