Valuing the contribution of an LNG terminal to the national security of supply

AIEE Symposium 2024

FTI CONSULTING

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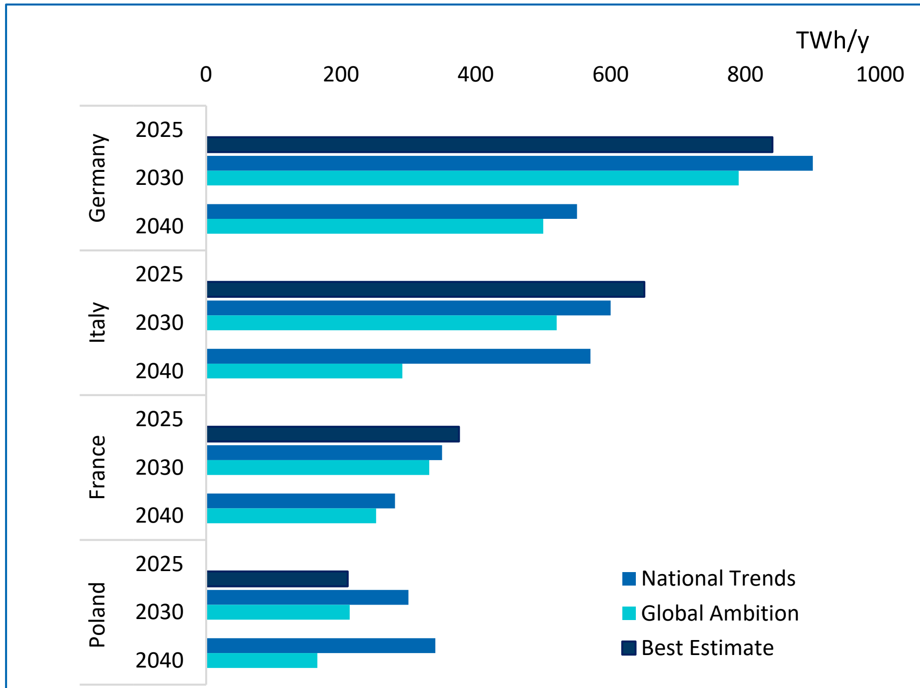
1. Context and objective

The combination of mid-term a gas demand and stranded asset risk calls for proper valuation of the benefits brought by an LNG infrastructure

Situation

- Security of supply Russia's war on Ukraine shows that energy can be used as a geopolitical weapon.
- European economies still heavily rely on natural gas : it accounted for 20.6 % of the final energy consumption in 2022.
- European natural gas resources (conventional) are reaching their limits with declining gas field production.
- LNG infrastructures are capital intensive and uncertainty considering future gas consumption demand levels limits private investment appetite.
- State aid could help mitigate default risks while meeting short to medium term demand, but **the potential benefits of the new infrastructure need to be assessed in the light of the stranded asset risk** it may represent for the taxpayer.

Gas demand scenarios in TYNDP 2022 for selected countries



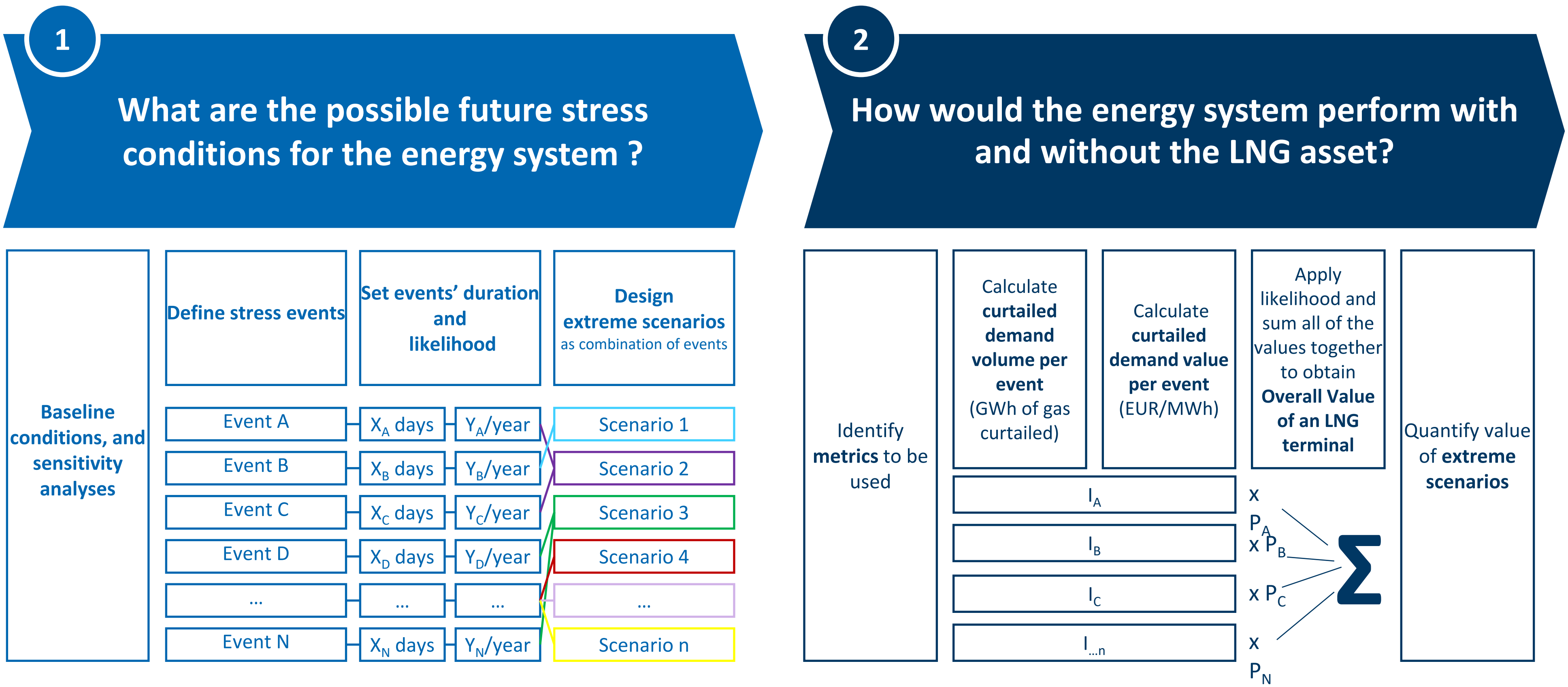
Paper contribution : Develop a systematic method to quantify the contribution of an LNG infrastructure of ensuring security of supply at a national scale, with a concrete application to an LNG terminal in a European country.

Source: Eurostat, ENTSO-G TYNDP 2022

2. Methodology

We establish a two-step methodology to assess the contribution to security of supply of an LNG terminal

Sequencing of our approach

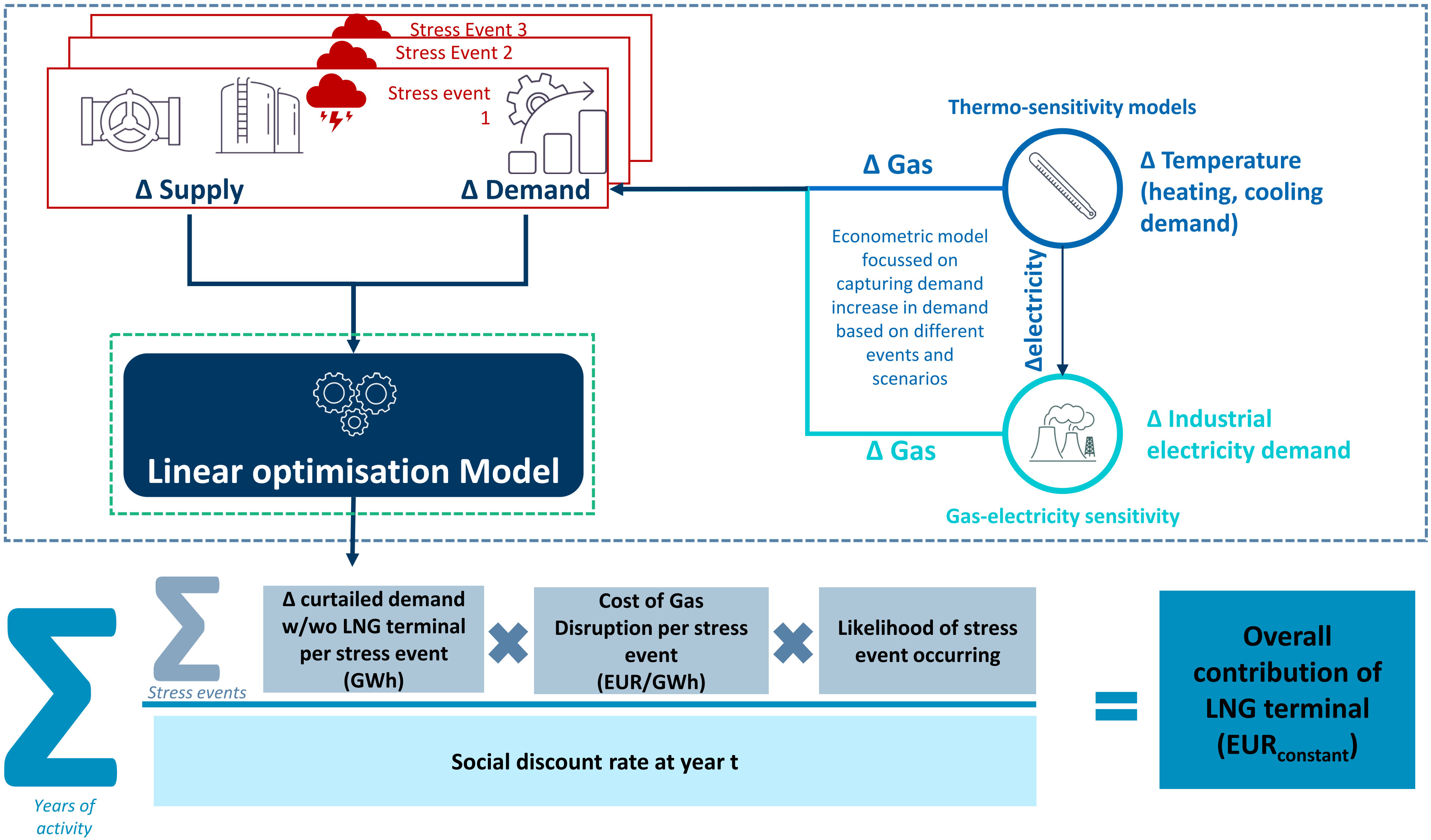


To have a tool auditable by policy makers, we simplify and limit our analysis to the natural gas sector and physical unbalances

Key Assumptions

Physical balance only	▪ Impacts of supply security events on prices in the wholesale market with and without the LNG terminal are not quantified. The deficits are calculated only in situations where the physical/contractual capacities are exceeded.
Gas only	▪ Downstream impact on electricity markets not measured, only impacts on gas.
100% availability under normal conditions	▪ All pipelines and LNGs are modelled to be available for the whole year as opposed to situations wherein periodic maintenance could coincide with the stress test events. As a result, full supply flexibility of the system is considered
Curtailment reduction based	▪ The contribution of the LNG terminal is based on the difference between the curtailed volume during stress event with and without the infrastructure. ▪ The cost of gas curtailed is based on alternative fuel-switching costs for gas used as fuel, and Gross Value Added for gas used as feedstock; following ACER methodology. ▪ For each stress event, likelihood from historical sources and public institution are assessed, with the most conservative one selected.
Inflexible EU import/export	▪ Reduction of export during stress events not modelled, thereby reducing the system flexibility ▪ Imports from neighbouring countries during stress events are not modelled, thereby reducing the system flexibility. It is however reasonable, given that a significative natural gas shock would affect all European countries (i.e. Russian crisis).

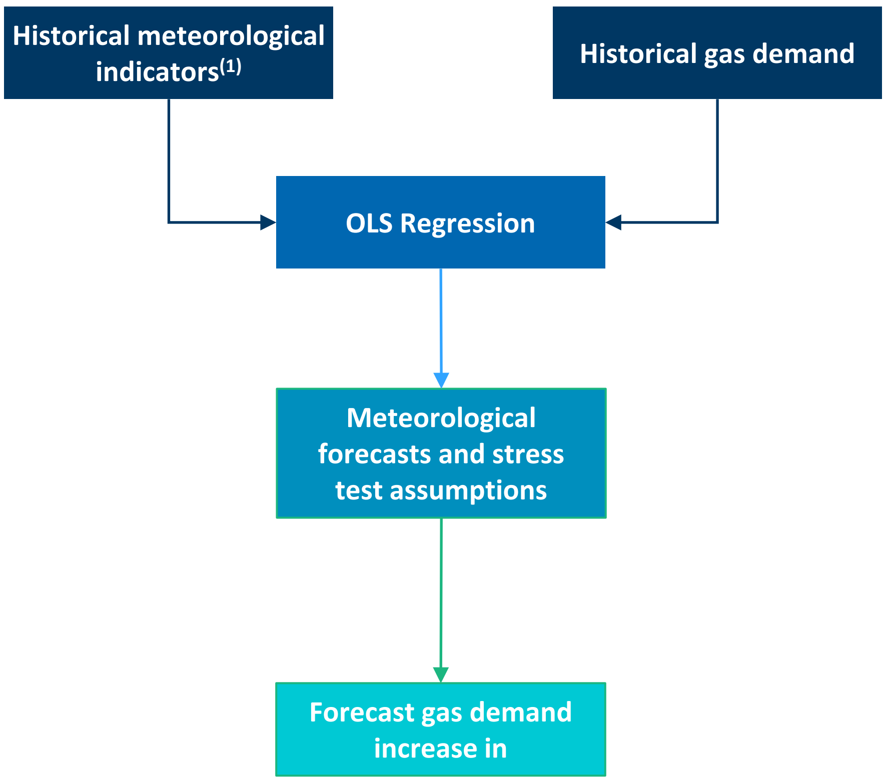
Schematic representation of our methodology



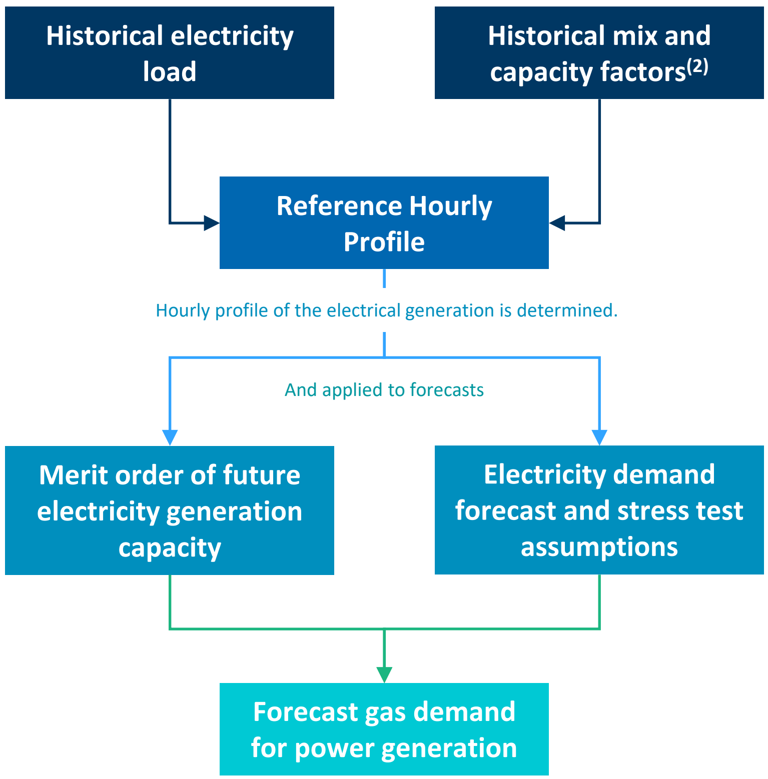
Historical gas demand correlation with weather, and future electricity capacity merit order, are used to forecasts weather-related stresses

Overview of regression models used to calibrate impact of stress events on future supply/demand conditions

Gas demand and **weather conditions**



Gas demand and **thermoelectricity generation**



Notes: (1) We applied Eurostat methodology to establish two meteorological indicators the Heating degree Day indicator (HDD), for cold snaps and the Cooling Degree Day indicator (CDD), for heatwave. Details can be found here ; https://ec.europa.eu/eurostat/cache/metadata/en/nrg_chdd_esms.htm. Theses indicators are built from the Italian historic temperatures –hourly data- that can be found here https://www.renewables.ninja/ (2) Hourly capacity factors for capacity can be found here https://www.renewables.ninja.

We applied a merit order of demand curtailment to assess how the different demand sectors will be relatively affected by gas shortages

Description of how cost of gas disruption is computed for each scenario resulting to demand not served

Demand by sector

% share by sector in 2030

% share by sector in 2040

Assessment is based on alternative fuel-switching costs for gas used as fuel, and Gross Value Added for gas used feedstock

2030

Volume Balancing Model → **Demand not Served**

2040

Volume Balancing Model → **Demand not Served**

Prices (gas, electricity, fuel oil)

Industry GVA

ACER – European Union Agency for the Cooperation of Energy Regulators

Cost of Gas Disruption Model

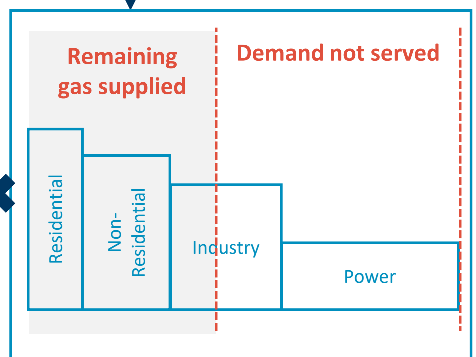
CoDG Residential

CoDG Non-Residential

CoDG Industrial

CoDG Power

✖



The demand that not served is allocated according to a demand merit order by sector, which varies from year to year. The sectoral CoDGs are factored in.

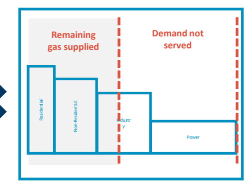
CoDG Residential

CoDG Non-Residential

CoDG Industrial

CoDG Power

✖



Cost of Gas Disruption (ACER)	2023 EUR/MWh
Power	67
Industry	106
Residential and Non-residential[2]	131

Notes:

1. The CoDG figures are based on ACER (2018), Study on the Estimation of the Cost of Disruption of Gas Supply in Europe. The provided values are inflated from 2018 to 2023.

3. Application : Valuation of an LNG terminal in Italy

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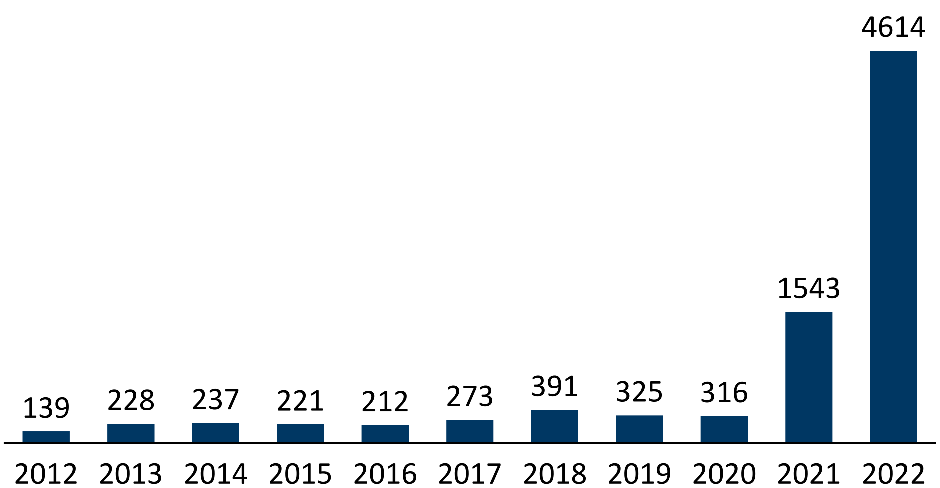
A: Situation and data calibration

As Italy became a re-exporting hub for the EU, we find relevant to assess the contribution of one LNG terminal in the country

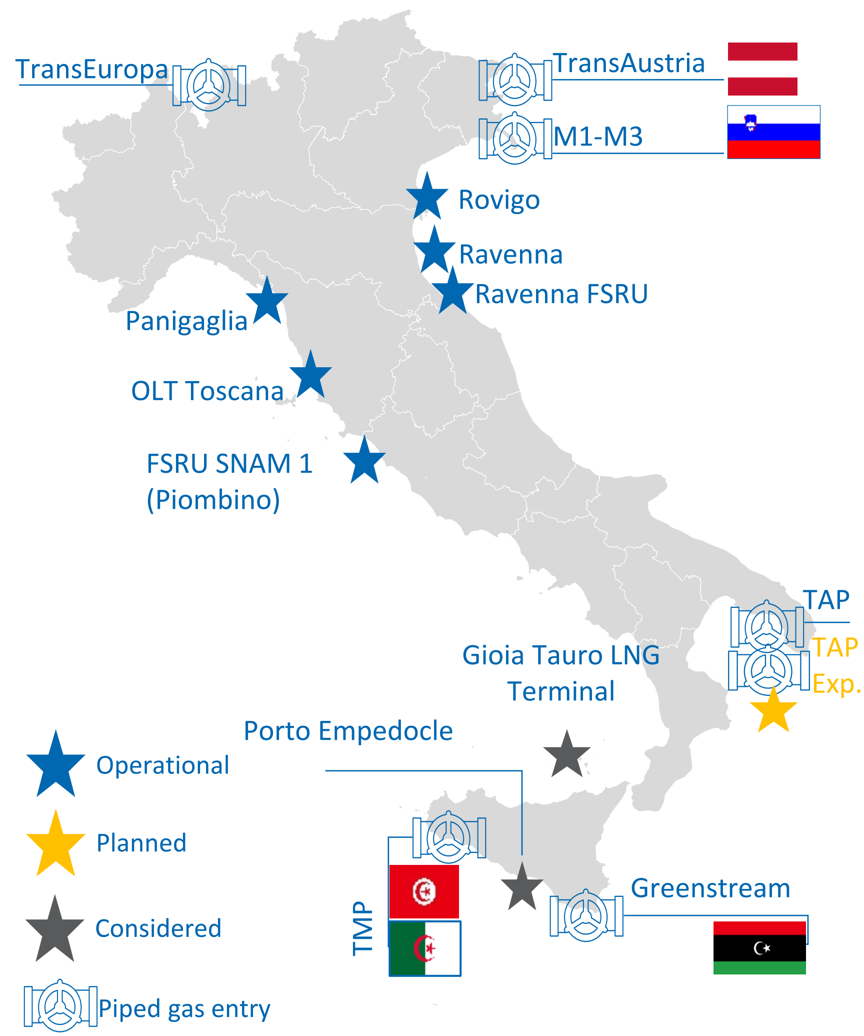
Italian context

- With the decline of Russian gas supply**, Italy has become an important gateway for natural gas imports** into Europe, where ensuring security of supply has become critical.
- In 2023, two LNG terminal projects were deemed "strategic and urgent" by the Energy Security Decree Law (Italian Decree Law 181/2023).
- In this context we **find relevant to assess the contribution that an LNG terminal** could make to the Italian economy by ensuring its security of supply.

Exports of natural gas from Italy from 2005 to 2022, mcm/year



Italy sources of natural gas (existing and planned)



Source : ENTSO-G TYNDP 2022, Statista

The baseline conditions rely on the high-level forecast of supply-demand balance of SNAM's PNIEC Reference Scenario

Supply and demand data from SNAM's Network Development Plan

Snam document : *Scenari di riferimento per i piani di sviluppo delle reti di trasporto del gas 2023-2032 e 2024-2033*[(1)]
[It includes 2030 & 2040 projections]

SNAM Reference Scenario (based on PNIEC)

Demand[1]	2030		2040	
	bcm	TWh	bcm	TWh
Total	63.9	676	58.4	618
Residential	26.2	277	26	275
Industry	7.7	81	7.6	81
Transport	1.2	12	1.6	17
Thermoelectric and Heat	24.6	260	18.9	200
Others	4.2	44	4.2	45

Supply[1]	2030		2040	
	bcm	TWh	bcm	TWh
National Production	4	42.3	1	10.6
Northern imports	0	0	0	0
Southern imports	41 – 50	433 - 529	26 - 50	275 - 529
LNG imports	19 – 26	201 – 275	8 - 26	85 - 275
Exports	9 – 15	95 – 159	0 – 14	0 – 148

Allocated to specific import pipelines and terminals[(2)]

Notes: **(1)** Biomethane is not included as SNAM provides separate supply-demand balances for biomethane and natural gas. Snam document : Scenari di riferimento per i piani di sviluppo delle reti di trasporto del gas 2023-2032 e 2024-2033, last accesed on 11/24/2023 https://www.snam.it/en/our-businesses/transportation/ten-year-plans/piano-decennale-Snam-Rete-Gas/2023-2032.html, (Ultimo aggiornamento di pagina: 10 Nov 2023, 12:05), we derive future daily demand based on 2018 historic profiles from SNAM day-ahead as it is the latest available complete data as a reference for nomal gas market behaviour without disruptions (e.g. 2020/21 due to Covid and 2022 Russian gas cut-off) and is also complete (i.e. data issues in 2019). SNAM, Dati operativi di business, Trend dal 2005, Rinomina day ahead (https://www.snam.it/it/trasporto/dati-operativi-business/2_Andamento_dal_2005). We then aggregate the demand to have a weekly profile due to optimisation constraints. (2) Distribution within a group based on historic utilisation rates.

In order to assess the LNG terminal value, we define eight stress events covering the supply and demand characteristics of the Italian market

Duration and likelihood of stress test events

Event	Sub-event	Duration	Likelihood
E1. Transmed Interruption **E2. Greenstream Interruption** **E3. TAP Interruption**	D1. Seasonal Disruption: Landslide, unrest in or sabotage	Heating season (6 x 4 weeks)	1 every 50 years (MiTE)
	D2. Medium Disruption: Economic issues (disputes) or pipeline rupture (mechanical damage)	Two months (Jan-Feb)	1 every 20 years (MiTe)
	D3. Short Disruption: Short technical issues (gas quality)	Two weeks (15th-28th Feb)	1 every 20 years (MiTe)
E4. Offshore LNG terminals interruption	D1. Short Disruption: Sea Storms, affecting offshore LNG terminals	2 weeks (15th-28th Feb)	1 every year per terminal (Authors analysis)
E5. National Storage Interruption	D1. Seasonal Disruption: Technical failure of Stogit gas storage	Heating season (6 x 4 weeks)	1 every 20 years (MiTE)
E6. Increased gas use in buildings	D1. Extreme cold Snap : Exceptional weather condition	Two weeks (ENTSOG) (15th-28th Feb)	1 every 20 years (MiTE)
E7. Increased gas demand for electricity	D1. Heat wave: Extreme heat accompanied by drought (reduced hydro)	Seven days (MiTE)	1 every 20 years (MiTE)
	D2. Snowstorm: Extreme snow and low solar irradiation reducing solar capacity	Seven days (MiTE) (January average)	1 every 20 years (MiTE)
E8. Increased gas demand for export	D1. Disruption in neighbouring countries (storm, strike, infrastructure failure, commercial dispute) leading to increase in export.	One week	1 every 20 years (Authors' analysis)

As sensitivity analyses, we also consider alternative conditions to our baseline

Sensitivity analyses to baseline conditions

<table>
<tr><th rowspan="2">Sensitivity</th><th rowspan="2">Description</th><th rowspan="2">Methodology / assumption</th><th colspan="3">Flows and capacities considered</th></tr>
<tr><th>Year</th><th>Baseline</th><th>Sensitivity</th></tr>
<tr><td rowspan="3">S1. Decrease in available exports from Algeria</td><td rowspan="3">Based on an increase in domestic consumption in Algeria, limiting the volumes available for export</td><td rowspan="3">- Increase in domestic gas consumption of 5% between 2022 and 2030[1] and then kept constant
- Increase in domestic production of 0.9% per year[2]</td><td>2028</td><td>25.4 bcm (normal)
30.5 bcm (max)</td><td>17.3 bcm (normal)
20.7 bcm (max) [reduction by 32%]</td></tr>
<tr><td>2030</td><td>27.1 bcm (normal)
32.6 bcm (max)</td><td>15.2 (normal)
18.2 (max) [reduction by 44%]</td></tr>
<tr><td>2040</td><td>26.9 bcm (normal)
32.3 bcm (max)</td><td>18.2 (normal)
21.8 (max) [reduction by 29%]</td></tr>
<tr><td rowspan="3">S2. Delay of TAP commissioning and reduction of available gas volume from Azerbaijan</td><td rowspan="3">Delay of doubling of the TAP capacity. Volumes are also reduced due to reduced export volumes available from Azerbaijan</td><td rowspan="3">- Commissioning date of the new TAP capacity push back to 2030 (against 2027 in 2022 TYNDP)
- Increase in domestic gas consumption of 5.68% between 2022 and 2030 and then kept constant</td><td>2028</td><td>17.7 bcm (normal)
21.2 bcm (max)</td><td>11.1 bcm (normal)
13.3 bcm (max)
[no TAP expansion and reduction by 22%]</td></tr>
<tr><td>2030</td><td>19.0 bcm (normal)
22.8 bcm (max)</td><td>13.1 bcm (normal)
15.7 bcm (max) [reduction by 31%]</td></tr>
<tr><td>2040</td><td>18.4 bcm (normal)
22.1 bcm (max)</td><td>12.7 bcm (normal)
15.2 bcm (max) [reduction by 31%]</td></tr>
<tr><td rowspan="3">S3. Higher industrial demand</td><td rowspan="3">Based on industrial gas demand being higher than expected. SNAM's reference scenario shows that industrial demand is expected to decrease, and a sensitivity analysis is made assuming it will remain constant.</td><td rowspan="3">- Industrial gas demand kept at 2022 level, i.e. 118 TWh per year</td><td>2028</td><td>8.2 bcm</td><td>11.1 bcm [additional 2.9 bcm]</td></tr>
<tr><td>2030</td><td>7.7 bcm</td><td>11.1 bcm [additional 3.4 bcm]</td></tr>
<tr><td>2040</td><td>7.6 bcm</td><td>11.1 bcm [additional 3.5 bcm]</td></tr>
</table>

Notes: (1) The 5% annual growth rate of domestic consumption is respectively in line with the historical growth (CREG synthèse gas 2023 2032, Commission de Régulation de l'Electricité et du Gaz, Algérie), and with forecast found in the literature (https://www.ajol.info/index.php/cread/article/view/210547). (2) https://www.offshore-technology.com/data-insights/natural-gas-in-algeria/?cf-view (3) Based on the historical analysis of the domestic consumption between 2018 and 2022 https://www.stat.gov.az/menu/6/statistical_yearbooks/?lang=en

B : Stress event and sensibilities

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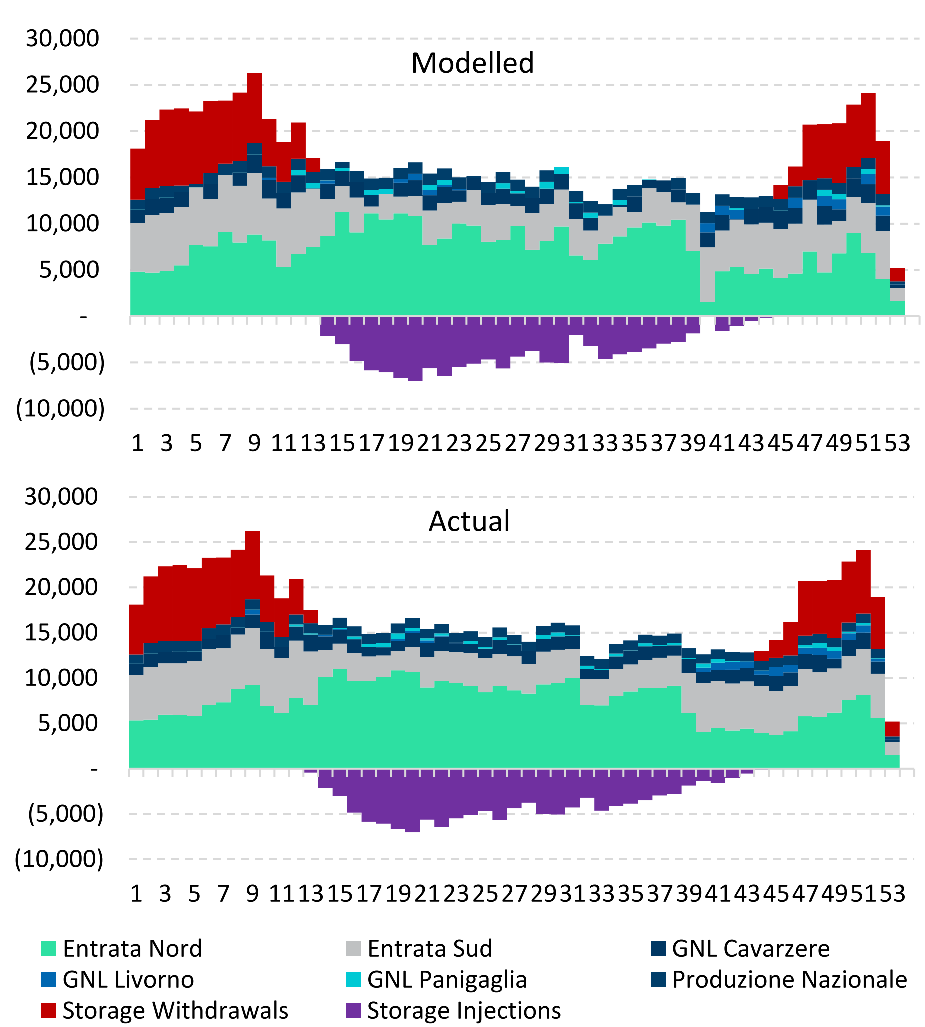
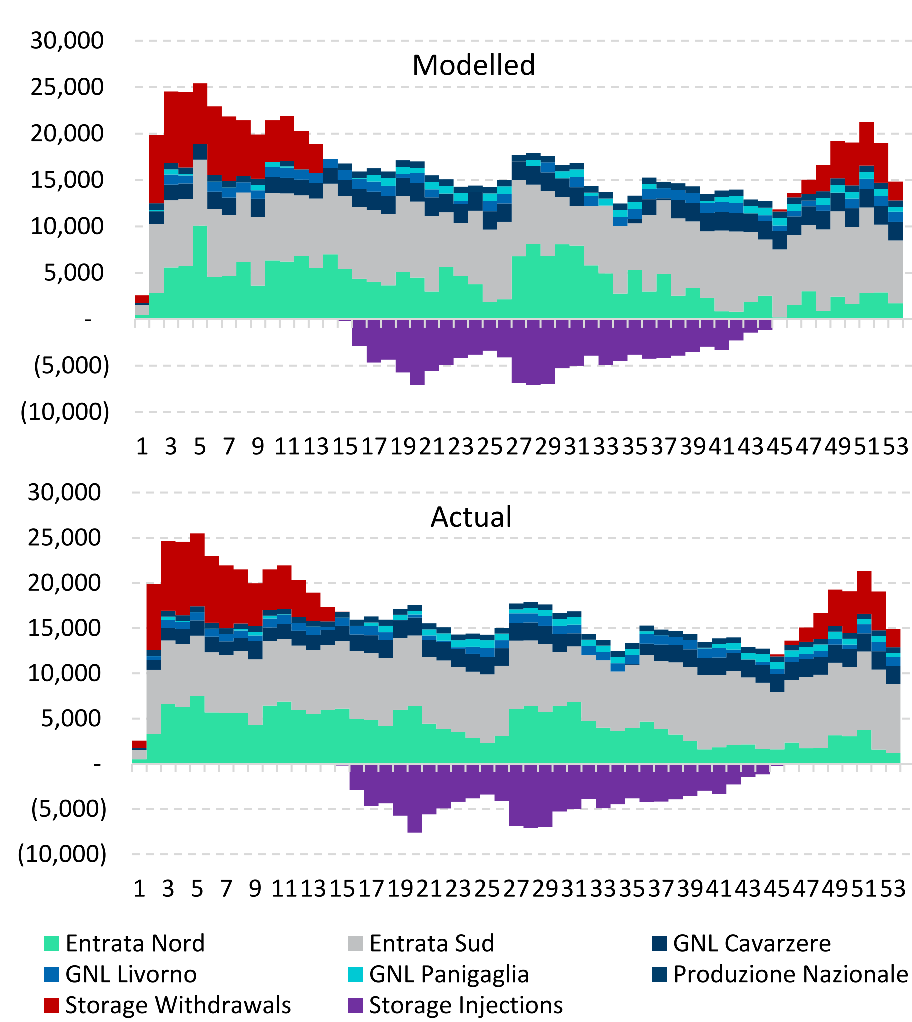
We compared modelled and actual historical results, which showed significant alignment, validating our modelling approach

2018



2022



Disruptions to TAP/Transmed have the biggest effect on avoided volume curtailment to while storage disruptions and heatwaves show little to no impact

Avoided gas curtailment thanks to the LNG terminal [GWh]

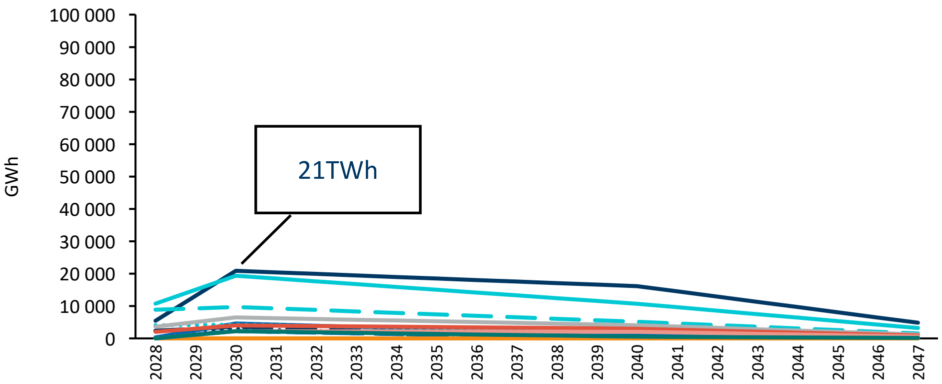
Duration	S0 : Baseline			S1 – less gas available from Algeria			S2 – delay of TAP and less gas from Azerbaijan			S3 – higher industrial demand		
	2028	*2030*	*2040*	*2028*	*2030*	*2040*	*2028*	*2030*	*2040*	*2028*	*2030*	*2040*
E1 Transmed seasonal	5,467	20,872	16,163	27,501	63,834	39,225	48,762	70,818	44,726	23,564	30,891	31,739
E1 Transmed 2mo	2,395	3,616	0	2,395	32,145	12,709	10,170	15,930	1,955	10,491	16,330	11,580
E1 Transmed 2wk	2,395	2,860	0	4,259	16,933	3,701	4,678	9,469	1,543	4,059	5,055	2,911
E2 Greenstream seasonal	318	4,606	1,227	5,415	46,583	6,198	6,094	5,558	3,255	1,747	4,048	2,030
E2 Greenstream 2mo	318	2,256	0	4,659	23,935	5,620	5,008	4,273	3,636	1,577	3,026	2,030
E2 Greenstream 2wk	318	2,256	0	4,659	16,701	2,389	5,008	4,249	2,944	1,577	3,026	2,030
E3 TAP seasonal	10,735	19,380	10,719	33,990	90,939	39,382	10,731	19,362	15,967	13,698	22,070	15,736
E3 TAP 2mo	8,852	9,711	5,155	11,118	42,417	13,783	6,399	11,370	3,928	6,741	11,253	6,806
E3 TAP 2wk	4,060	4,290	2,030	8,312	16,933	3,572	5,088	5,957	2,944	4,059	5,055	2,030
E4 Offshore LNG Trmls	3,601	6,497	4,080	6,426	12,505	8,424	6,925	8,890	6,140	4,373	7,908	5,504
E5 Storage seasonal	0	0	0	0	0	0	0	0	0	0	0	0
E6 DemandBuildings	2,033	4,031	3,003	4,121	25,807	5,306	4,090	5,957	0	5,868	5,055	3,824
E7 DemandElec Heat	0	0	0	0	0	0	0	0	0	0	0	0
E7 DemandElec Snow	0	2,256	2,030	4,230	25,772	4,512	4,895	4,447	4,060	923	3,026	2,311
E8 DemandExport	0	2,256	535	3,988	29,101	3,960	4,986	4,814	2,133	314	3,280	1,366

Example : "E1 seasonal 2030" amounts to **20.9 TWh** in the baseline situation, but it goes to :
- **63.8 TWh** in sensitivity analysis S1 if there is less gas available from Algeria
- **70.8 TWh** in sensitivity analysis S2 if there is delay of TAP and less gas from Azerbaijan
- **30.9 TWh** in sensitivity analysis S3 in case of higher industrial demand

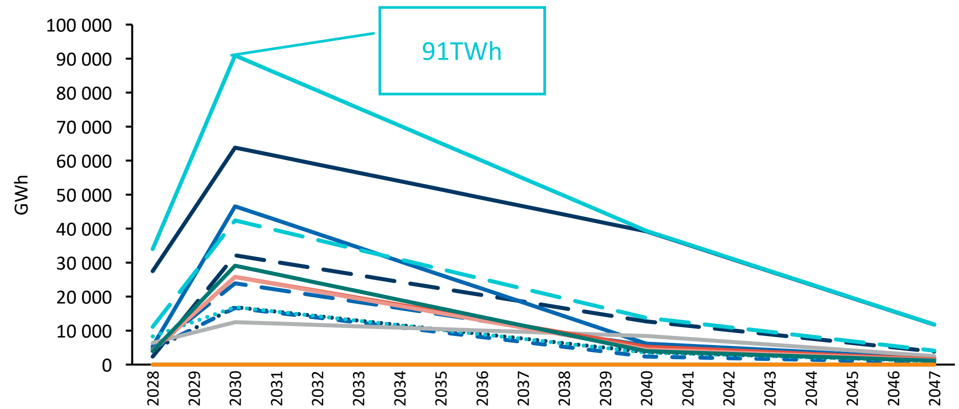
Similar trend is maintained across different sensitivities, as the reduction in gas consumption drives the reduction in avoided curtailment in the long term

Avoided demand curtailment volume [GWh] due to the LNG terminal, 2028-2047

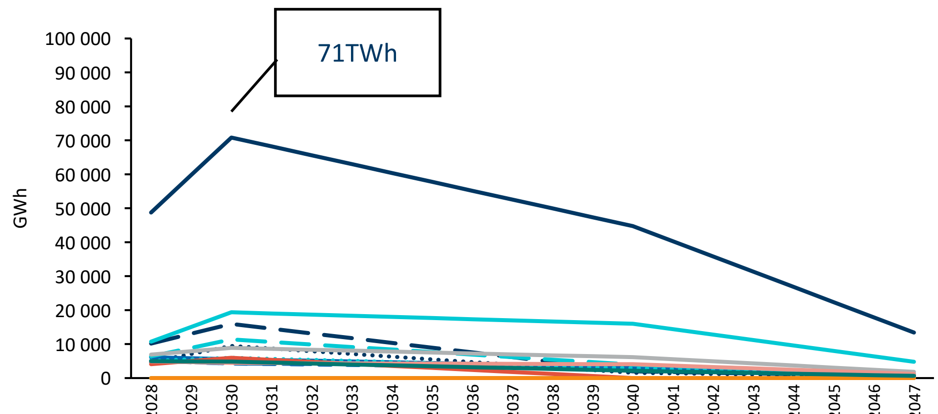
S0 – Baseline scenario



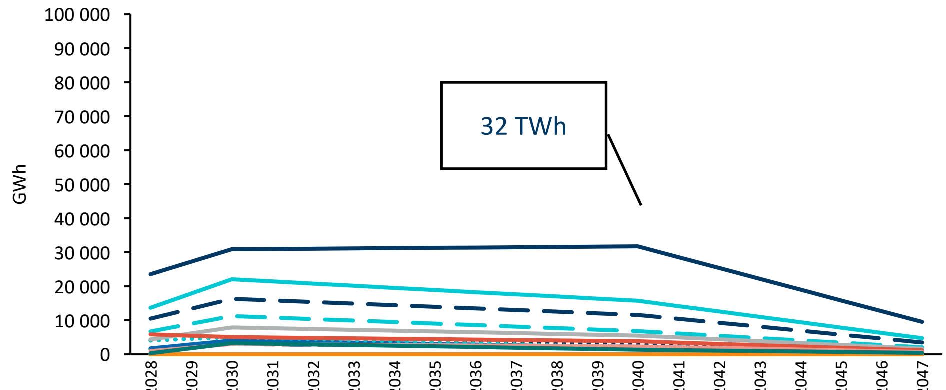
S1 – less available from Algeria

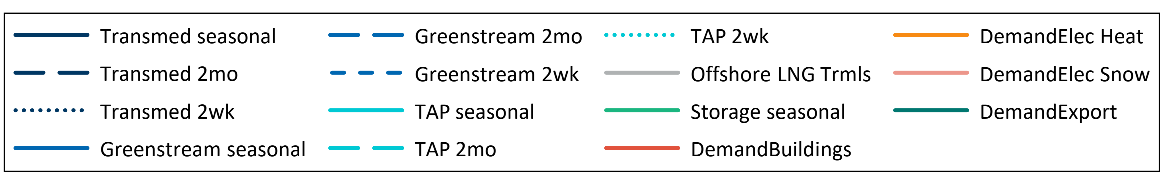


S2 – delay of TAP expansion and less gas from Azerbaijan



S3 – higher industrial demand





We find that the LNG terminal can save up to 3.9-5.4 bn $EUR_{constant}$ (before estimating its likelihood) during a single event (seasonal interruptions of TAP or Transmed)

Un-probabilized value of avoided gas curtailment due to the LNG terminal [2023, 2030, and 2040; mln $EUR_{constant}$]

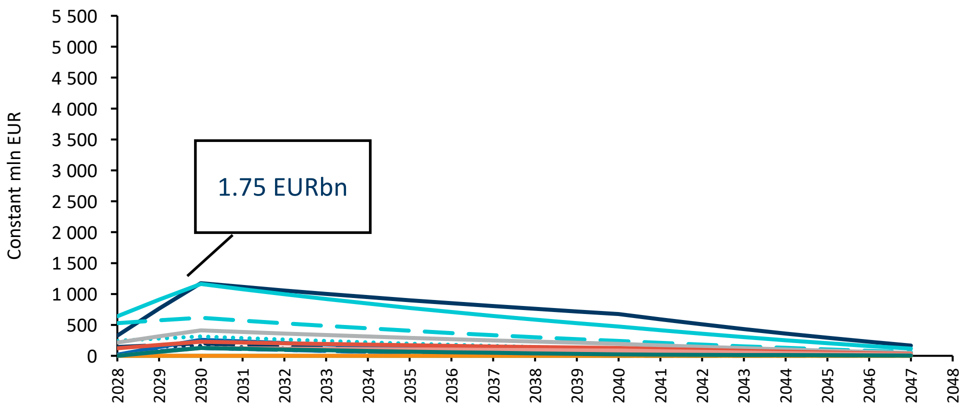
Duration	S0 : Baseline			S1 – less gas available from Algeria			S2 – delay of TAP and less gas from Azerbaijan			S3 – higher industrial demand		
	2028	2030	2040	2028	2030	2040	2028	2030	2040	2028	2030	2040
E1 Transmed seasonal	326	1,175	677	1,642	3,868	1,798	2,919	4,034	1,937	1,447	1,937	1,507
E1 Transmed 2mo	143	204	0	143	1,918	672	607	897	82	666	1,028	577
E1 Transmed 2wk	143	161	0	254	1,061	221	279	533	65	283	393	188
E2 Greenstream seasonal	19	260	51	323	2,713	262	364	312	136	104	228	85
E2 Greenstream 2mo	19	127	0	278	1,382	241	304	240	152	94	170	85
E2 Greenstream 2wk	19	13	0	278	975	100	304	240	123	94	170	85
E3 TAP seasonal	641	1,162	474	2,032	5,365	1,777	641	1,161	730	818	1,317	716
E3 TAP 2mo	529	617	241	664	2,524	714	382	711	189	402	704	330
E3 TAP 2wk	243	312	110	497	1,061	214	304	406	148	243	355	130
E4 Offshore LNG Trmls	215	412	194	384	837	415	421	590	309	261	515	270
E5 Storage seasonal	0	0	0	0	0	0	0	0	0	0	0	0
E6 DemandBuildings	122	227	126	246	1,587	232	244	375	0	350	305	160
E7 DemandElec Heat	0	0	0	0	0	0	0	0	0	0	0	0
E7 DemandElec Snow	0	127	85	254	1,544	189	292	250	170	55	170	97
E8 DemandExport	0	127	22	238	1,649	166	298	271	89	19	184	57

Ex.: E1 seasonal 2030 amounts to **1.2 bn $EUR_{constant}$**(1) in the baseline situation, going up to:
- **4.8 bn $EUR_{constant}$**(1) in sensitivity analysis S2 if there is delay of TAP and less gas from Azerbaijan
- **4.6 bn $EUR_{constant}$**(1) in sensitivity analysis S1 if there is less gas available from Algeria
- **2.3 bn $EUR_{constant}$**(1) in sensitivity analysis S3 in case of higher industrial demand

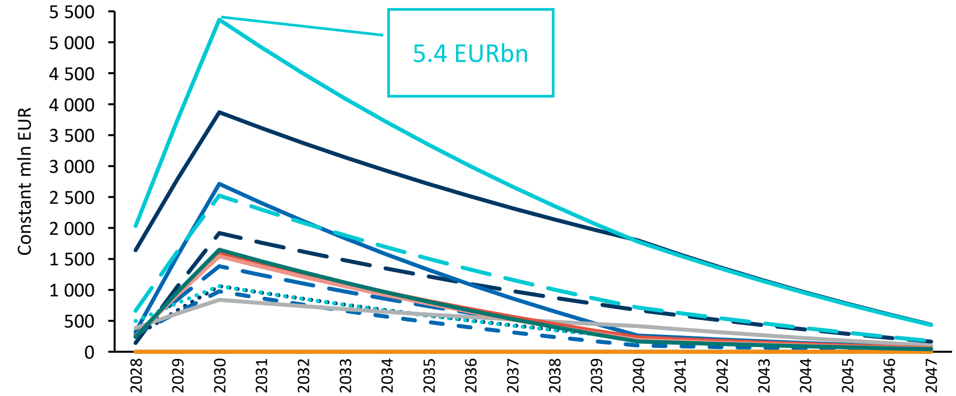
The decrease of the avoided curtailment value of a single event (un-probabilized) is accelerated as we apply ACER social discount rate

Un-probabilized value of avoided curtailment of demand [mln $EUR_{constant}$ (1)] due to the LNG terminal, 2028-2047

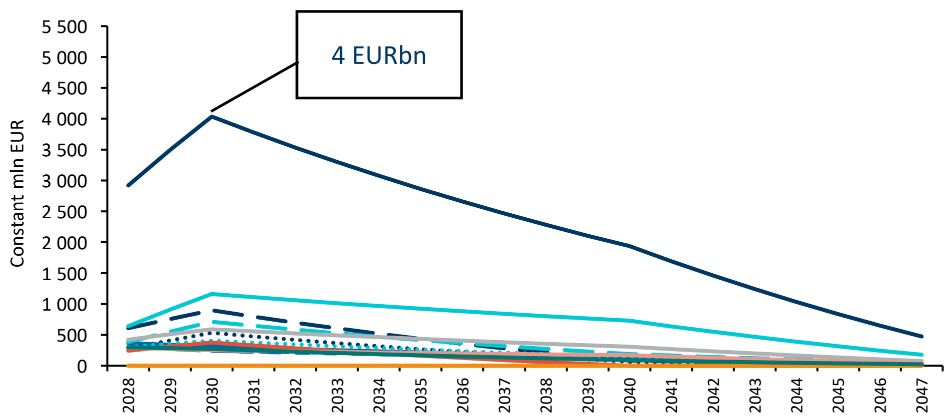
S0 – Baseline scenario



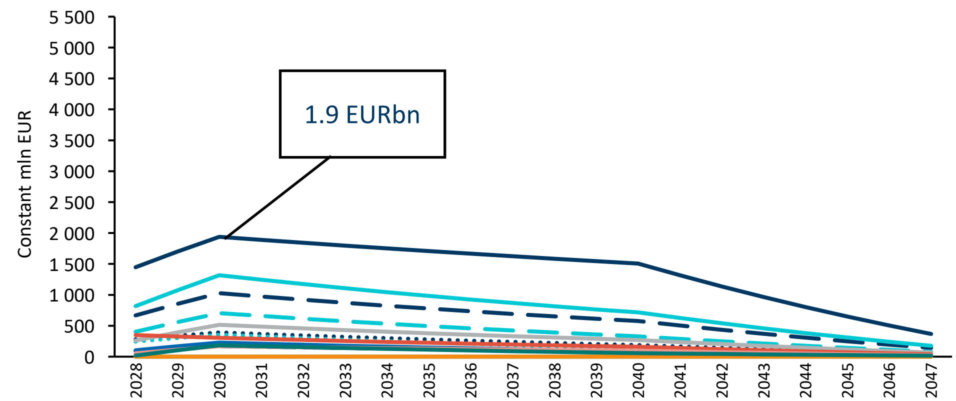
S1 – less available from Algeria

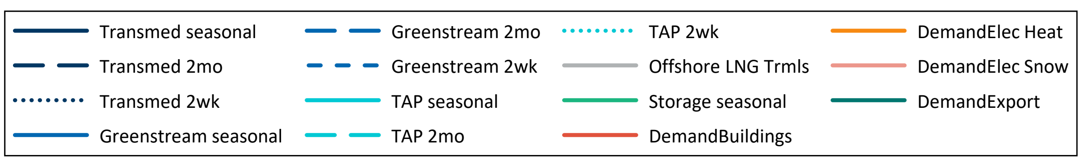


S2 – delay of TAP expansion and less gas from Azerbaijan



S3 – higher industrial demand





The yearly probabilized contribution of the LNG terminal can reach up to 107 mln $EUR_{constant}$ per event

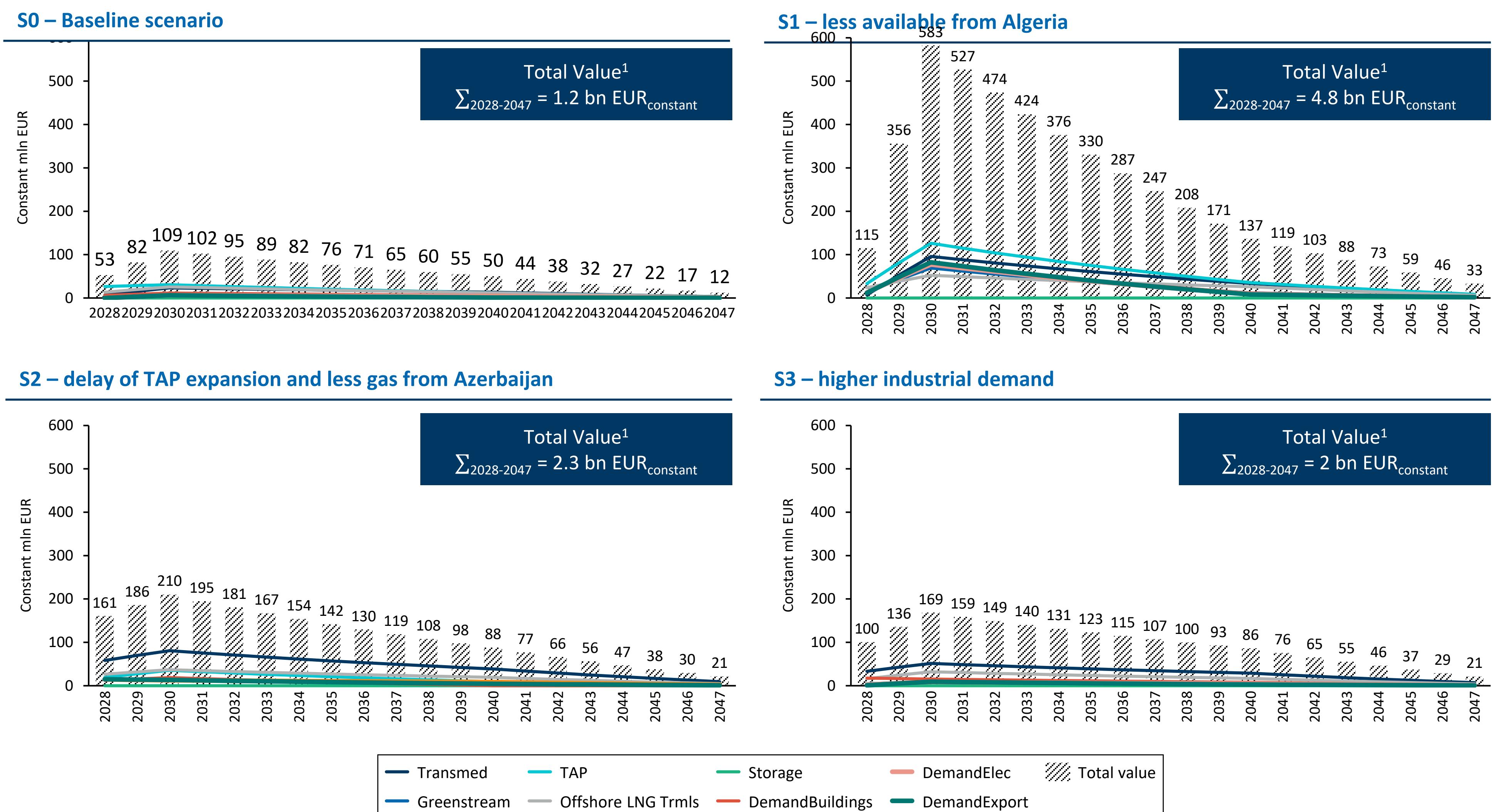
Probability-weighted value of avoided gas curtailment for different stress events and sensitivities, [2023, 2030, and 2040; mln $EUR_{constant}$]

Duration	S0 : Baseline			S1 – less gas available from Algeria			S2 – delay of TAP and less gas from Azerbaijan			S3 – higher industrial demand		
	2028	*2030*	*2040*	*2028*	*2030*	*2040*	*2028*	*2030*	*2040*	*2028*	*2030*	*2040*
E1 Transmed seasonal	**7**	**28**	**22**	33	77	36	58	81	39	29	39	30
E1 Transmed 2mo	8	12	0	7	96	34	30	45	4	33	51	29
E1 Transmed 2wk	8	10	0	13	53	11	14	27	3	14	20	9
E2 Greenstream seasonal	**0**	**6**	**2**	6	54	5	7	6	3	2	5	2
E2 Greenstream 2mo	1	8	0	14	69	12	15	12	8	5	9	4
E2 Greenstream 2wk	1	1	0	14	49	5	15	12	6	5	9	4
E3 TAP seasonal	14	28	15	41	107	36	13	23	15	16	26	14
E3 TAP 2mo	**30**	**37**	**19**	33	126	36	19	36	9	20	35	16
E3 TAP 2wk	14	19	9	25	53	11	15	20	7	12	18	6
E4 Offshore LNG Trmls	**15**	**31**	**19**	24	52	26	26	37	19	16	32	17
E5 Storage seasonal	0	0	0	0	0	0	0	0	0	0	0	0
E6 DemandBuildings	**7**	**14**	**10**	12	79	12	12	19	0	18	15	8
E7 DemandElec Heat	0	0	0	0	0	0	0	0	0	0	0	0
E7 DemandElec Snow	0	8	7	13	77	9	15	13	9	3	9	5
E8 DemandExport	**0**	**8**	**2**	12	82	8	15	14	4	1	9	3

To avoid double counting, we only keep the highest impact event among event groupings and added alongside other independent events, assuming that each events groupings is independent other groupings

We find that the total contribution of the LNG terminal, i.e. the 20y discounted sum of the selected events(1), varies between 1.2 (S0) and 4.8 (S1) bn EUR$_{constant}$

Probability-weighted value of avoided curtailment of demand [mln EUR$_{constant}$] due to the LNG Terminal, 2028-2047



Notes: (1) to avoid double counting we only took into consideration the highest impact event among event groupings and added alongside other independent events, assuming that each events groupings is independent other groupings

4 : Conclusion and limits

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Applying our methodology, we were able to make an initial estimate of the contribution of a given LNG infrastructure to ensuring security of supply at a national level

Main Results	We have developed a **methodology to quantify the contribution** of new infrastructure to **energy security at a national level,** in order to facilitate rational public decision making. When applying it to the **case of an LNG terminal in Italy**, we found that over 20 years, the terminal is estimated to avoid curtailment costs of **€1.2 billion** in our base scenario and up to €4.8 billion if gas supply from Algeria were to be lower than expected.
Limits	As we limited our analysis to the gas curtailment (physical volume) , and thus we **left out other monetized benefit** (reduction in gas and power prices), **non-monetised benefits** (increase in market diversification). In addition, the **benefits** brought by the LNG terminal **need to be compared to the costs** incurred by the CAPEX intensive infrastructures, **especially regarding stranded assets risks** in a context of expected gas demand reduction in the European countries.
Outlook	The methodology could be developed to **consider market response to price signals during stress events** and the modelling could be expanded **integrate entire European gas and electricity systems**, as well as the respective networks' constraints.

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Appendix

The model uses a standard linear programming to reallocate volumes of any security-of-supply condition modelled

Standard form of linear programming

minimize: $C_1x_1 + C_2x_2 + \cdots + C_nx_n$ ← **Objective function**

subject to: $a_{12}x_1 + a_{12}x_2 + \cdots + a_{1n}x_n \leq b_1$ ← **Constraints**

$x_1, x_2, \ldots x_n \geq 0$ ← **Decision variables**

To reallocate volumes, a supply-demand balance is obtained by minimizing deficits and storage imbalances

Adoption of linear programming for the model

minimize: **total_deficit** + **storage_imbalance**

subject to:

Weekly constraints:

- national_production ≤ production_capacity
- pipeline_import ≤ pipeline_capacity
- LNG_import ≤ LNG_capacity
- storage_withdrawal ≤ withdrawal_capacity
- storage_injection ≤ injection_capacity
- supply + storage_withdrawal – (demand + exports) – storage_injections = 0

Annual constraints (calendar year):

- annual_stored ≥ 90% × working_volume [EU regulation]
- annual_supply = expected_supply

Constraints are designed to ensure model equilibrium; they are adjusted depending on the security of supply stress events

Constraints

Constraints related to production and import	Notes
1. National_production ≤ production_capacity 2. Pipeline_import ≤ pipeline_capacity [historical/forecast max] 3. LNG_import ≤ LNG_capacity [historical max/physical cap]	• All supply sources per week are restricted based on **the weekly capacities.** • These capacities are set based on: ▪ historical maximum as proxy for contractual capacities when simulating historical years; and ▪ Pre-allocated forecast flows (based on historic utilisation) with 120% flexibility for pipelines to reflect likelihood of contractual flexibilities ▪ Full physical capacities for LNG terminals given the possibility to obtain volumes from the LNG spot market. **It is also conservative to assume that full supply flexibility could be utilized.** • For security of supply events (e.g. unavailable pipeline for 6 months), these constraints are modified based on the duration of time that they occur.
Constraints related to storage flexibility	
4. Storage_withdrawal ≤ withdrawal_capacity 5. Storage_injection ≤ injection_capacity	• For historical years, average **weekly withdrawal and injection capacities** are set as the limit to guide the model to gradually allocate storage action throughout the year. • For future years, these capacities are updated to monthly maximum capacities in order to allow the possibility of storing 90% of the working volume as set in constraint 7. Actual physical and injection capacities could be higher in the case of Italy
Other constraints to balance the model	
6. Supply + storage_withdrawal – (demand + exports) – storage_injections = 0	**Weekly balances** are targeted (i.e. zero deficits), and any violation of this constraint entails a **demand not served** for a certain scenario.
7. Annual_stored ≥ 90% × working_volume	The total storage needs to be **at least 90% as set by the REPowerEU gas storage regulation since 2022**. [1] This factor is not applied to the validation scenarios of 2018 and 2022 where the actual targets for Italy were less than 90%
8. Annual_supply = expected_supply	The total imports and production are set with an objective to achieve the demand

Notes (1) REGULATION (EU) 2022/1032, para 6, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv%3AOJ.L_.2022.173.01.0017.01.ENG&toc=OJ%3AL%3A2022%3A173%3ATOC

In the baseline conditions, supply flows are then disaggregated based on expected utilisation of infrastructure

Methodology for specific flows pre-allocation to set future baseline conditions

Demand[1]	2030	2040
	bcm	bcm
Total Demand	63.9	58.4
Exports	15	14
Total to Balance	**78.9**	**72.4**

Supply	2030	2040
	bcm	bcm
National Production	4	1
Northern imports	0	0
Southern imports	**49.2**	**46.3**
LNG imports	**25.6**	**24.1**

	2030 Bcm	2040 Bcm
North import	**0.0**	**0.0**
TARVISIO	0.0	0.0
PASSO GRIES	0.0	0.0
GORIZIA	0.0	0.0

	2030 Bcm	2040 Bcm	Initial reference utilisation
South Import	**49.2**	**46.3**	
MAZARA DEL VALLO (Transmed)	27.1	25.6	60%
GELA (Greenstream)	3.0	2.8	16%
MELENDUGNO (TAP)	11.9	11.2	61%
(A) …ENDUGNO 2 (TAP expansion)	7.1	6.7	(3) 61%

	2030 Bcm	2040 Bcm	Initial reference utilisation
LNG	**25.6**	**24.1**	
PANIGAGLIA	2.9	2.7	60%
CAVARZERE	10.7	9.9	83%
LIVORNO	4.9	4.5	67%
SNAM FSRU 1	3.5	3.5	70%
SNAM FSRU 2	3.5	3.5	70%

1. **Balance supply range proportionally according to demand + exports (maximum)**
2. **Distribute flows according to historic utilisation (2022) initially, then adjusted to total expected future imports**
3. **For the new TAP capacity, we use the same utilisation rates of the existing TAP(1)**
4. **For the new LNG terminals, we use the average utilisation of existing LNG terminals**

A. **TAP expansion is considered in the PNIEC**
In tale percorso si inserisce anche il cosiddetto raddoppio del ***TAP*** *che consentirà di disporre di una capacità di import di gas dal 2026.* (PNIEC June 2023) [1,2]

Notes: (1) Expansion of the current TAP capacity (480 GWh/day [ENTSOG Transmission capacity map]) involves an increase of 292GWh/day according to TYNDP 2022. (2) PNIEC June 2023 update.

Certain stress events are not considered for modelling because of the LNG terminal's expected minimal impact on security of supply under such events

Events not considered for further modelling

Event	Sub-event	Duration	Likelihood (source)	Rationale
Reduction of national volume	Reduction of national production	One month (January)	1 every 20 years (MiTE)	• Minimal effect given that the forecasted volumes for national production is less than 5% of total gas demand • Calculated avoided gas curtailment of <u>0 GWh in 2030</u>
Electrical infrastructure failure	Electrical blackout on electrical gas compression stations	Two days (15th-17th Feb)	1 every 50 years (MiTE)	• Event would also impact the additional LNG terminal and hence not show any difference • Calculated avoided gas curtailment of <u>0 GWh in 2030</u>
	Communication and ICT control infrastructure collapse	Two days (15th-17th Feb)	1 every 50 years (MiTE)	
Social events	Strike of personnel of Snam and/or NG infrastructure operators	7 days	1 every 30 years (MiTE)	
	Pandemic affecting personnel of Snam and/or NG infrastructure operators	30 days	1 every 50 years (MiTE)	
LNG terminals Interruption	Seasonal Disruption: Diversion of LNG cargos towards more profitable markets, affecting all LNG terminals – Zero LNG import	Heating season (6 x 4 weeks)	1 every 3 years (MiTE)	• Diversion of LNG cargoes would also impact the additional LNG terminal and hence not show any difference • Calculated avoided gas curtailment of <u>0 GWh in 2030</u>
National Storage Interruption	Short Disruption: Storm and thunder damage on Stogit storage	1 week	1 every 20 years (MiTE)	• Seasonal impact (6 x 4 weeks) is found to have ~0 impact so a shorter duration is not expected to demonstrate the additional LNG terminal value • Calculated avoided gas curtailment of <u>0 GWh in 2030</u>
Increased gas demand for electricity	Dunkleflaute: Cold spell combined with reduced renewables	2 weeks (15th-28th Feb)	1 every 20 years (ENTSO-E)	• Complex characterization as there is no accepted definition of impact across Europe, hence there is limited data for static modelling for the Italian system • Relative importance is likely to decrease fast as gas generation is less utilised post 2030 in the EU. This event is partly redundant with E7-snowstorm induced increase in gas demand, hence limiting the additional value