HI WEST 23 (Less-Advanced)

Ammonia Import Terminal Brunsbüttel

Reasons for grouping [ENTSOG]

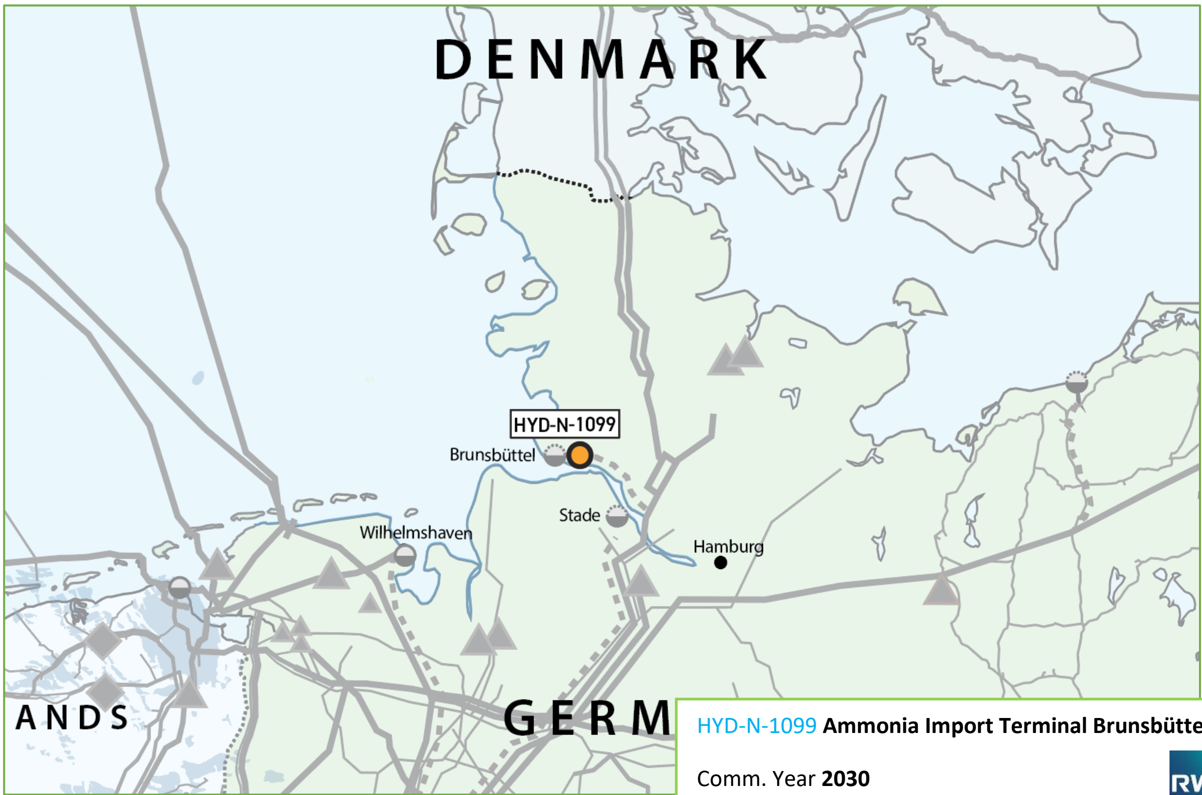
The project group is an ammonia terminal including a cracker in Wilhelmshaven, Germany (HYD-N- 1099).

This project will enable hydrogen imports to Germany.

Objective of the group [Promoter]

New liquefied hydrogen terminal incl. hydrogen embedded in other chemical substances with the objective of injecting the hydrogen into the grid.

By 2026, around 300,000 tons of green NH3 per year will arrive via the terminal in Brunsbüttel. In the second phase of the project a large-scale cracker will be installed at the terminal site to produce green H2 for the pipeline network. At the same time, the capacity of the terminal will be increased to 2,000,000 tons of green NH3, which amounts to 258,000 tons of H2 after the cracking process. With its direct access to the North Sea and its connection to European inland waterways as well as the rail system, the Brunsbüttel site offers ideal logistical conditions for the project. Furthermore, it will be connected to the H2ercules network of OGE RWE through expected pipelines of Gasunie, Gascade and Schleswig-Holstein Netz, which are already stated in the German Gas Network Development Plan. This enables a cross-border H2 supply to the Dutch, Belgian, French and Czech market. Hence, the project will contribute to the establishment of an integrated H2 infrastructure network.



HYD-N-1099 **Ammonia Import Terminal Brunsbüttel**

Comm. Year **2030**

A. Project group technical information [Promoter/ ENTSOG]

Project technical information [Promoter]

Hydrogen Terminal

TYNDP Project code	Hydrogen carrier	H_2 Import capacity [GWh/d]	Injection capacity [GWh/d]	Storage capacity [m³]
HYD-N-1099	Ammonia	30	23	125,000

Capacity increment [ENTSOG]

TYNDP Project code	Point name	Operator	From system	To system	Capacity increment [GWh/d]	Comm. year
HYD-N-1099	LH2_Tk_DE	RWE Supply & Trading GmbH	Terminal Germany (LH2_Tk_DEE)	Transmission Germany (DE Hydrogen)	23.5	2030

B. Project Cost Information

During the TYNDP 2022 Project Data Collection, promoters were asked to indicate whether their costs were confidential or not. The following tables display the non-confidential costs provided by the promoters (as of December 2022, end of PCI project collection). The amounts provided can differ from the figures used by the project promoters in other contexts, where costs can be updated and/or evaluated using different methodologies or assumptions.

[ENTSOG]

TYNDP Project code	CAPEX [M€]	CAPEX range [%]	OPEX [M€]	OPEX range [%]
HYD-N-1099	440	40%	40	20%

Description of the cost and range [Promoter]

The major parts of the CAPEX are the cracker itself and the ammonia storage tank, followed by the hydrogen compression. This comprises already approx. 70% of the CAPEX. As the ammonia crackers are under development the cost estimation accuracy is limited which results in the CAPEX range of 40%. The OPEX is driven by O&M costs and costs for the feedstock as well as energy costs for the cracking process.

C. Project Benefits [ENTSOG]

C.1 Summary of benefits

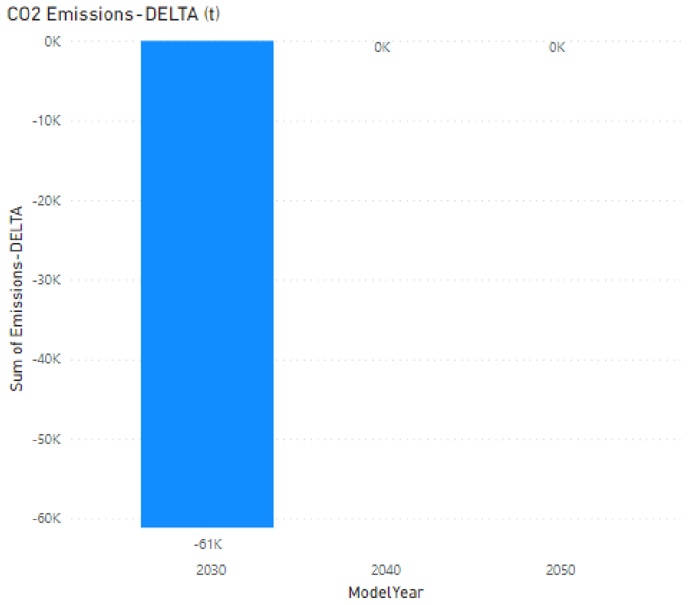
This section provides a summarised analysis by ENTSOG of the main benefits stemming from the realisation of the overall group. More details on the indicators are available in Annex D of TYNDP 2022[1].

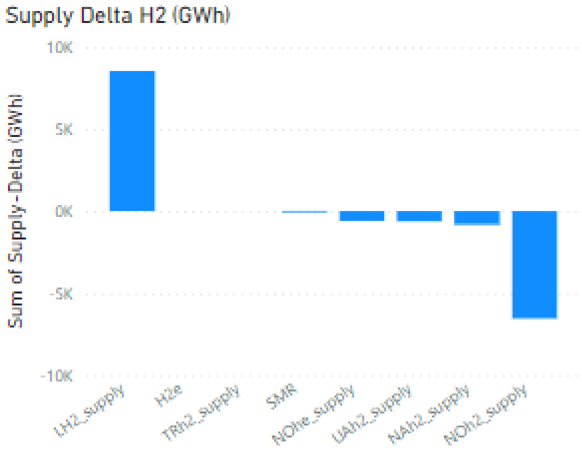
[1] https://www.entsog.eu/sites/default/files/2023-04/ENTSOG_TYNDP_2022_Annex_D_Methodology_230411.pdf

Distributed Energy

Sustainability benefits

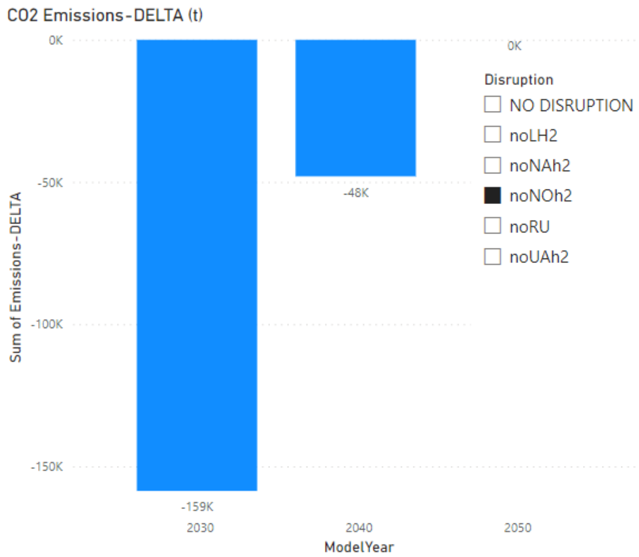
Thanks to the project group, from 2030, the newly built terminal improves and diversifies hydrogen supply in Germany. In the reference case, which analyses yearly demand in two periods (average winter and average summer), the project group will contribute to sustainability by reducing overall CO2 emissions by 61 kt in 2030. This can be explained as in 2030 the project group enables mainly the replacement of blue hydrogen imports from Norway with green hydrogen liquid imports.

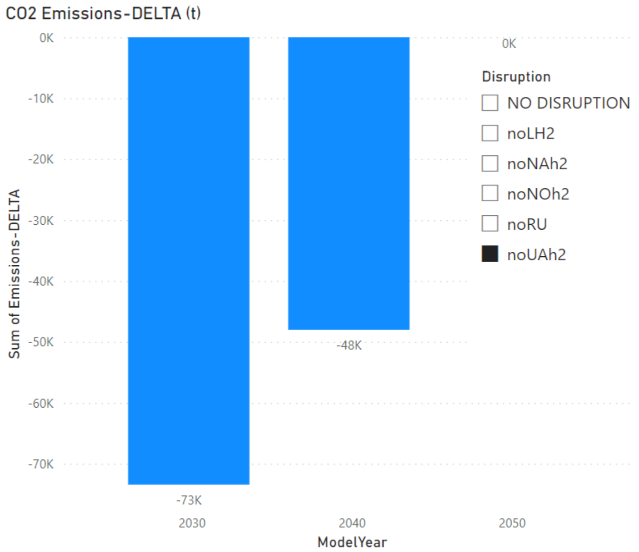


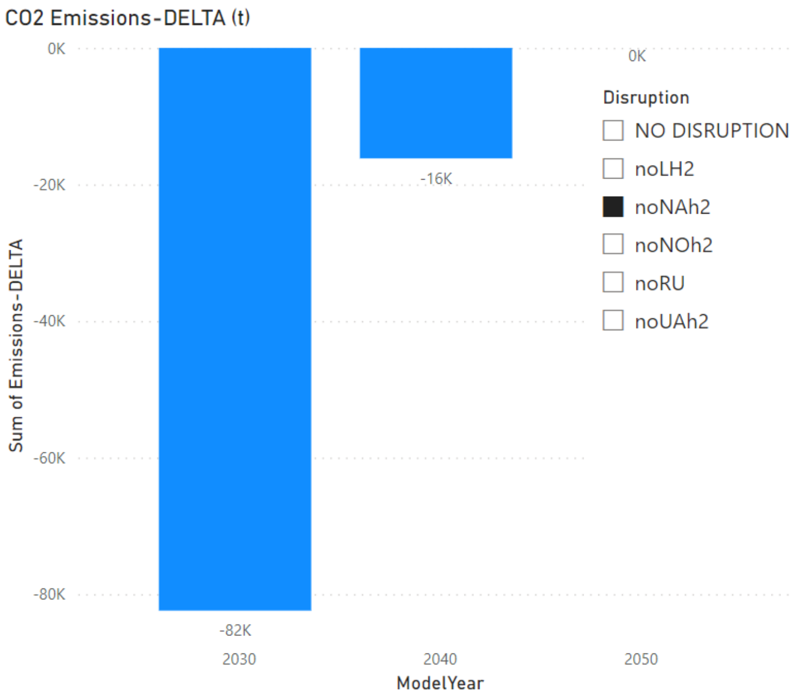


Sustainability benefits are increased under supply disruption cases, such as Norway, Ukraine, or North Africa Disruption for 2030 and 2040. For example, in case of Norway disruption the project group will reduce CO2 emissions by 159 kt in 2030 and by 48 kt in 2040.

1 noNOh2 : Norway disruption / 2 noUAh2 : Ukraine disruption/ 3 noNAh2 : North Africa disruption







Security of Supply:[2]

> Reference case:

In the reference case, the project is not further mitigating hydrogen demand curtailment risk in average summer and average winter for European countries. However, it is important to mention that the SoS benefits of this project group could be limited due to a competing(s) project group(s) (such as WEST 24A, WEST 24 B) located in the same geographical area enabling, as well, liquid import supplies to flow to Germany.

2030 DE- Benefits

2040 DE- Benefits

2050 DE- Benefits

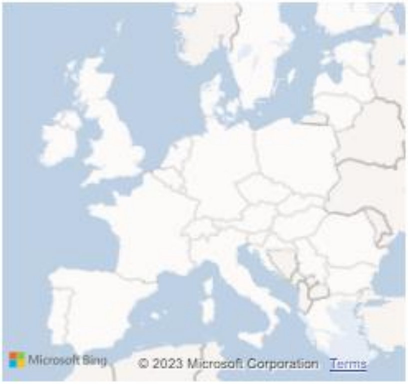
[2] *As for the hydrogen system there is no existing infrastructure level available yet, ENTSOG has identified a possible hydrogen network according to the information provided by promoters in their project submission for the TYNDP/PCI process (i.e., H2 Infrastructure level). Therefore, the System Assessment shows the results that could be reached (for different timestamps) under the hypothesis of a full commissioning of the H2 infrastructure projects that were submitted by project promoters but that are not yet in place. Therefore, even in configurations where no demand curtailment is identified (e.g., average winter in 2030) these results should not be read as an absence of H2 infrastructure needs for the given scenario. On the contrary, the full availability of the planned infrastructures composing the H2 infrastructure level is assumed to avoid the potential demand curtailment.*

> Climatic stress cases:

Similar under 2 -week and 2-week dunkelflaute climatic stress case, as well as under peak day climatic case the project group is not contributing to the mitigation of h2 demand curtailment risk in Europe.

2030 DE- Benefits

2040 DE- Benefits



2050 DE- Benefits

> Disruption cases (S-1):

In case of supply disruption cases such as Norway, Ukraine or North Africa supply disruption the project, similar as in the reference case, is not further mitigating the risk of hydrogen demand curtailment.

> Single largest capacity disruption (SLCD):

In case of SLCD many European countries benefitting on small scale from this project group by mitigating the risk of demand curtailment from 2030 onward. Thanks to the project group respective countries mitigate the risk of demand curtailment by 1-2%.

Benefits 100% - 20% 20% - 5% 5% - 0%

SLCD Benefits - 2030 - Distributed Energy

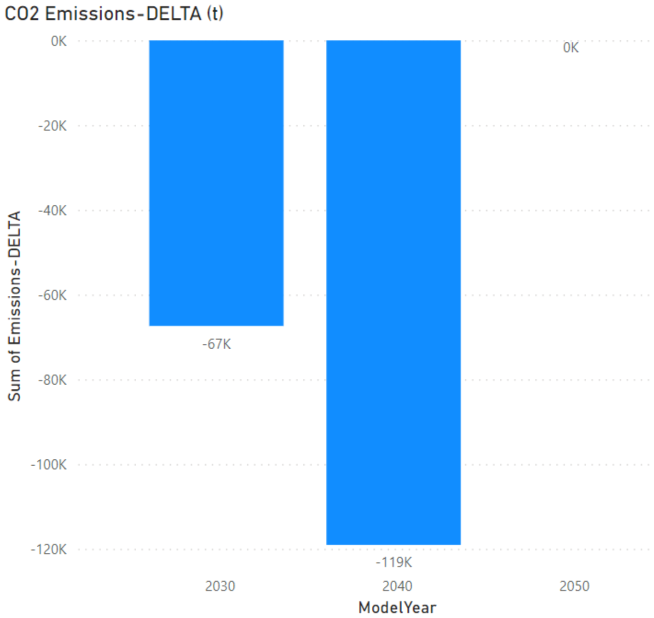
SLCD Benefits - 2040 - Distributed Energy

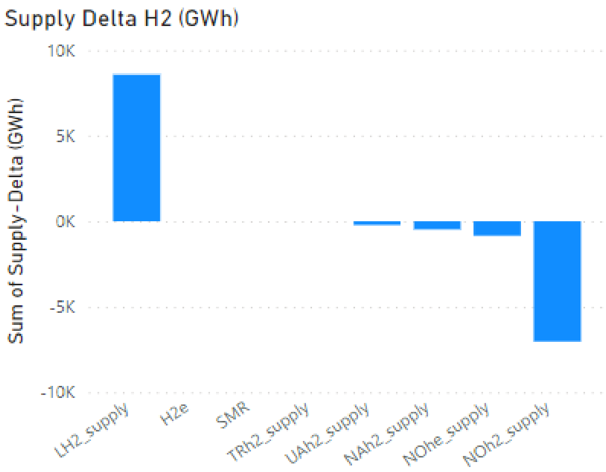
SLCD Benefits - 2050 - Distributed Energy

Global Ambition

Sustainability benefits

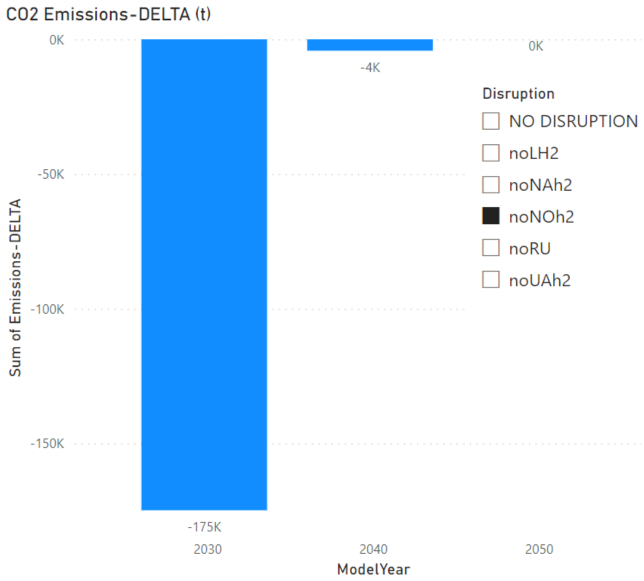
In the reference case, which analyses yearly demand in two periods (average winter and average summer), the project group will contribute to sustainability by reducing overall CO2 emissions by 67 kt in 2030 and by 119 kt in 2040. This can be explained as in 2030 the project group enables mainly the replacement of blue hydrogen imports from Norway and in 2040 the project replaces blue hydrogen locally produced (I.e SMR).

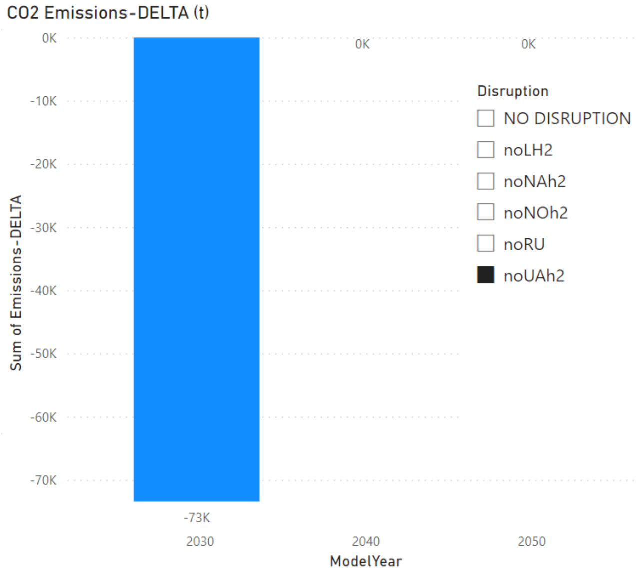


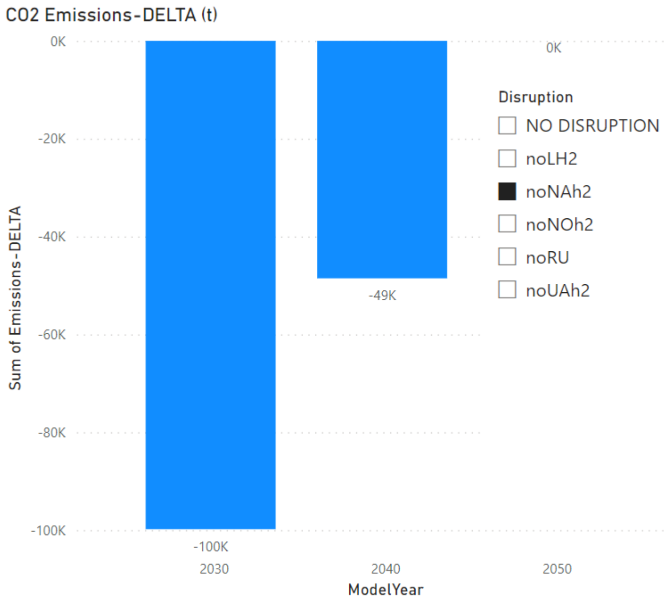


Sustainability benefits are increased under supply disruption cases, such as Norway, Ukraine, or North Africa Disruption for 2030. For example, in case of North Africa disruption the project group will reduce CO2 emissions by 100 kt in 2030.

1 noNOh2 : Norway disruption / 2 noUAh2 : Ukraine disruption/ 3 noNAh2 : North Africa disruption







Security of supply benefits

> Reference case

In the reference case, the project does not further mitigate hydrogen demand curtailment risk in average summer and average winter for European countries. However, it is important to mention that the SoS benefits of this project group could be limited due to a competing(s) project group(s) (such as WEST 24A, WEST 24 B) located in the same geographical area enabling, as well, liquid import supplies to flow to Germany.

2030 GA- Benefits

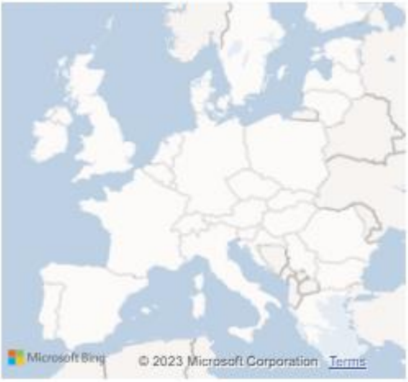
2040 GA- Benefits

2050 GA- Benefits

> Climatic stress cases

Similar under 2 -week and 2-week dunkelflaute climatic stress case, as well as under peak day climatic case the project group is not contributing to the mitigation of h2 demand curtailment risk in Europe.

2030 GA- Benefits



2040 GA- Benefits

2050 GA- Benefits

> Disruption cases (S-1)

In case of supply disruption cases such as Norway, Ukraine or North Africa supply disruption the project, similar as in the reference case, is not further mitigating the risk of hydrogen demand curtailment.

> Single largest capacity disruption (SLCD):

In case of SLCD many European countries benefitting on small scale from this project group by mitigating the risk of demand curtailment from 2030 onwards. Thanks to the project group respective countries mitigate the risk of demand curtailment by 1-2%.

Benefits 100% - 20% 20% - 5% 5% - 0%

SLCD Benefits - 2030 - Global Ambition

SLCD Benefits - 2040 - Global Ambition

SLCD Benefits - 2050 - Global Ambition

C.2 Quantitative benefits [ENTSOG]

The following tables display all the benefits quantified by ENTSOG through specific indicators and stemming from the realisation of the considered project group.

CO2 Emissions:

ModelYear	Disruption	Scenario	Unit	Emissions-DELTA	Emissions-PLUS	Emissions-MINUS
2030	NO DISRUPTION	DE	tonne	-61147,80	538677299	538738446,8
2030	noLH2	DE	tonne	-2,40	540175890,2	540175892,6
2030	noNAh2	DE	tonne	-82395,38	539785356,1	539867751,5
2030	noNOh2	DE	tonne	-158605,00	538877197,8	539035802,8
2030	noUAh2	DE	tonne	-73417,58	539378771,9	539452189,5
2030	NO DISRUPTION	GA	tonne	-67384,15	592910448,4	592977832,6
2030	noLH2	GA	tonne	-163,10	594817481,2	594817644,3
2030	noNAh2	GA	tonne	-99803,57	594141433,2	594241236,7
2030	noNOh2	GA	tonne	-174796,19	593310994,3	593485790,4
2030	noUAh2	GA	tonne	-73417,58	593627617,9	593701035,5
2040	NO DISRUPTION	DE	tonne	0,00	392077044	392077044
2040	noLH2	DE	tonne	0,00	392213883,4	392213883,4
2040	noNAh2	DE	tonne	-16175,17	392188097,7	392204272,9
2040	noNOh2	DE	tonne	-48003,73	392144022,6	392192026,3
2040	noUAh2	DE	tonne	-48003,73	392399182,9	392447186,6
2040	NO DISRUPTION	GA	tonne	-119054,95	396523251,6	396642306,6
2040	noLH2	GA	tonne	0,00	397455196,7	397455196,7
2040	noNAh2	GA	tonne	-48528,59	397301976,6	397350505,2
2040	noNOh2	GA	tonne	-4219,61	397450977,1	397455196,7
2040	noUAh2	GA	tonne	0,00	397478498,3	397478498,3
2050	NO DISRUPTION	DE	tonne	0,00	232557734,8	232557734,8
2050	noLH2	DE	tonne	0,00	232557734,8	232557734,8
2050	noNAh2	DE	tonne	0,00	232557734,8	232557734,8
2050	noNOh2	DE	tonne	0,00	232557734,8	232557734,8
2050	noRU	DE	tonne	0,00	232557734,8	232557734,8
2050	noUAh2	DE	tonne	0,00	232557734,8	232557734,8
2050	NO DISRUPTION	GA	tonne	0,00	228306706,5	228306706,5
2050	noLH2	GA	tonne	0,00	228306706,5	228306706,5
2050	noNAh2	GA	tonne	0,00	228306706,5	228306706,5
2050	noNOh2	GA	tonne	0,00	228306706,5	228306706,5
2050	noRU	GA	tonne	0,00	228306706,5	228306706,5
2050	noUAh2	GA	tonne	0,00	228306706,5	228306706,5

Curtailment Rate (SLCD):

Country	2030-DE-DELTA	2030-GA-DELTA	2040-DE-DELTA	2040-GA-DELTA	2050-DE-DELTA	2050-GA-DELTA
France	-1%	-1%	-2%	-1%	-2%	-1%
Austria	-1%	-1%	-2%	-1%	-2%	-1%
Belgium	-1%	-1%	-2%	-1%	-1%	-1%
Czechia	-1%	-1%	-2%	-2%	-2%	-1%
Denmark	-1%	-1%	-2%	-1%	-2%	0%
Estonia	-1%	-1%	-2%	-1%	-2%	-1%
Finland	-1%	-1%	-2%	-1%	-2%	-1%
Germany	-1%	-1%	-2%	-2%	-1%	-1%
Italy	-1%	-1%	-2%	-1%	-2%	-1%
Latvia	-1%	-1%	-2%	-1%	-1%	-1%
Lithuania	-1%	-1%	-2%	-1%	-1%	-1%
Poland	-1%	-1%	-2%	-1%	-2%	-1%
Portugal	-1%	-1%	-2%	-1%	-1%	-1%
Slovenia	0%	0%	-2%	-1%	-2%	-1%
Sweden	-1%	-1%	-2%	-1%	-2%	-1%
Switzerland	0%	0%	-2%	-1%	-1%	-1%
The Netherlands	0%	0%	-2%	-1%	-2%	-1%
Bulgaria	-1%	-1%	-1%	0%	0%	-1%
Croatia	0%	0%	-1%	-1%	0%	-1%
Greece	-1%	-1%	-1%	0%	0%	0%
Hungary	-1%	-1%	-1%	-1%	0%	-1%
Romania	-1%	-1%	-1%	-1%	0%	-1%
Slovakia	-1%	-1%	-1%	-1%	-1%	-1%
Spain	-1%	-1%	-1%	-1%	-2%	-1%

Curtailment Rate (Climatic Stress):

SimulationPeriod	Country	2030-DE-DELTA	2030-GA-DELTA	2040-DE-DELTA	2040-GA-DELTA	2050-DE-DELTA	2050-GA-DELTA
Average2W	Austria	-1%	-1%	-1%	-1%	0%	0%
Average2W	Belgium	0%	-1%	-1%	-1%	0%	0%
Average2W	Bulgaria	0%	-1%	0%	-1%	0%	0%
Average2W	Croatia	0%	0%	0%	0%	0%	0%
Average2W	Cyprus	0%	0%	0%	0%	0%	0%
Average2W	Czechia	-1%	-1%	-1%	-1%	0%	0%
Average2W	Denmark	-1%	-1%	0%	-1%	0%	-1%
Average2W	Estonia	-1%	-1%	0%	0%	-1%	0%
Average2W	Finland	-1%	-1%	0%	0%	0%	-1%
Average2W	France	-1%	-1%	0%	-1%	0%	-1%
Average2W	Germany	-1%	-1%	0%	0%	0%	0%
Average2W	Greece	0%	-1%	-1%	0%	0%	0%
Average2W	Hungary	0%	-1%	0%	0%	0%	0%
Average2W	Ireland	0%	0%	0%	0%	0%	0%
Average2W	Italy	-1%	0%	0%	0%	0%	0%
Average2W	Latvia	-1%	-1%	0%	0%	0%	0%

Average2W	Lithuania	-1%	-1%	0%	0%	0%	0%
Average2W	Luxembourg	0%	0%	0%	0%	0%	0%
Average2W	Malta	0%	0%	0%	0%	0%	0%
Average2W	Poland	-1%	-1%	0%	0%	0%	-1%
Average2W	Portugal	-1%	-1%	0%	-1%	0%	-1%
Average2W	Romania	0%	-1%	0%	0%	0%	0%
Average2W	Serbia	0%	0%	0%	0%	0%	0%
Average2W	Slovakia	-1%	-1%	0%	0%	0%	0%
Average2W	Slovenia	0%	0%	0%	-1%	0%	-1%
Average2W	Spain	-1%	-1%	0%	0%	0%	0%
Average2W	Sweden	-1%	-1%	0%	0%	-1%	-1%
Average2W	Switzerland	0%	0%	-1%	0%	0%	0%
Average2W	The Netherlands	0%	0%	-1%	-1%	-1%	0%
Average2W	United Kingdom	0%	0%	0%	0%	0%	0%
Average2WDF	Austria	-1%	-1%	-1%	-1%	0%	-1%
Average2WDF	Belgium	-1%	-1%	0%	-1%	0%	0%
Average2WDF	Bulgaria	0%	-1%	-1%	-1%	0%	0%
Average2WDF	Croatia	0%	0%	0%	0%	0%	-1%
Average2WDF	Cyprus	0%	0%	0%	0%	0%	0%
Average2WDF	Czechia	-1%	-1%	0%	-1%	0%	0%
Average2WDF	Denmark	-1%	-1%	-1%	-1%	0%	-1%
Average2WDF	Estonia	-1%	-1%	0%	0%	-1%	0%
Average2WDF	Finland	-1%	-1%	-1%	-1%	0%	0%
Average2WDF	France	-1%	-1%	-1%	0%	0%	-1%
Average2WDF	Germany	-1%	-1%	0%	0%	0%	0%
Average2WDF	Greece	0%	-1%	0%	-1%	0%	0%
Average2WDF	Hungary	0%	-1%	0%	0%	0%	0%
Average2WDF	Ireland	0%	0%	0%	0%	0%	0%
Average2WDF	Italy	-1%	0%	-1%	0%	0%	0%
Average2WDF	Latvia	-1%	-1%	0%	0%	0%	0%
Average2WDF	Lithuania	-1%	-1%	0%	0%	0%	-1%
Average2WDF	Luxembourg	0%	0%	0%	0%	0%	0%
Average2WDF	Malta	0%	0%	0%	0%	0%	0%
Average2WDF	Poland	-1%	-1%	0%	0%	0%	-1%
Average2WDF	Portugal	-1%	-1%	-1%	0%	0%	0%
Average2WDF	Romania	0%	-1%	0%	0%	0%	-1%
Average2WDF	Serbia	0%	0%	0%	0%	0%	0%
Average2WDF	Slovakia	-1%	-1%	0%	0%	0%	0%
Average2WDF	Slovenia	0%	0%	-1%	-1%	0%	-1%
Average2WDF	Spain	-1%	-1%	0%	-1%	0%	0%
Average2WDF	Sweden	-1%	-1%	-1%	-1%	-1%	0%
Average2WDF	Switzerland	0%	0%	-1%	0%	0%	0%
Average2WDF	The Netherlands	0%	0%	0%	-1%	-1%	0%
Average2WDF	United Kingdom	0%	0%	0%	0%	0%	0%
DC	Austria	-1%	-1%	0%	0%	0%	-1%

DC	Belgium	-1%	-1%	0%	0%	0%	0%
DC	Bulgaria	0%	-1%	-1%	0%	0%	0%
DC	Croatia	0%	0%	-1%	0%	0%	0%
DC	Cyprus	0%	0%	0%	0%	0%	0%
DC	Czechia	-1%	0%	0%	0%	0%	0%
DC	Denmark	-1%	-1%	0%	0%	0%	0%
DC	Estonia	0%	-1%	-1%	0%	-1%	0%
DC	Finland	0%	-1%	0%	0%	0%	0%
DC	France	-1%	0%	-1%	0%	0%	0%
DC	Germany	-1%	0%	0%	-1%	0%	0%
DC	Greece	0%	0%	-1%	0%	0%	0%
DC	Hungary	0%	0%	-1%	0%	0%	0%
DC	Ireland	0%	0%	0%	0%	0%	0%
DC	Italy	0%	-1%	0%	0%	-1%	0%
DC	Latvia	0%	-1%	-1%	0%	0%	-1%
DC	Lithuania	0%	-1%	-1%	0%	0%	0%
DC	Luxembourg	0%	0%	0%	0%	0%	0%
DC	Malta	0%	0%	0%	0%	0%	0%
DC	Poland	0%	-1%	-1%	0%	0%	0%
DC	Portugal	-1%	0%	-1%	0%	0%	0%
DC	Romania	0%	-1%	-1%	0%	0%	-1%
DC	Serbia	0%	0%	0%	0%	0%	0%
DC	Slovakia	-1%	-1%	-1%	0%	0%	0%
DC	Slovenia	0%	0%	-1%	0%	0%	-1%
DC	Spain	-1%	-1%	0%	0%	0%	0%
DC	Sweden	0%	-1%	0%	0%	-1%	0%
DC	Switzerland	0%	0%	0%	0%	-1%	0%
DC	The Netherlands	0%	0%	0%	0%	-1%	0%
DC	United Kingdom	0%	0%	0%	0%	0%	0%

D. Environmental Impact [Promoter]

Any gas infrastructure has an impact on its surroundings. This impact is of particular relevance when crossing some environmentally sensitive areas. Mitigation measures are taken by the promoters to reduce this impact and comply with the EU and National regulations.

TYNDP Code	Type of infrastructure	Surface of impact	Environmentally sensitive area
HYD-N-1099	NH3 cracker	n.a	n.a

Potential impact	Mitigation measures	Related costs included in project CAPEX and OPEX	Additional expected costs

Environmental Impact explained [Promoter]

By providing up to 258,000 tons of green hydrogen per year the import site in Brunsbüttel will contribute to a reduction of fossil fuels demand in the industry as well as in the mobility sector. The foreseen amounts of hydrogen have the potential to reduce the GHG emissions by at least 1,700,000 tons CO_2 per year assuming a substitution of gray hydrogen. Depending on the specific usage of hydrogen the GHG emission avoidance can be even higher.

The operation of the import facility has no negative impact on climate change. The construction of facilities has a minor environmental impact. The shipment of green ammonia can be compared to the shipment of LNG, therefore no additional impact on climate is expected. In general, the build-up of large-scale electrolyser capacities, which are needed at the production sites for green ammonia, leads globally to an increased demand of rare earth-elements. This issue has to be addressed to ensure that resources are being mined in a sustainable and environmental-friendly way. By pushing the development of electrolyser technologies in its domestic projects RWE is working towards reducing the necessary amounts of rare elements for electrolyser facilities in the near-term future. In addition to that, RWE is defining internal policies to minimize the environmental impact of all its activities.

E. Other benefits [Promoter]

Missing benefits are all benefits of a project which may be not captured by ENTSOG analysis.

As a necessary condition a missing benefit cannot have discrepancies with the benefits already covered by the assessment run by ENTSOG and this condition needs to be proved and justified.

Description of Other benefits [Promoter]

- **Facilitation of technology development as a first mover towards the large scale ammonia cracking**

F. Useful links [Promoter]

Useful links:

https://www.rwe.com/en/research-and-development/project-plans/brunsbuettel-project-location/

https://www.wasserstoff-leitprojekte.de/leitprojekte/transhyde