Breidablikk emissions study

Rystad Energy Advisory
October 2024

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About

Breidablikk field study

Assessment of net emissions from production at the Breidablikk field

Summary document

Research by: Rystad Energy

Research for: equinor

On behalf of Equinor, Rystad Energy has studied the change in global emissions from the Breidablikk field production. This involves calculations of both direct and indirect global emission effects of an increased oil and gas supply from the Breidablikk field in the future, in the form of point estimates for emission intensity and associated uncertainty ranges. Relevant relationships between oil, gas and other energy markets, emission effects and government regulations (e.g. allowance systems) have been investigated. The approach and framework used in this work, is aligned with the work previously done for the Norwegian Ministry of Energy. The report is based on a literature review of relevant work in the field, publicly available forecasts for future demand for various sources of energy, as well as Rystad Energy's databases for supply-side data.

Deliverables

Breidablikk emission assessment

Chapters	Description
Executive summary	*Key take aways and summary from the report*
Background Breidablikk	*Overview of Breidablikk's oil & gas production and its contribution to domestic oil supply in Norway*
Framework for assessment of Breidablikk emissions	*Introduction of three-step framework used to assess the impact of Breidablikk's oil and gas production on global emissions*
Step 1 - Oil and gas replacement	*Assessment of how the market responds to a change in supply of oil (i.e., how much less oil is produced somewhere else if Breidablikk starts production), including definition of elasticities and investigation of supply and demand elasticities*
Step 2 - Other energy substitution	*Assessment of substitution in other energy markets when Breidablikk oil and gas production displaces consumption of other energy sources*
Step 3 - Production intensity impact	*Assessment of emissions from production of oil and gas if Breidablikk produces instead of other producers*
Sensitivities	*Investigation of the effects of different energy demand scenarios and non-energy oil demand*
Appendix	*Supporting material with details from the various chapters*

Source: Rystad Energy research and analysis

Key terms used throughout the report

Key term	Definition
Abatement cost	The expense incurred to reduce or prevent greenhouse gas emissions
Break-even price	The minimum price at which production becomes financially viable, covering all costs including exploration, extraction, and operational expenses
Carbon dioxide equivalents	A metric used to compare the global warming potential of different greenhouse gases by expressing their impact in terms of the equivalent amount of carbon dioxide
Coal-to-gas switching	The process of shifting from coal-fired power generation to natural gas-fired power generation
Demand elasticity	Demand elasticity if the change in demand when there is a change in price. Demand elasticities are usually negative
Marginal supply	The additional quantity that is provided to the market when there is a slight increase in demand, typically representing the output from the most expensive or least efficient producer
Primary Energy	Natural resources in their raw form, available for direct use without any conversion processes (incl. oil, gas, coal, renewables, biomass etc.)
Real Prices	The real value is the nominal value after it has been adjusted for inflation
Supply elasticity	Elasticity of supply is the responsiveness of a supply of a good after a change in its market price. Supply elasticities are positive
Scope 1	Scope 1 covers emissions from scources that an organization owns or controls directly
Scope 2	Scope 2 covers emissions that a company causes indirectly and come from where the energy it purchases and uses is produced
Scope 3	Scope 3 encompasses value chain emissions that are not produced by the company itself and are not the result of activities from assets owned or controlled by them

Source: Rystad Energy research and analysis

Key terms used throughout the report

Key term	Definition
Bbl(s)	Barrels
Bbls/d	Barrels per day
Bcm	Billion cubic metres
Boe	Barrels of oil equivalent
Bcf	Billions of standard cubic feet
Condensate	A mixture of hydrocarbons which exist in gaseous phase at reservoir conditions but are produced as a liquid at surface conditions
Crude	Unrefined petroleum
GWP	Global Warming Potential
ICE	Internal Combustion Engine
Km	Kilometers
m^3	Cubic meters
Mbbl	Million barrels
Mt	Million tonnes
NGL	Natural Gas Liquids
Petroleum	Naturally occurring mixtures of hydrocarbons which are found beneath the Earth’s surface in liquid, solid or gaseous form
Tcf	Trillion square feet of natural gas

Source: Rystad Energy research and analysis

Conversion factors and efficiencies used throughout the report

Key numerical assumptions

Assumption	Value
Electric vehichle efficiency	80%
Gasoline car/ICE[1] efficiency	30%
CO_2 kg/TJ Crude oil	73,300
Methane kg/TJ Crude oil	10

Unit conversion factors used

Units			Conversion factor
bcm	to	mmboe	5.88
barrel of oil	to	tonnes	0.136
Methane GWP[2]	to	CO_2 GWP[2]	29.8
boe	to	kWh	1,603
boe	to	GJ	5.771
tonne oil	to	GJ	42.3
Sm3	to	boe	6.29

1) Internal Combustion Engine; 2) Global warming potential

Source: Rystad Energy research and analysis; IPCC Stationary Combustion factors; Greenhouse gas protocol; Hjelkrem et al. (2020); Guidehouse (International comparison of fossil power efficiency and CO_2 intensity - Update 2018); EPA (Greenhouse Gas Inventory Guidance: Direct Emissions from Stationary Combustion Sources)

Content

Breidablikk can reduce global emissions by 1.0 Mt CO_2e over its lifetime in the reference case

	Key takeaways	Narrative
1	**Constitutes 1% of the Norwegian cumulative oil & gas production**	Breidablikk, one of the latest additions to the Norwegian North Sea and a subsea tie-back to Grane, started its production in 2023 and is expected to provide around 16 kboe/day of oil throughtout the field's lifespan, in total 235 mboe. The field is anticipated to account for ~1% of Norway's cumulative oil and gas production between 2023 and 2060.
2	**Can decrease oil production emission intensity in Norway by ~2%**	According to the reference case the inclusion of Breidablikk into Norway's overall oil and gas production could lead to reduction in the average emission intensity. Emission intensities from the Norwegian oil & gas production is projected to decrease by ~2% on average by including Breidablikk production. Low upstream emissions due to electrification and the pre-existing production at Grane, causes a lower than average emission intensity. This is despite relatively high midstream emissions of Breidablikk's as a result of the low API of the crude produced. Breidablikk is also in a disadvantaged position due to low gas production which is more favourable net emissions impact than oil production.
3	**Can reduce global emissions by ~1 Mt CO_2e**	The reference case concludes that production at Breidablikk has the potential to reduce global emissions with ~1 Mt CO_2e over the asset's lifespan, in a balanced energy transition scenario (IEA's "Announced Pledges Scenario"). This reduction is equivalent to a decrease of 4.2 kg CO_2e per boe. The reduction in emissions can be understood by comparing total emissions generated by Breidablikk to the total emissions displaced by the oil and gas poduced by Breidablikk.

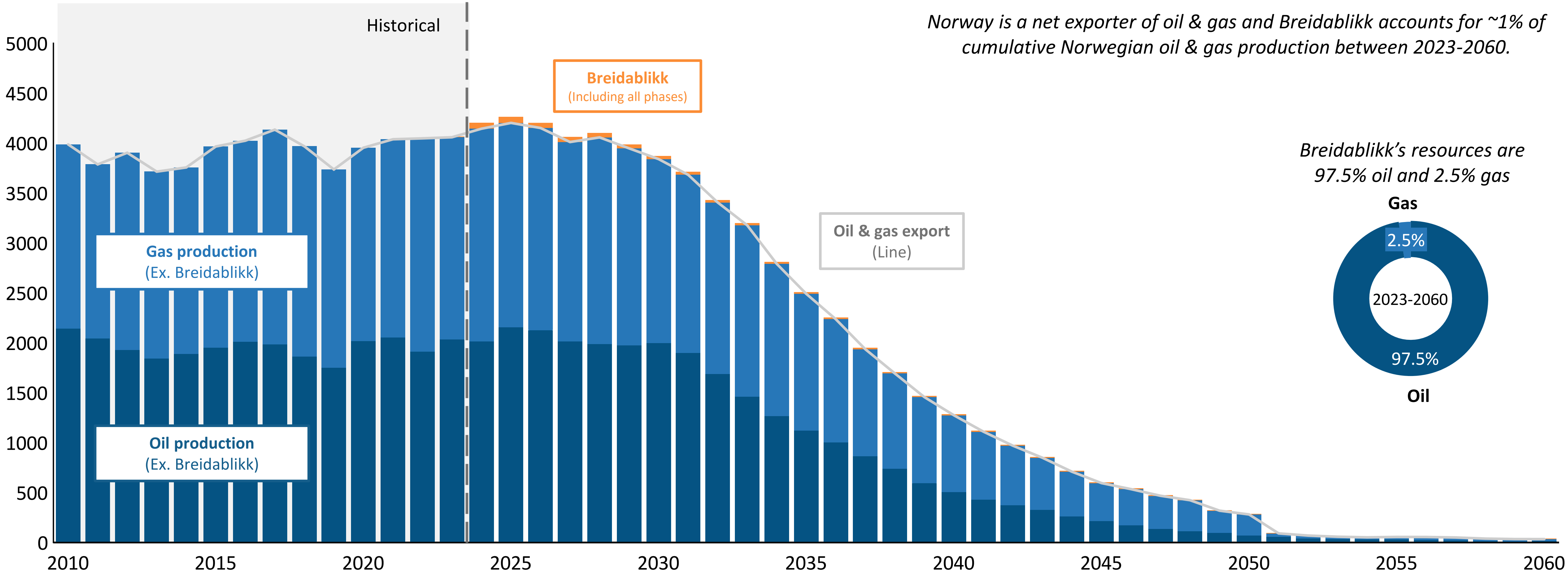
Source: Rystad Energy research and analysis

Reference case 1

Breidablikk accounts for ~1% of cumulative Norwegian oil & gas production between 2023-2060 mostly producing oil

Norwegian oil supply and export

Thousand barrels per day (kbbl/d)



Norway is a net exporter of oil & gas and Breidablikk accounts for ~1% of cumulative Norwegian oil & gas production between 2023-2060.

Breidablikk's resources are 97.5% oil and 2.5% gas

1) Includes production from existing fields, undeveloped discoveries, and future discoveries.
Source: Rystad Energy research and analysis; Rystad Energy UCube; Equinor

Breidablikk is in a disadvantaged position due to the field’s characteristics compared to NCS peers…

Norwegian O&G production contributes to reduced emissions globally

RystadEnergy

Netto klimagassutslipp fra økt olje- og gassproduksjon på norsk sokkel

15/02/2023

Hovedrapport

Februar 2023

Rystad Energy report for the Norwegian Ministry of Energy (2023)

- The report analyses the net climate effect of increased future oil and gas production on the Norwegian Continental Shelf (NCS).
- The report covers all Norwegian fields.
- The main conclusion demonstrates that the climate effect of increased future Norwegian production is **reduced emissions globally.**

Source: Rystad Energy research and analysis

The Breidablikk field is disadvantaged environmentally

Breidablikk only produces a marginal amount of gas. Gas has a favorable substitutive effect on coal which contribute to reduce global GHG-emissions.

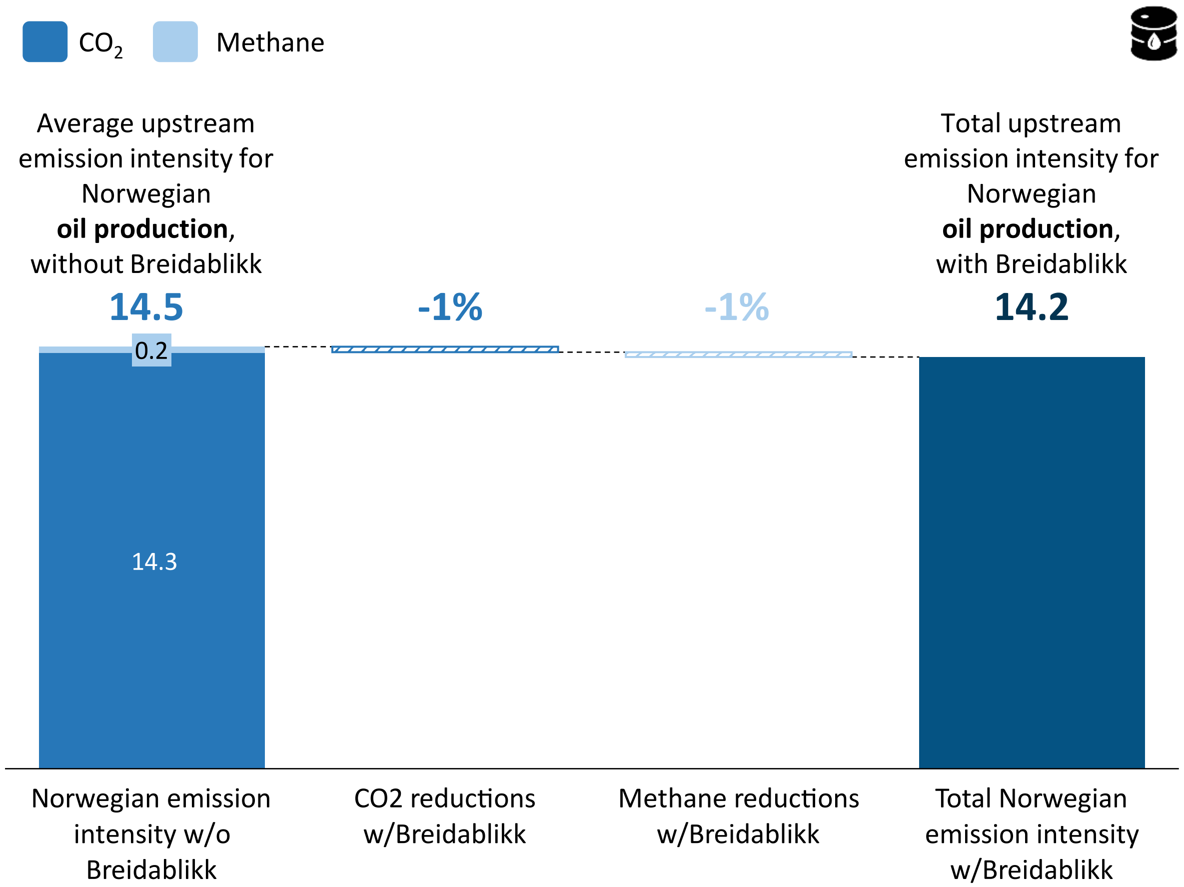
The field is not expected to be electrified until 2030 which keeps emissions up during the first years of production

The oil produced at Breidablikk is heavy with a low API, meaning that it contributes to higher emissions than the average Norwegian field

… But is favorable in terms of bringing down total upstream emission intensity from the NCS

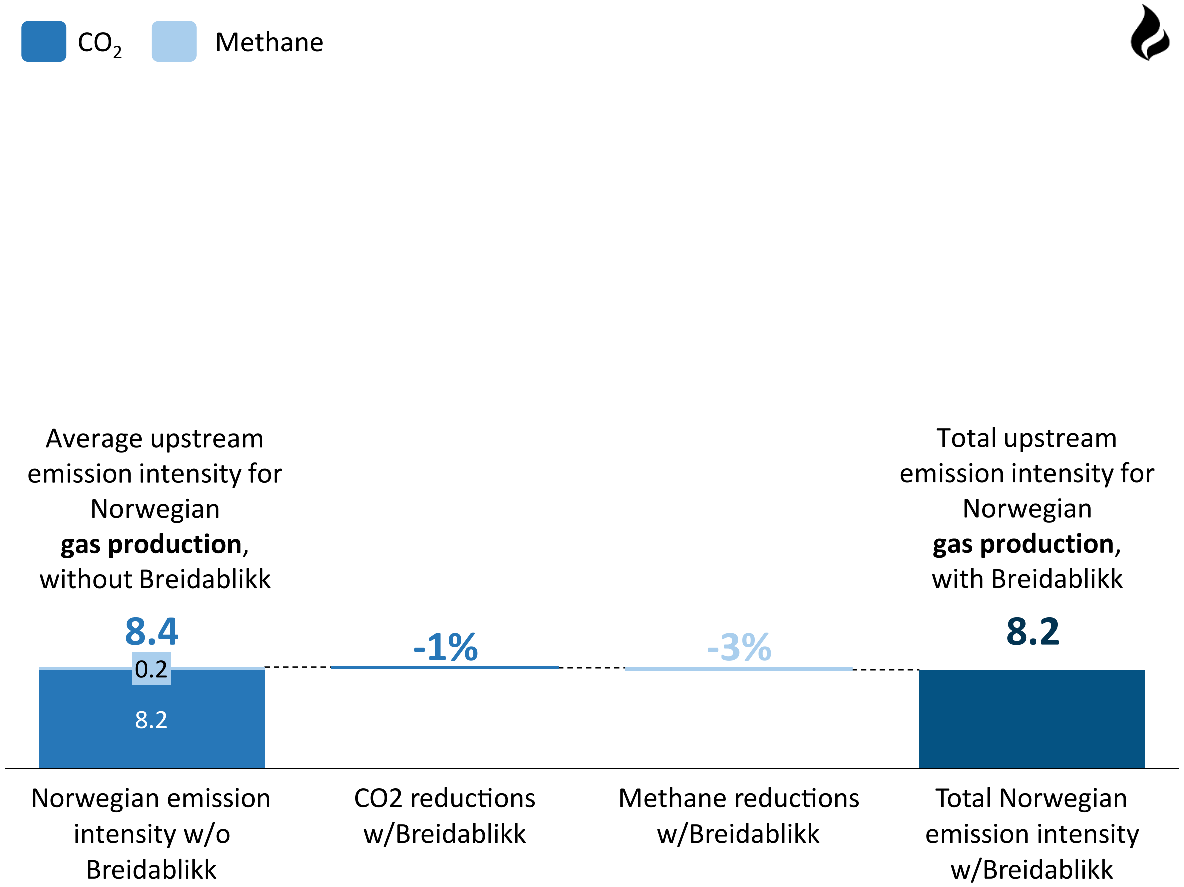
Upstream oil emission savings for Norway with Breidablikk - 2035

Kg CO_2e/bbl emission intensity



Upstream gas emission savings for Norway with Breidablikk - 2035

Kg CO_2e/boe emission intensity



Note: All numbers are weighted average emission intensities weighted by production. The Norwegian emission intensity for 2035 is estimated assuming no new Norwegian electrification of fields 1) Methane numbers for Norway are obtained using IEA Global Methane Tracker 2023 adjusted with a GMP factor of 25% towards 2035.

Source: Rystad Energy research and analysis; Rystad Energy UCube

Breidablikk's impact on global emissions is assessed through three key steps…

Total global greenhouse gas emissions impact from adding the Breidablikk field

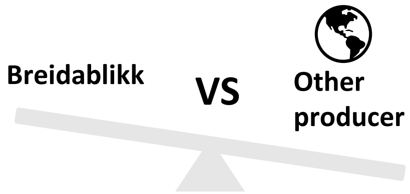
Breidablikk emissions

Assessment of Scope 1 + 2 + 3 emissions from producing oil & gas from Breidablikk

Scope 1, 2 & 3

1 Oil & Gas replacement

Assessment of how the market responds to a change in supply (i.e., how much less oil & gas is produced somewhere else if Breidablikk starts production)

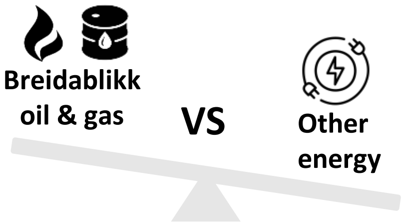


? *Key question 1:*
If Breidablikk produces, how much less is produced somewhere else?

Scope 3

2 Other energy substitution

Assessment of substitution in other energy markets when Breidablikk oil & gas production displaces consumption of other energy sources

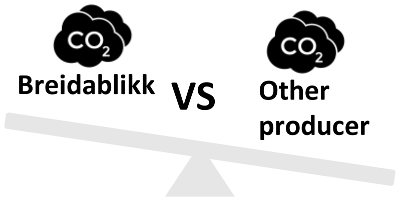


? *Key question 2:*
If Breidablikk produces, how much less energy is consumed from other sources?

Scope 3

3 Production intensity impact

Assessment of emissions from production of oil & gas if Breidablikk produces instead of other producers



? *Key question 3:*
If Breidablikk produces, how much emissions are saved from lower emissions intensity?

Scope 1 & 2

Net global emissions change

Total change in emissions from producing oil & gas from Breidablikk

Source: Rystad Energy research and analysis

Emission type X

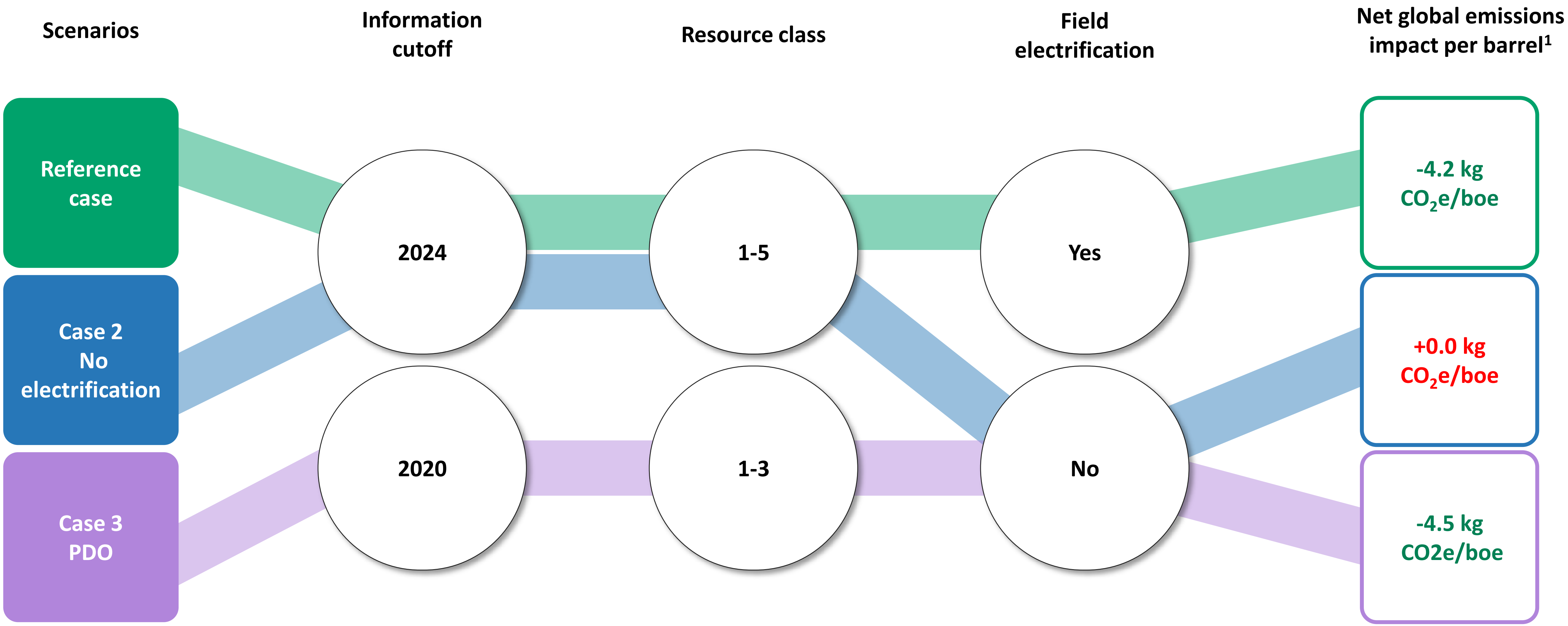
…with several key assumptions made across the three steps

Total global greenhouse gas emissions impact from adding the Breidablikk field

	1 Oil & Gas replacement	2 Other energy substitution	3 Production intensity impact
	Replacement impact assumption	*Energy substitution assumption*	*Production replacement assumption*
Oil	**Global market:** Breidablikk assumed to impact supply and demand on a global level as oil market is considered very liquid and easily traded	**Substitution of energy in Electric vehicles:** Increased oil consumption as a result or increased oil production from Breidablikk assumed to displace electricity demand from electric vehicles	**Marginal global supply:** Breidablikk will replace marginal oil supply, with associated production emission intensity
Gas	**European gas market & global LNG market:** Breidablikk assumed to impact European gas supply, which is a function of global LNG elasticity as LNG is a marginal price setter of gas in Europe	**Substitution of energy in Power Generation (70% Coal, 30% Renewables):** Increased gas production from Breidablikk will displace demand for coal in power generation, as Breidablikk contribute to declining LNG prices increasing competitiveness of gas in power generation in geographies using coal (e.g., Asia)	**LNG imports from USA:** Breidablikk will replace marginal LNG imports to Europe and associated production emission intensity
Timeline	**Long-term effects from market response, other energy substitution and production intensity improvement**		

Source: Rystad Energy research and analysis

The reference case yields the second lowest net global emissions per barrel impact



Scenarios

Information cutoff

Resource class

Field electrification

Net global emissions impact per barrel[1]

Reference case

Case 2 No electrification

Case 3 PDO

2024

2020

1-5

1-3

Yes

No

-4.2 kg CO_2e/boe

+0.0 kg CO_2e/boe

-4.5 kg CO2e/boe

1) Emissions impact calculated under a balanced transition scenario corresponding to IEA’s “Announced Pledges Scenario”
Source: Rystad Energy research and analysis; Equinor

Reference case 7

Production from Breidablikk decreases global emissions by 1.0 Mt CO_2e over the field's lifetime given electrification from 2030

Total global greenhouse gas emissions impact from adding the Breidablikk field to Grane's production

Breidablikk emissions

Breidablikk's total emissions (Scope 1+2+3) of 107 Mt CO_2e

① **Oil and gas replacement**

Every boe produced at Breidablikk will lead to 0.87 bbl of other oil and 0.74 boe of other natural gas supply not produced elsewhere in the long-term, which is a function of supply and demand elasticities

② **Other energy substitution**

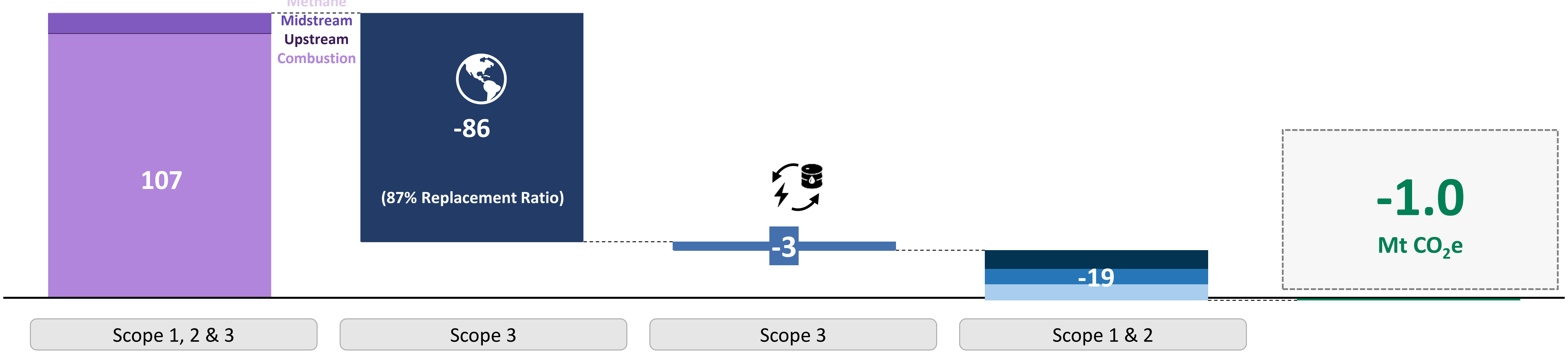
Increased oil and gas production displaces global emissions from electricity[1] and coal power plants, respectively

③ **Production intensity impact**

Lower emission intensity production from Breidablikk avoids production emissions from displaced oil and gas production

Net global emissions change

Over the projects lifetime, Breidablikk's production results in net emissions decrease of 1 Mt CO_2 globally



Emission type X

1) Oil production linked to the level of electricity use

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"

Source: Rystad Energy research and analysis; Equinor

RystadEnergy

Net global emissions are reduced by 4.2 kg CO_2e per boe of Breidablikk's oil and gas

Per barrel global greenhouse gas emissions impact from adding the Breidablikk field to Grane's production

Breidablikk emissions

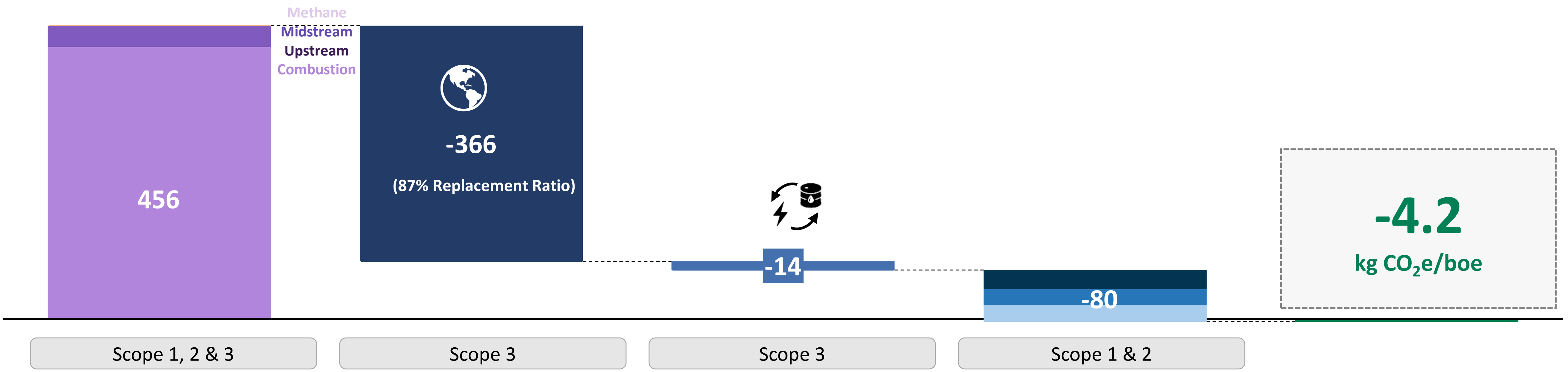
1 Oil and gas replacement

2 Other energy substitution

3 Production intensity impact

Net global emissions change

Oil and gas production (kg CO_2e/boe)

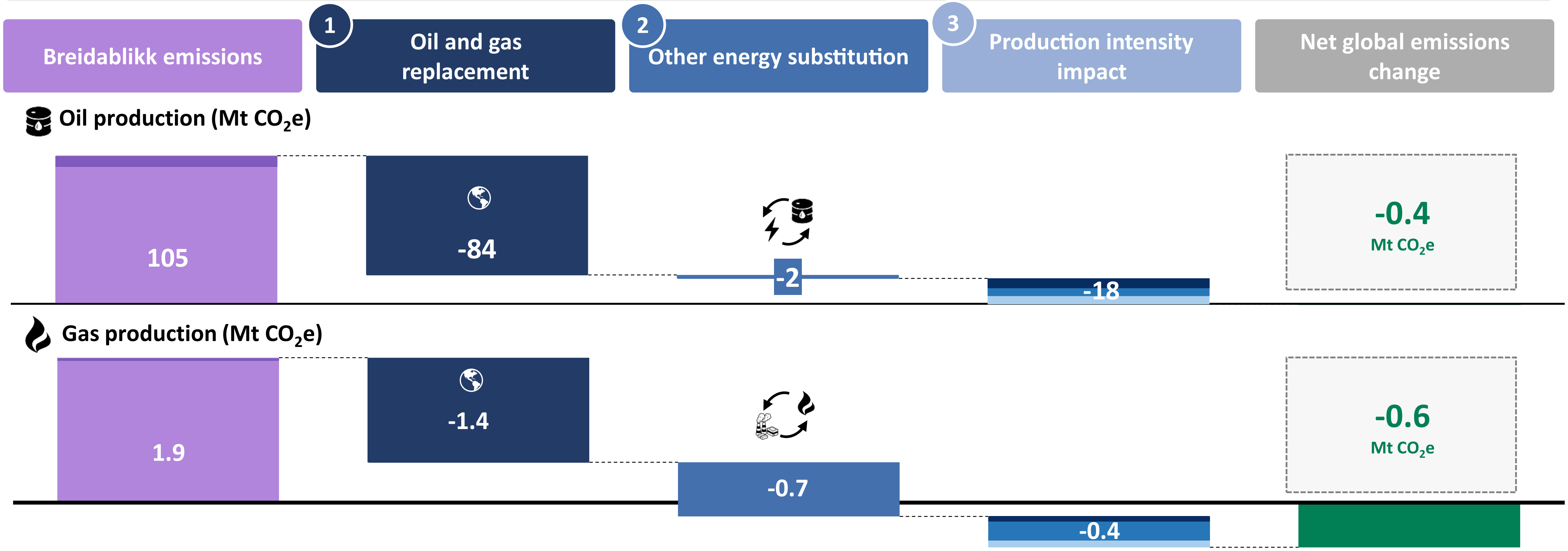


Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

Emission type X

Gas production contributes to less than 2% of total production emissions, but contributes with 60% of the net global emission reductions

Net global emissions impact from the Breidablikk field split by oil and gas

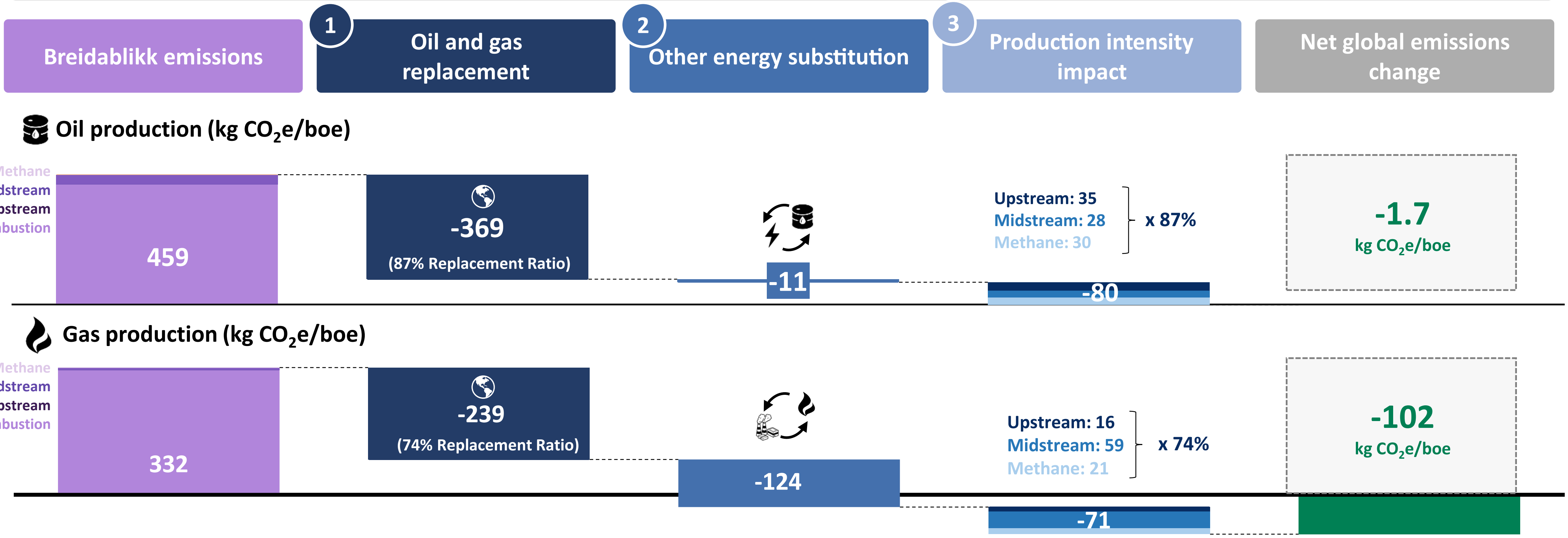


Total impact of Breidasblikk's production is -1 Mt CO_2e

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

Net global emission reduction per boe are far greater for Breidablikk’s gas

Net global emission impact per barrel from the Breidablikk field



Weighted impact of Breidasblikk’s production is -4.3 kg CO_2e/boe

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA’s “Announced Pledges Scenario”
Source: Rystad Energy research and analysis; Equinor

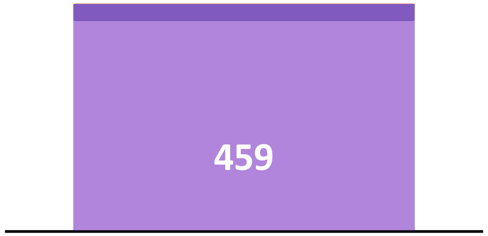
Breidablikk's oil and gas production has a weighted emission intensity of 455 kg CO_2e/boe

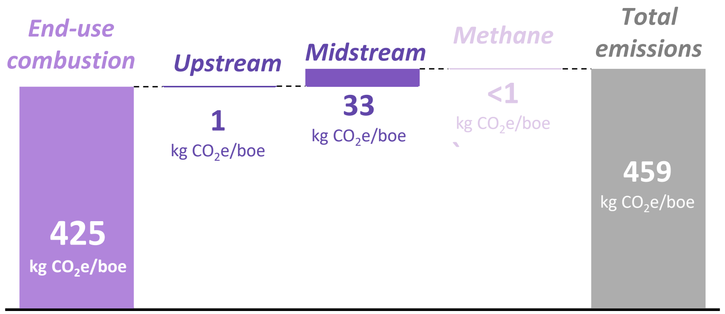
Breidablikk Emissions

Approach

Assumptions

Oil production (kg CO_2/boe)

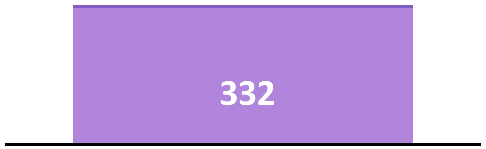


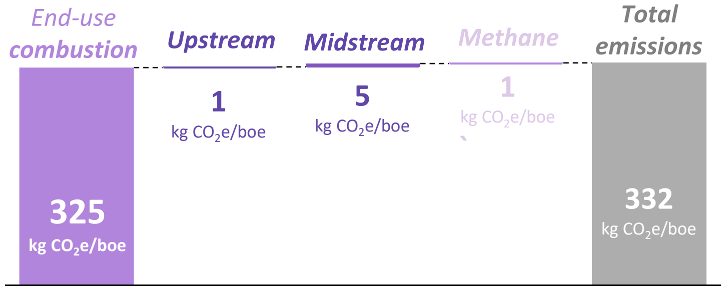


Each barrel of oil produced at Breidablikk will cause ***459 kg CO2e*** *of emissions from end-use, upstream, midstream and methane related emissions*

- Electrification of Breidablikk after 2030 is assumed for upstream emissions
- Oil refinement emissions intensity calculated based om Breidablikk's API values is used for midstream
- All methane emissions are upstream related

Gas production (kg CO_2/boe)





Every boe of gas produced at Breidablikk will cause ***332 kg CO2e*** *of emissions from end-use, upstream, midstream and methane related emissions*

- Electrification of Breidablikk after 2030 is assumed for upstream emissions
- Average emissions intensity for Norwegian gas transport to Europe in 2035 of 5 kg CO_2e/boe is used for midstream
- Methane emissions are considered in upstream and midstream only.

Weighted oil and gas production impact of **+455 kg CO_2e/boe**

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

Supply and demand elasticities drive displacement of other supply sources; 87% of oil and 74% of gas production from Breidablikk will displace production from other suppliers

1 O&G replacement

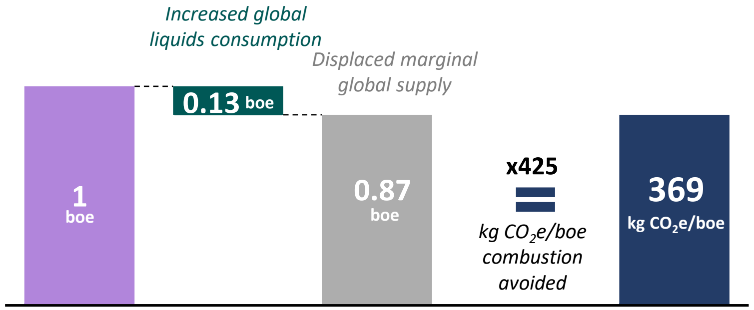
Approach

Assumptions

Oil production (kg CO_2/boe)

-369

(87% Replacement Ratio)



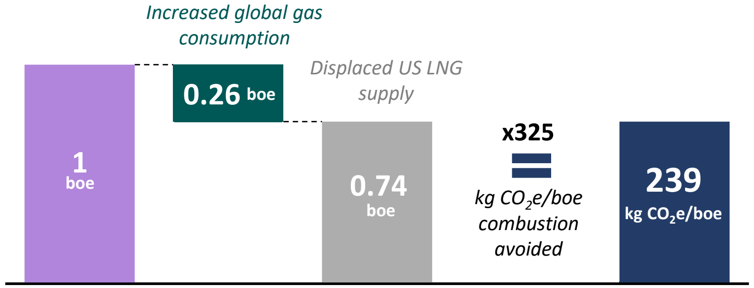
Every barrel of oil produced at Breidablikk, will lead to ***0.87 boe*** *of other supply not being produced globally over the longer term*

- Long-term crude oil demand is price inelastic with elasticity of -0.12 from academic literature review
- In the long-term supply is very responsive to changes in price with oil supply elasticity of 0.8 in 2035
- Global average oil combustion emissions of 425 kg CO_2e/boe

Gas production (kg CO_2/boe)

-239

(74% Replacement Ratio)



Every boe of gas produced at Breidablikk will lead to ***0.74 boe*** *of other supply not produced globally over the longer term*

- Long-term natural gas demand is partially elastic with elasticity of -0.64 from academic literature review
- In the long-term supply of natural gas is very responsive to changes in price with a supply elasticity of 1.8 in 2035
- Global average gas combustion emissions of 325 kg CO_2e/boe

Weighted oil and gas replacement impact of -366 kg CO_2e/boe

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

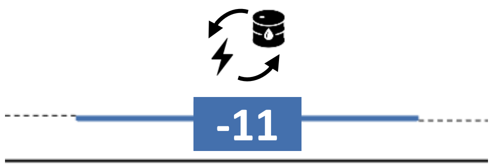
Increased oil and gas consumption from Breidablikk's production displaces emissions from EV's electricity demand and coal-fired power generation respectively

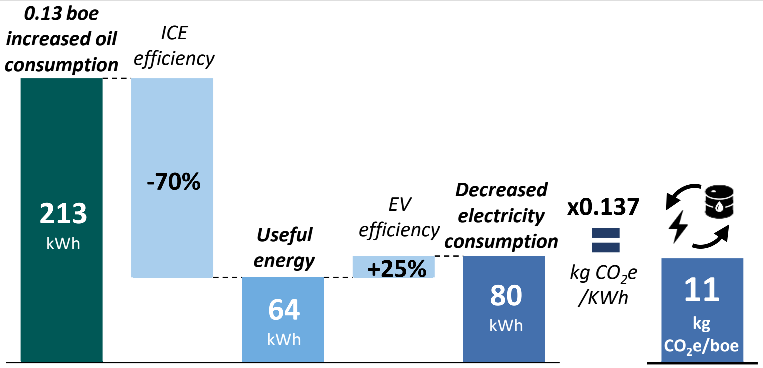
2 Other energy substitution

Approach

Assumptions

Oil production (kg CO_2/boe)





Each boe of oil produced at Breidablikk will displace ***11 kg CO_2e*** *of global emissions from EV electricity demand*

- Useful energy is substituted on 1:1 basis, whereby increased oil consumption decreases electric vehicle (EV) electricity demand
- Global average power mix emissions intensity of 0.137 kg CO_2e/kWh in 2035 as in IEA APS scenario

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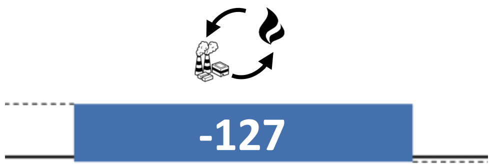
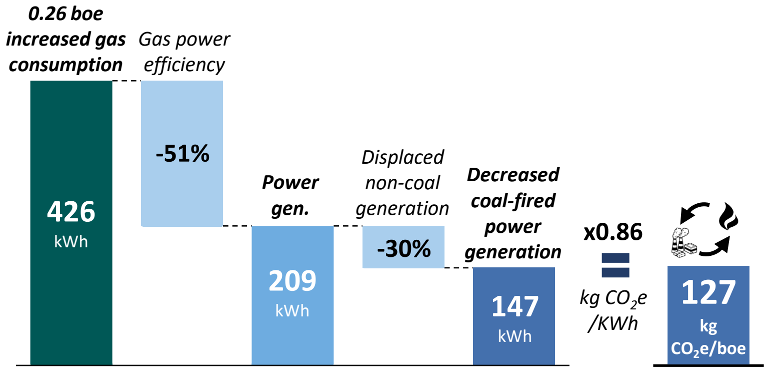
Gas production (kg CO_2/boe)





Every boe of gas produced at Breidablikk will displace ***127 kg CO_2e*** *of global emissions caused by coal-power generation*

- Useful energy is substituted on 1:1 basis, whereby increased gas consumption displaces other forms of power generation
- Political ambitions to decarbonize the power mix and decreased gas costs drives coal-fired power generation displacement. Assume 70% of power generation substitution is coal and 30% non-coal, as ~ 70% of LNG volumes is imported to countries with coal-fired electricity generation and stated ambition to phase out
- Global average coal-fired power generation emissions intensity of 0.86 kg CO_2e/kWh

Weighted oil and gas energy substitution impact of **-14 kg CO_2e/boe**

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

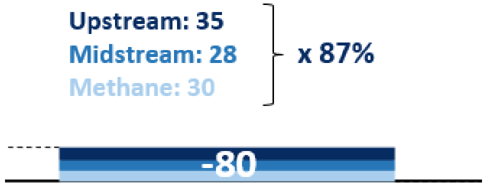
Displaced oil supply has >2x and gas supply >10x the emissions intensity compared to volumes from Breidablikk

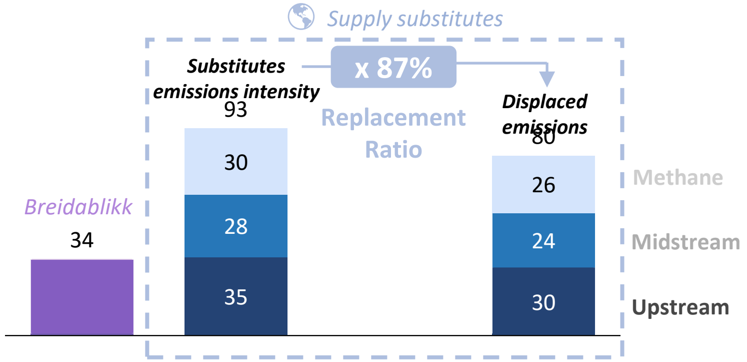
3 Production intensity impact

Approach

Assumptions

Oil production (kg CO_2/boe)

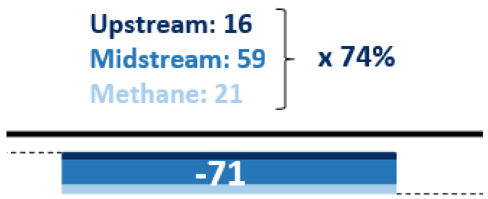


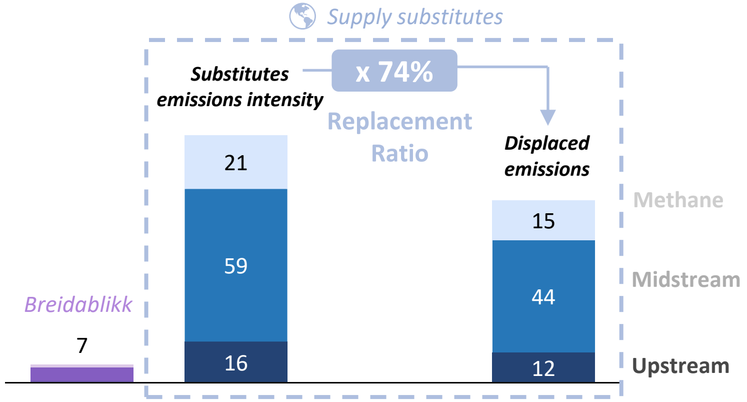


Each barrel of oil produced at Breidablikk will displace ***80 kg CO_2e*** *of global production emissions from substitute sources of oil production*

- Breidablikk oil production substitutes marginal global oil supply as more expensive oil supply will be displaced by Breidablikk oil production
- Average upstream, midstream, and methane intensities for global oil production with breakeven above 50 USD/boe are used
- Only upstream methane emissions are included

Gas production (kg CO_2/boe)





Every boe of gas produced at Breidablikk will displace ***71 kg CO_2e*** *of global production emissions from substitute sources of gas production*

- US LNG is the marginal supplier to European market
- Breidablikk gas production will displace US LNG as it is more expensive than pipeline imports
- Emissions intensity of US LNG delivered in Europe is used
- Both upstream and midstream methane emission sources are considered

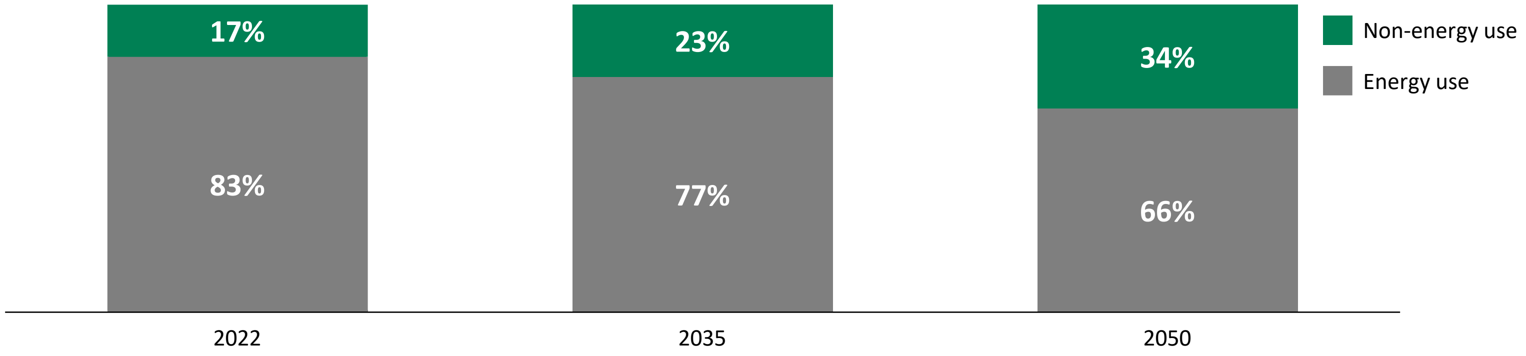
Weighted oil and gas production impact of **-80 kg CO_2e/boe**

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

Accounting for non-energy related oil demand the total global emission impact from Breidablikk's oil production would be 22.8 Mt CO_2e lower

IEA oil demand split by energy and non-energy usage under the abalanced scenarios (IEA APS)[1]

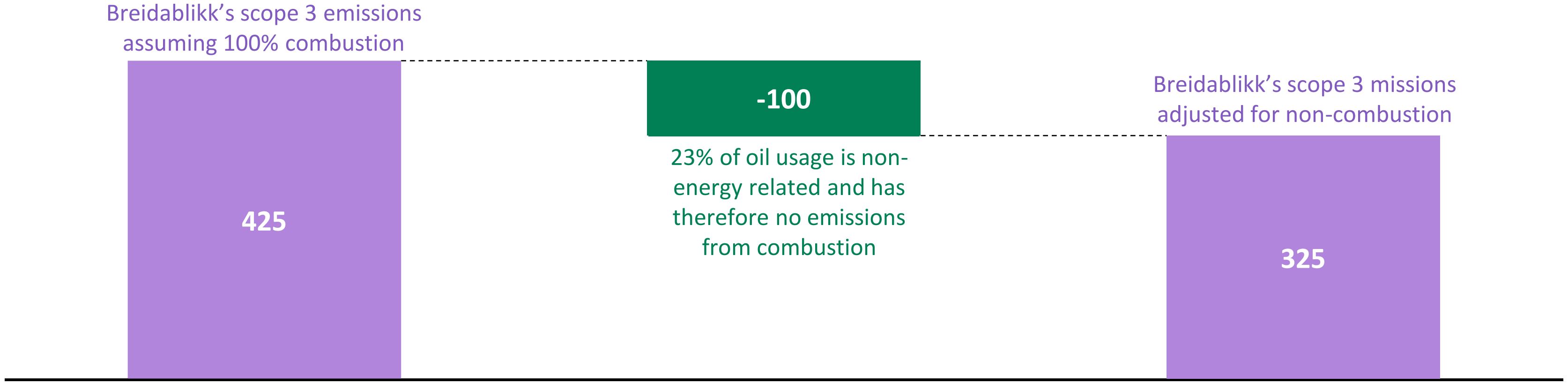
%



Impact of non-energy oil use on Scope 3 emissions

Total emissions from Breidablikk's oil production adjusted by non-energy demand impact

kg CO_2e/boe



- In 2035 **23 %** of oil demand will stem from non-energy related usage i.e. plastics according to IEAs APS scenario
- This results in only 77% of oil being combusted with per barrel emissions of 425 kg CO_2/boe
- When accounting for this the downstream Scope 3 emissions of Breidablikk are therefore reduced by **100 kg CO_2e/boe**

---

1) Under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Sources: Rystad Energy research and analysis; Equinor

Content

The Breidablikk field, found in the North Sea in 1992, with reserves of ~190 million barrels (mboe) of oil under the PDO

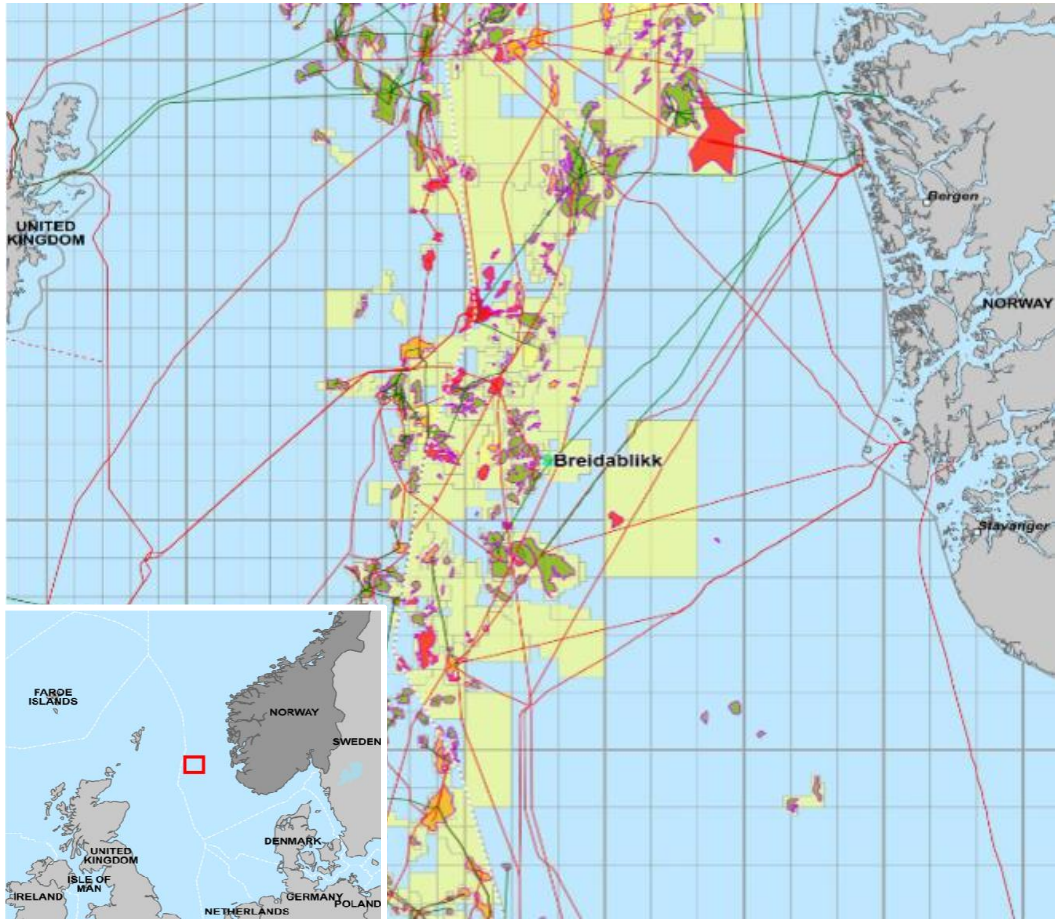
About Breidablikk Field Area

Discovery

Breidablikk is an offshore field located in the central North Sea, about 10 kilometers northeast of the Grane field, at a water depth of 130 meters. The field comprises two key discoveries: the D-structure, identified in 1992, and the F-structure, discovered in 2013. Operated by Equinor, which holds a 39% stake, the remaining ownership is shared between Vår Energi (34.4%), Petoro (22.2%), and ConocoPhillips (4.4%). Breidablikk's estimated reserves total around 190 million barrels of oil equivalents (boe).

Production profiles and export

Breidablikk is one of the largest oil discoveries on the Norwegian Continental Shelf (NCS), which commenced production in October 2023, four months ahead of schedule. As the field ramps up production, it will help offset declining output from the nearby Grane field, maintaining activity levels on the platform. The Breidablikk field is tied back to the Grane platform for processing, with the oil then piped to the Sture terminal west of Bergen for export, primarily destined for European markets.

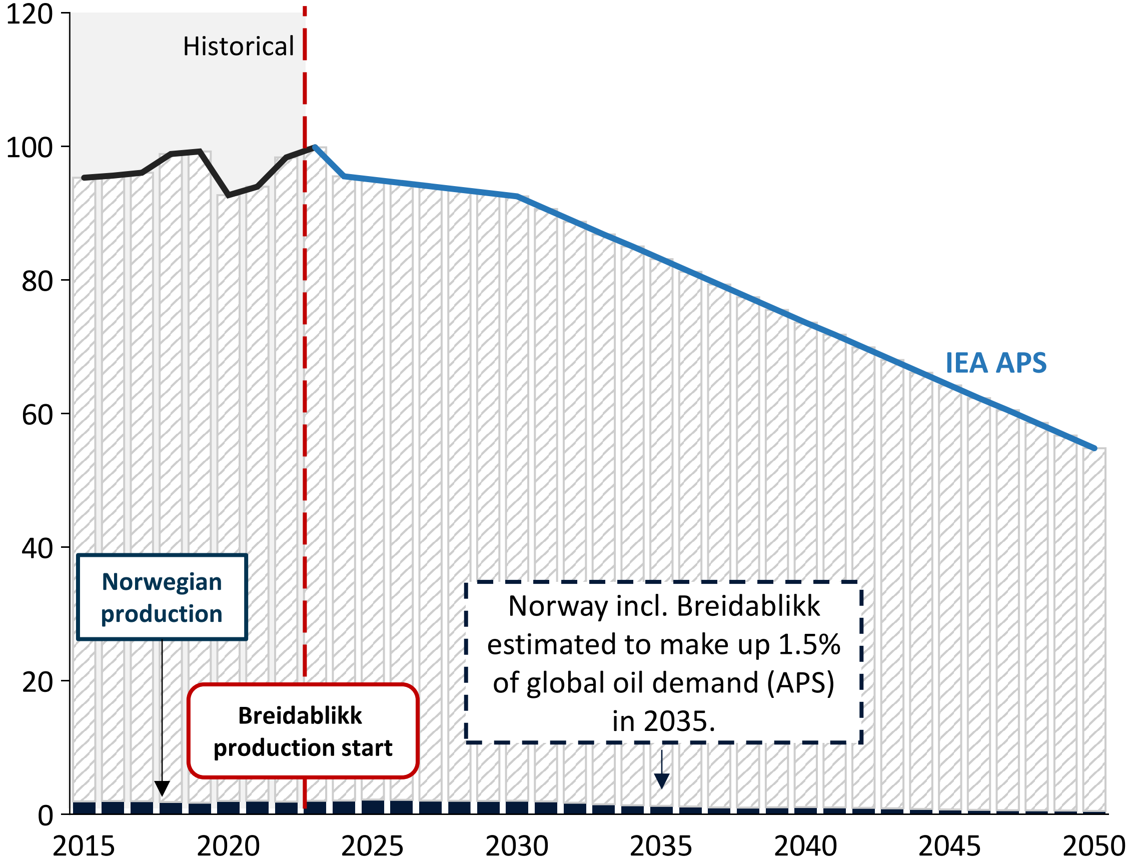


Source: Rystad Energy research and analysis; Equinor; Norwegian Petroleum Directorate (NPD); Norwegian Offshore Directorate (NOD)

Norwegian production makes up ~1.5% of global oil production and 3% of global gas production, of which Breidablikk is a minor contributor

Overview of global oil production

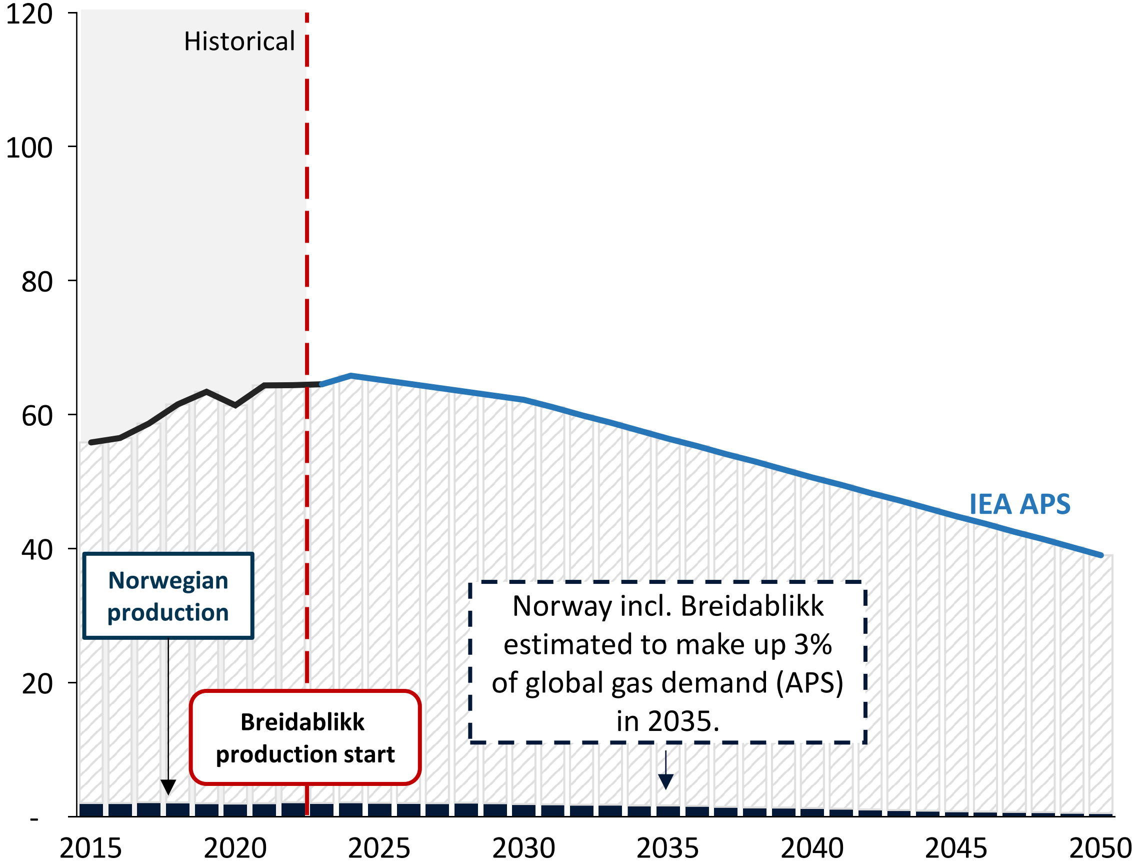
Million barrels per day (mbbl/d)



Norway incl. Breidablikk estimated to make up 1.5% of global oil demand (APS) in 2035.

Overview of global gas production

Million barrels of oil equivalents per day (mboe/d)



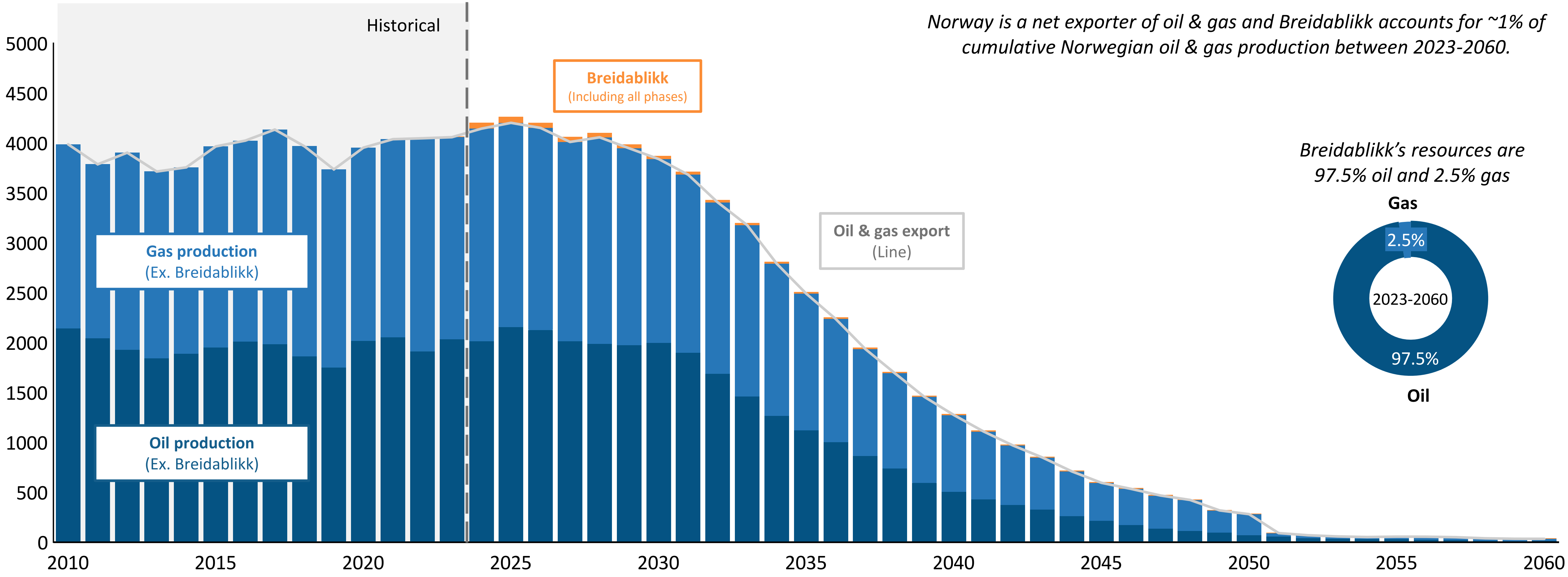
Norway incl. Breidablikk estimated to make up 3% of global gas demand (APS) in 2035.

Source: Rystad Energy research and analysis; Rystad Energy Ucube; IEA

Breidablikk accounts for ~1% of cumulative Norwegian oil & gas production between 2023-2060 with the largest share being oil

Norwegian oil supply and export

Thousand barrels per day (kbbl/d)



Norway is a net exporter of oil & gas and Breidablikk accounts for ~1% of cumulative Norwegian oil & gas production between 2023-2060.

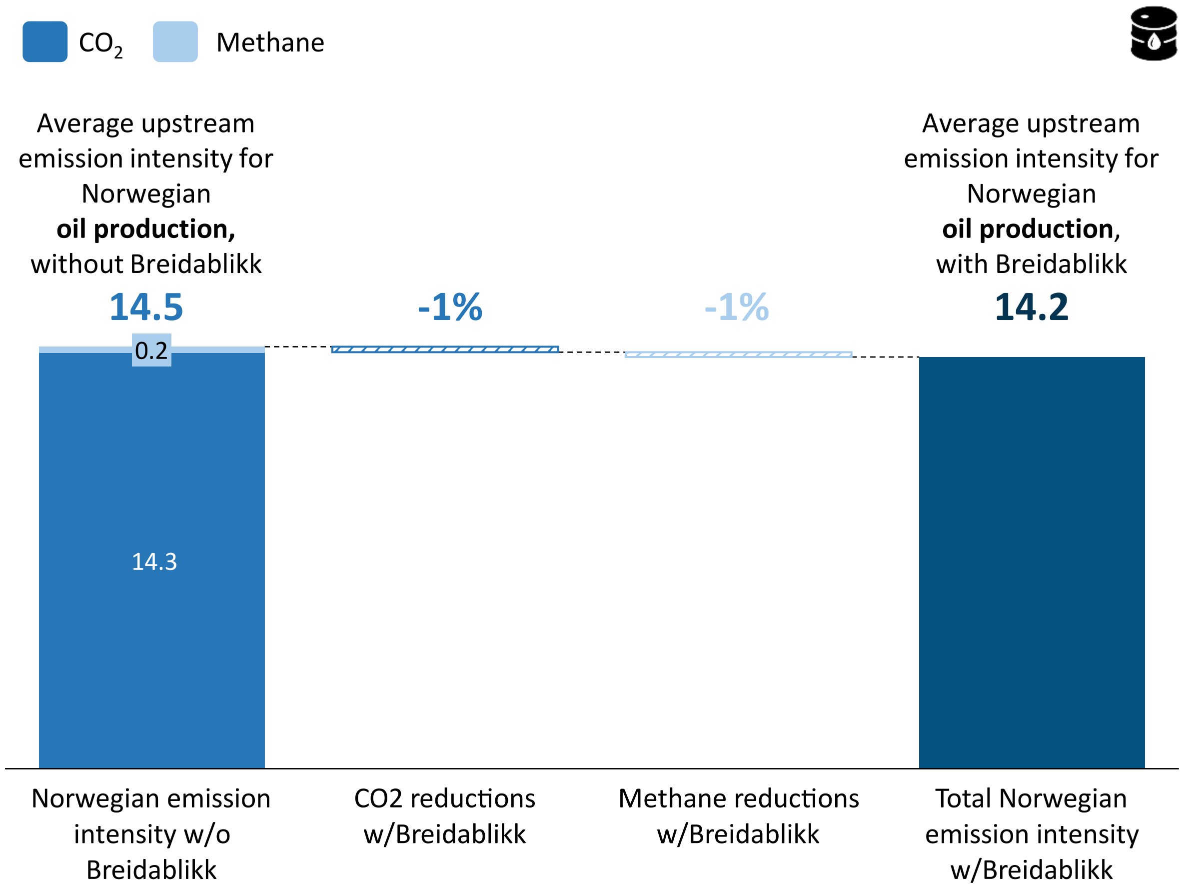
Breidablikk's resources are 97.5% oil and 2.5% gas

1) Includes production from existing fields, undeveloped discoveries, and future discoveries.
Source: Rystad Energy research and analysis; Rystad Energy UCube; Equinor;

Breidablikk is favorable in terms of bringing down total upstream emission intensity from the NCS

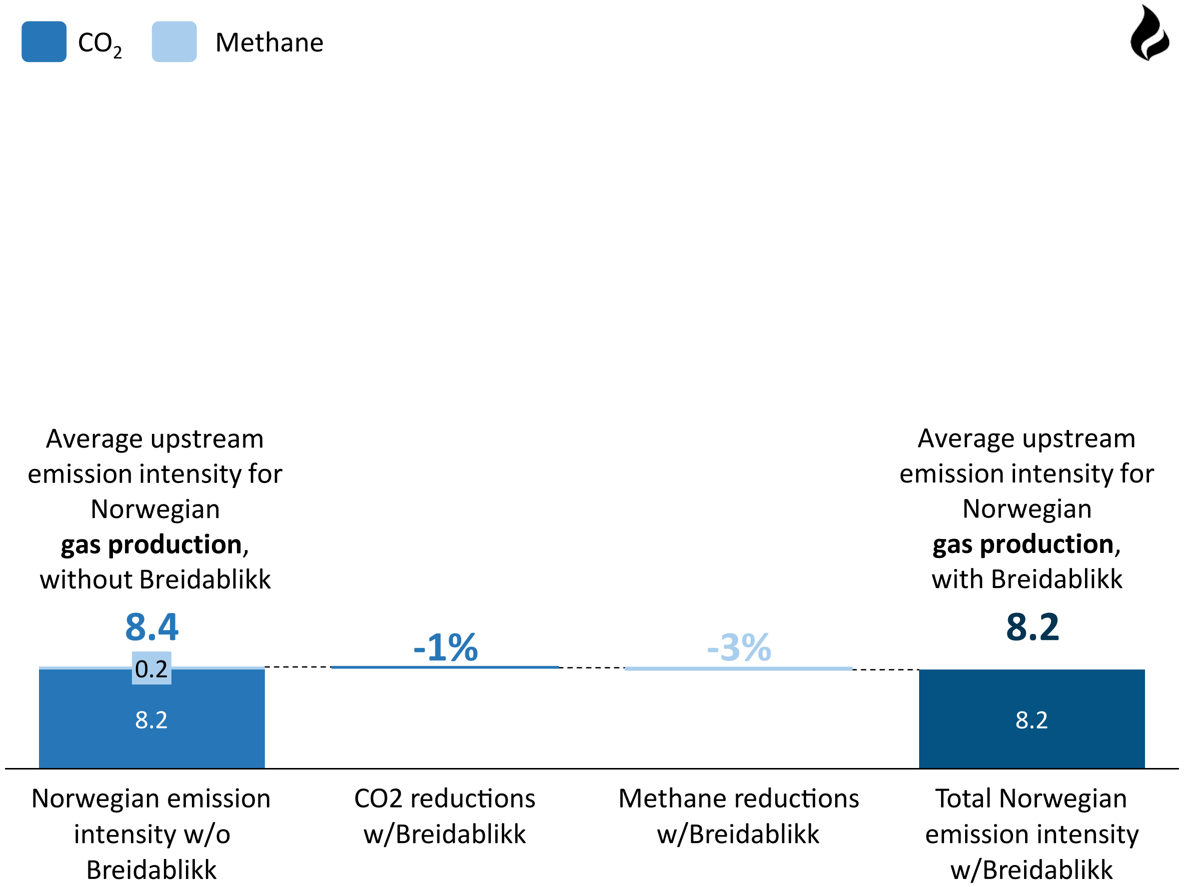
Upstream oil emission savings for Norway with Breidablikk - 2035 [1]

Kg CO_2e/bbl emission intensity



Upstream gas emission savings for Norway with Breidablikk - 2035 [1]

Kg CO_2e/boe emission intensity



Note: All numbers are weighted average emission intensities weighted by production. The Norwegian emission intensity for 2035 is estimated assuming no new Norwegian electrification of fields 2) Methane numbers for Norway are obtained using IEA Global Methane Tracker 2023 adjusted with a GMP factor of 25% towards 2035.

Source: Rystad Energy research and analysis; Rystad Energy Ucube

Content

Four key assumptions form the reference case scenario for emission impact calculation for Breidablikk

Assumptions	Description
Emissions allocation	Breidablikk is tied back to the already producing Grane hub. The addition of Breidablikk to the Grane hub causes a marginal increase to the hub's total emissions. This marginal increase will be used as the upstream intensity for Breidablikk.
Field electrification	Electrification of the Grane hub is included in the base case as the planning process is advanced. The assumption of electrification is also made in the Norwegian Revised National Budget.
Inclusion of resource class 1-5	Norway's petroleum resources 1-5 range from those in active production or with approved development plans to reserves under consideration, potential resources needing further evaluation, and undiscovered prospects based on geological data. The base case includes resource classes 1-5 as these are likely to impact the timeline relevant to the assessment of 2023-2060, especially when supported by the electrification of the hub.
Applying the latest data	Since the first PDO in 2020, the visibility of the field's production and emissions profile has changed. To reflect the most recent data, the current profile will be used, with production continuing out to 2060, with electrification starting in 2030.

Source: Rystad Energy research and analysis; Equinor; Norwegian Offshore Directorate

The North Sea oil fields Breidablikk and Svalin are tied back to the Grane platform

Grane is a field in the central part of the North Sea and has since 2003 been developed with an integrated accommodation, drilling and processing facility standing on a bottom-fixed steel jacket. The recoverable reserves of Grane are estimated to around 950 million barrels of oil. Breidablikk and Svalin are tied back to the Grane platform.

Breidablikk is located 10 kilometers northeast of the Grane platform. The field is developed with four subsea frames that are connected to the Grane platform. Breidablikk commenced production in October 2023.

Svalin is situated 6 km southwest of Grane and consists of one well from the Grane platform and a subsea template linked to the Grane platform by pipeline. The field came on stream March 2014.

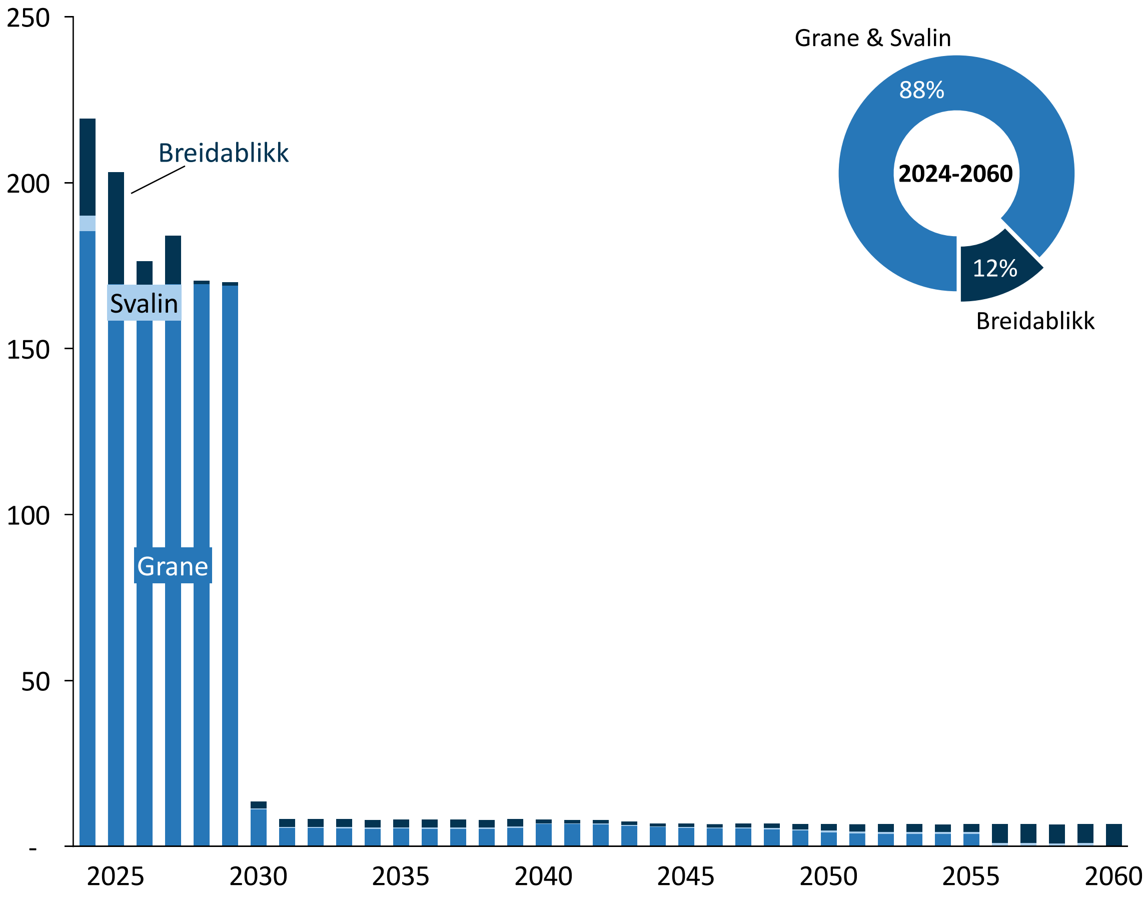
Source: Rystad Energy research and analysis; Equinor; Norwegian Offshore Directorate

Reference case

Marginal increase in emissions from Breidablikk are small while production volumes remain high thus giving a low upstream emission intensity

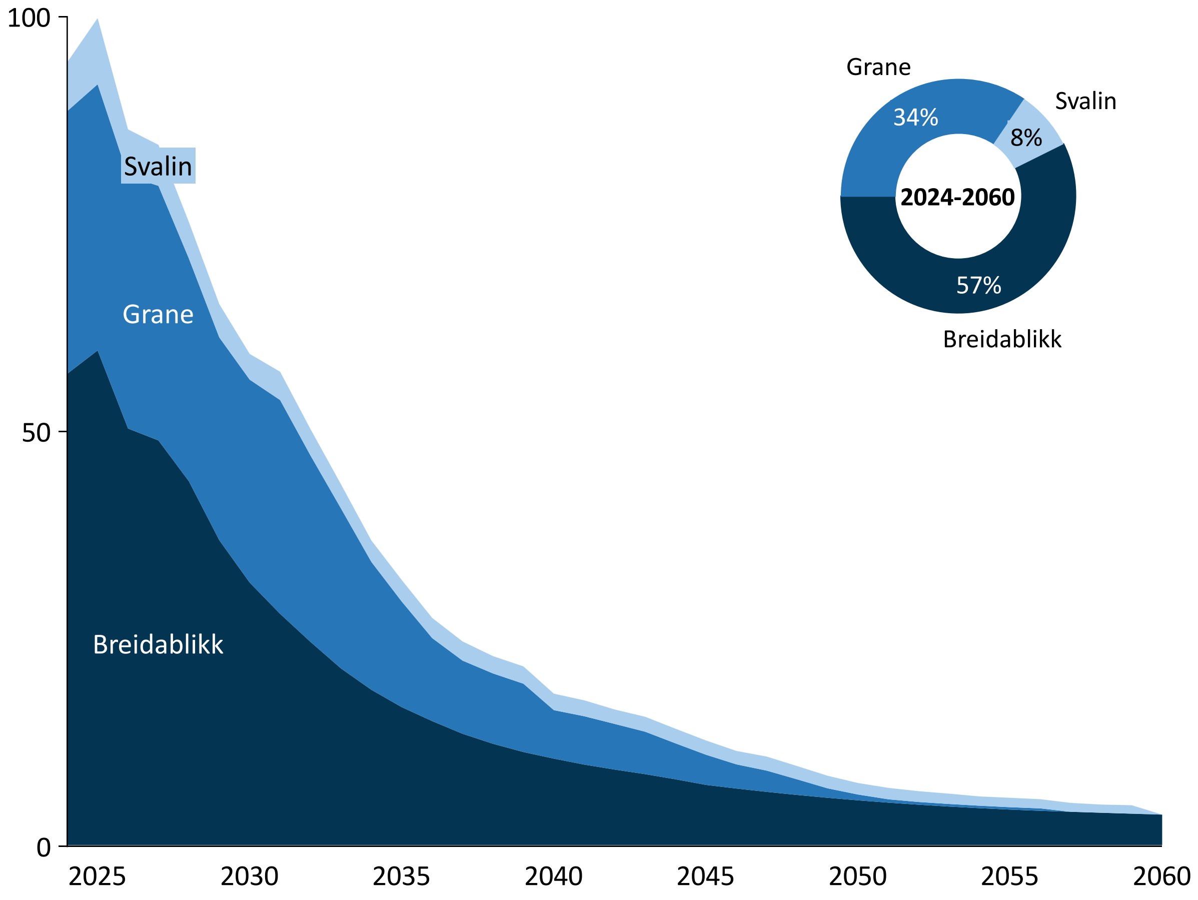
Hub[1] scope 1 & 2 emissions profile and emission share between fields

Kilo tonnes CO2



Hub production profile and volume share

Daily production (kboe/d)

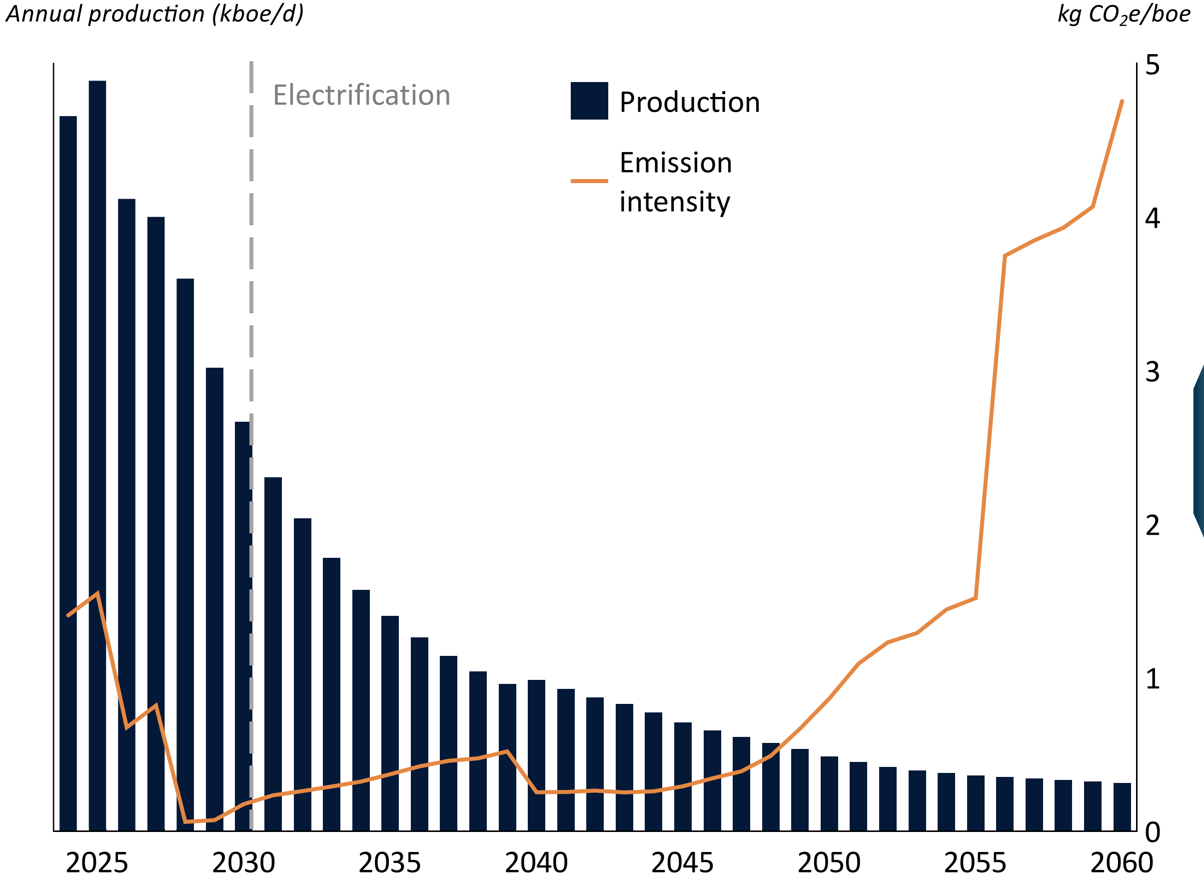


1) The hub is referring to the Grane, Breidablikk and Svalin fields combined.
Source: Rystad Energy research and analysis; Equinor

Reference case

Electrifications of Grane is assumed for reference case, as is done in the Norwegian Revised National Budget

Breidablikk oil and gas production- and emission intensity profile with electrification



The O&G sector is Norway's largest emitter, accounting for ~30% of national emissions. Electrifying existing facilities requires major renovations and is only viable for long-lifespan sites. For such facilities, electrification is the measure that provide the greatest CO2 reductions per dollar spent.

The assumption of electrification is also made in the Norwegian Revised National Budget.

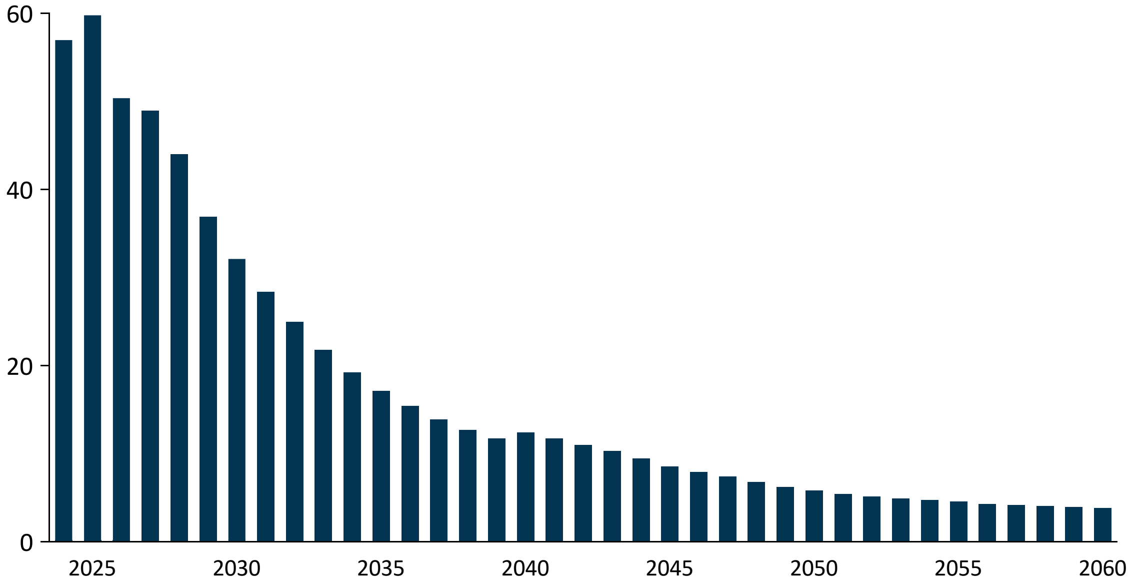
Field electrification is included as the reference case in the analysis

Source: Rystad Energy research and analysis; Equinor

Using the latest production profiles, with RC 1-5, yields more accurate results regarding field's lifetime production

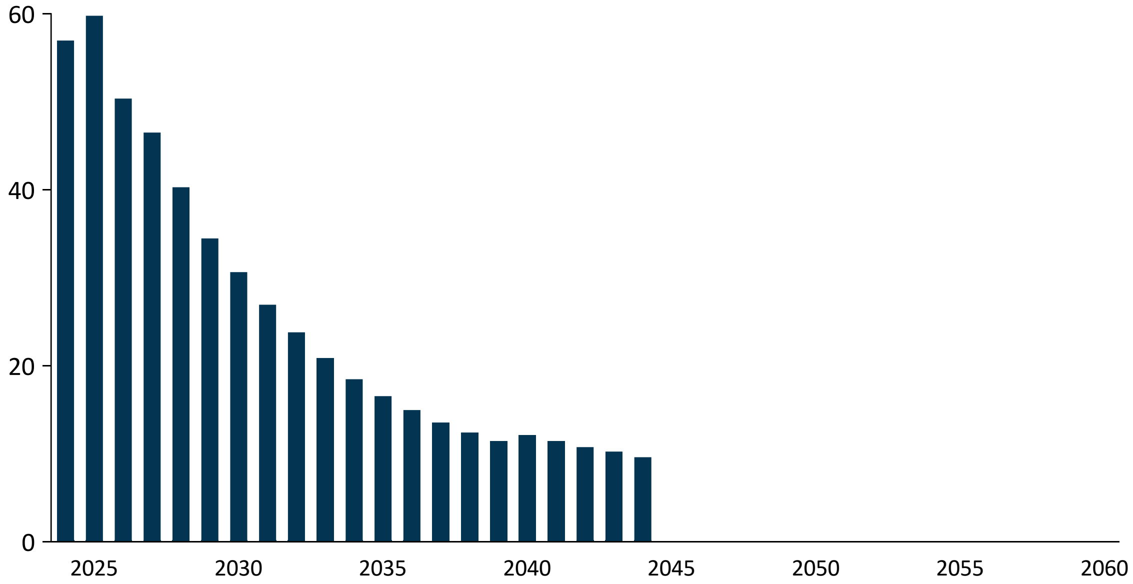
Breidablikk production profile as of September 2024

Annual production (kboe/d)



Breidablikk production profile according to PDO data

Annual production (kboe/d)



- The latest data, from 2024 for resource classes 1-5.
- Including resource classes 1-5 yields a projected decommissioning in 2060 and an estimated life production of 235 million barrels of oil equivalents.

- PDO data from 2020 for resource classes 1-3.
- Including resource classes 1-3 yields a projected decommissioning year in 2044, with an estimated life production of 196 million barrels of oil equivalents.

The production profile data is selected from the newest available data at Breidablikk and includes resource classes 1-5

Source: Rystad Energy research and analysis; Equinor

Impact on global emissions by adding the Breidablikk field is assessed through three key steps

Total global greenhouse gas emissions impact from adding the Breidablikk field

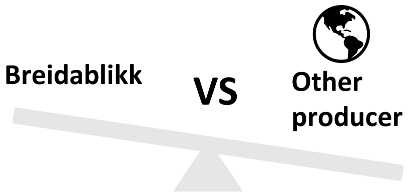
Breidablikk emissions

Assessment of Scope 1 + 2 + 3 emissions from producing oil & gas from Breidablikk

Scope 1, 2 & 3

1 Oil & Gas replacement

Assessment of how the market responds to a change in supply (i.e., how much less oil & gas is produced somewhere else if Breidablikk starts production)

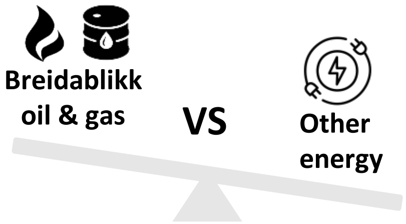


Key question 1:
If Breidablikk produces, how much less is produced somewhere else?

Scope 3

2 Other energy substitution

Assessment of substitution in other energy markets when Breidablikk oil & gas production displaces consumption of other energy sources

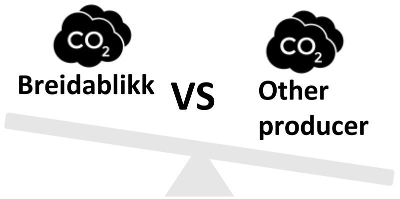


Key question 2:
If Breidablikk produces, how much less energy is consumed from other sources?

Scope 3

3 Production intensity impact

Assessment of emissions from production of oil & gas if Breidablikk produces instead of other producers



Key question 3:
If Breidablikk produces, how much emissions are saved from lower emissions intensity?

Scope 1 & 2

Net global emissions change

Total change in emissions from producing oil & gas from Breidablikk

Source: Rystad Energy research and analysis

Emission type X

The key assumptions made across the three steps for oil and gas

Total global greenhouse gas emissions impact from adding the Breidablikk field

	1 **Oil & Gas replacement**	2 **Other energy substitution**	3 **Production intensity impact**
	Replacement impact assumption	***Energy substitution assumption***	***Production replacement assumption***
Oil	**Global market:** Breidablikk assumed to impact supply and demand on a global level as oil market is considered very liquid and easily traded	**Substitution of energy in Electric vehicles:** Increased oil consumption as a result or increased oil production from Breidablikk assumed to displace electricity demand from electric vehicles	**Marginal global supply:** Breidablikk will replace marginal oil supply, with associated production emission intensity
Gas	**European gas market & global LNG market:** Breidablikk assumed to impact European gas supply, which is a function of global LNG elasticity as LNG is a marginal price setter of gas in Europe	**Substitution of energy in Power Generation (70% Coal, 30% Renewables):** Increased gas production from Breidablikk will displace demand for coal in power generation, as Breidablikk contribute to declining LNG prices increasing competitiveness of gas in power generation in geographies using coal (e.g., Asia)	**LNG imports from USA:** Breidablikk will replace marginal LNG imports to Europe and associated production emission intensity
Timeline	**Long-term effects from market response, other energy substitution and production intensity improvement**		

Source: Rystad Energy research and analysis

Breidablikk study very well aligned with previous work conducted on the NCS in 2023

Key changes between this report and previous Norway work

Breidablikk assessment – September 2024

RystadEnergy

Breidablikk emissions study

Draft

Rystad Energy Advisory
September 2024

NCS assessment – February 2023

RystadEnergy

Netto klimagassutslipp fra økt olje- og gassproduksjon på norsk sokkel

17. februrar 2023

Demand	**Demand updated to reflect latest IEA scenarios from World Energy Outlook 2023**
Supply	**Supply curves from Rystad Energy databases updated based on latest information and available data**
Analysis year	**Year of analysis focus updated to 2035 (vs. 2030) to reflect single most representative year for Breidablikk**
Other	**1. Elasticity of supply adjusted based on the extended literature review;** **2. Scope 3 emissions assumptions updated based on the latest values as published by the IPCC** **3. Inclusion of methane in scope 3 emissions** **4. Inclusion of scope 2 emissions from electrification**

Source: Rystad Energy research and analysis

Three different cases have been analyzed, with electrification and marginal allocations being assumed for the reference case

	Reference case	Case 2 No electrification	Case 3 PDO
Electrified after 2030	✓	✗	✗
Production volume	**235** *mboe*	**235** *mboe*	**196** *mboe*
Decomissiong year	2060	2060	2044
Information cutoff	2024 *(post production)*	2024 *(post production)*	2020 *(pre production)*
Oil end use	100% Combusted	100% Combusted	100% Combusted

Source: Rystad Energy research and analysis; Equinor

Framework

Reference case

Production from Breidablikk decreases global emissions by 1.0 Mt CO_2e over the field's lifetime given electrification from 2030

Total net global greenhouse gas emissions impact from adding the Breidablikk field to Grane's production

Breidablikk emissions

Breidablikk's total emissions (Scope 1+2+3) of 107 Mt CO_2e

1 Oil and gas replacement

Every boe produced at Breidablikk will lead to 0.87 bbl of other oil and 0.74 boe of other natural gas supply not produced elsewhere in the long-term, which is a function of supply and demand elasticities

2 Other energy substitution

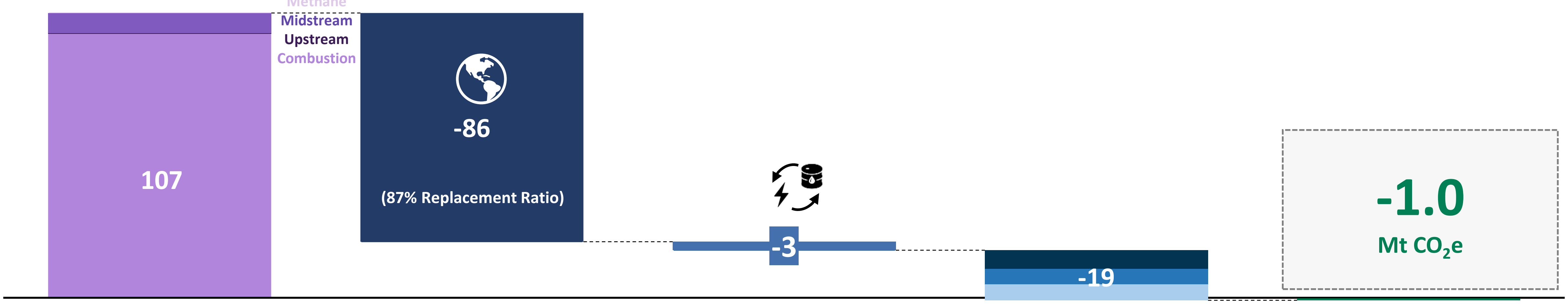
Increased oil and gas production displaces global emissions from electricity[1] and coal power plants, respectively

3 Production intensity impact

Lower emission intensity production from Breidablikk avoids production emissions from displaced oil and gas production

Net global emissions change

Over the projects lifetime, Breidablikk's production results in net emissions decrease of 1 Mt CO_2 globally



Scope 1, 2 & 3

Scope 3

Scope 3

Scope 1 & 2

Emission type: X

1) Oil production linked to level of electricity use

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"

Source: Rystad Energy research and analysis; Equinor

Reference case

Global emission intensity reduced by 4.2 kg CO2$_e$ per boe by Breidablikk's production

Per barrel net global greenhouse gas emissions impact from adding the Breidablikk field to Grane's production

Breidablikk emissions

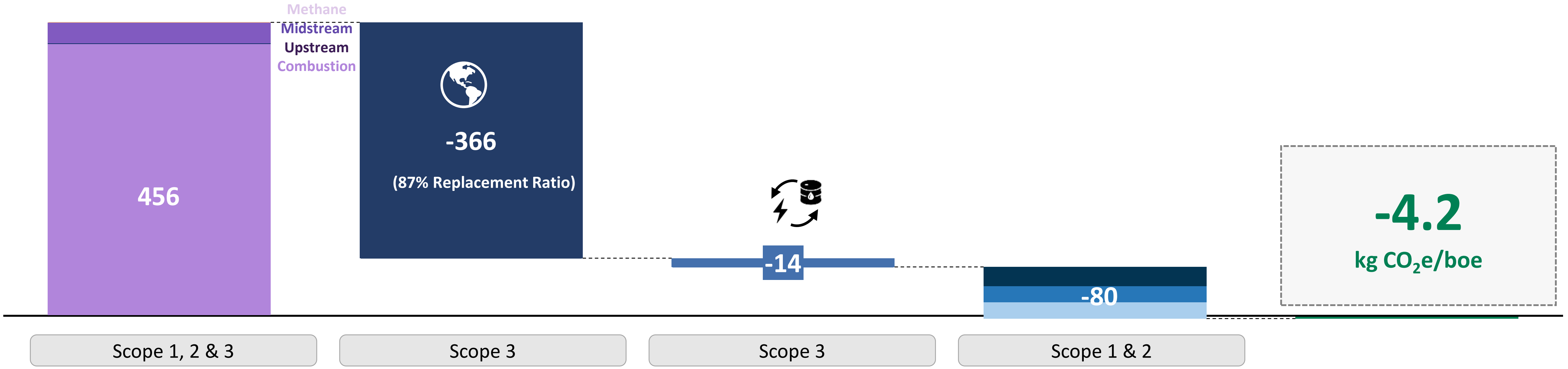
1 Oil and gas replacement

2 Other energy substitution

3 Production intensity impact

Net global emissions change

Oil and gas production (kg CO$_2$e/boe)



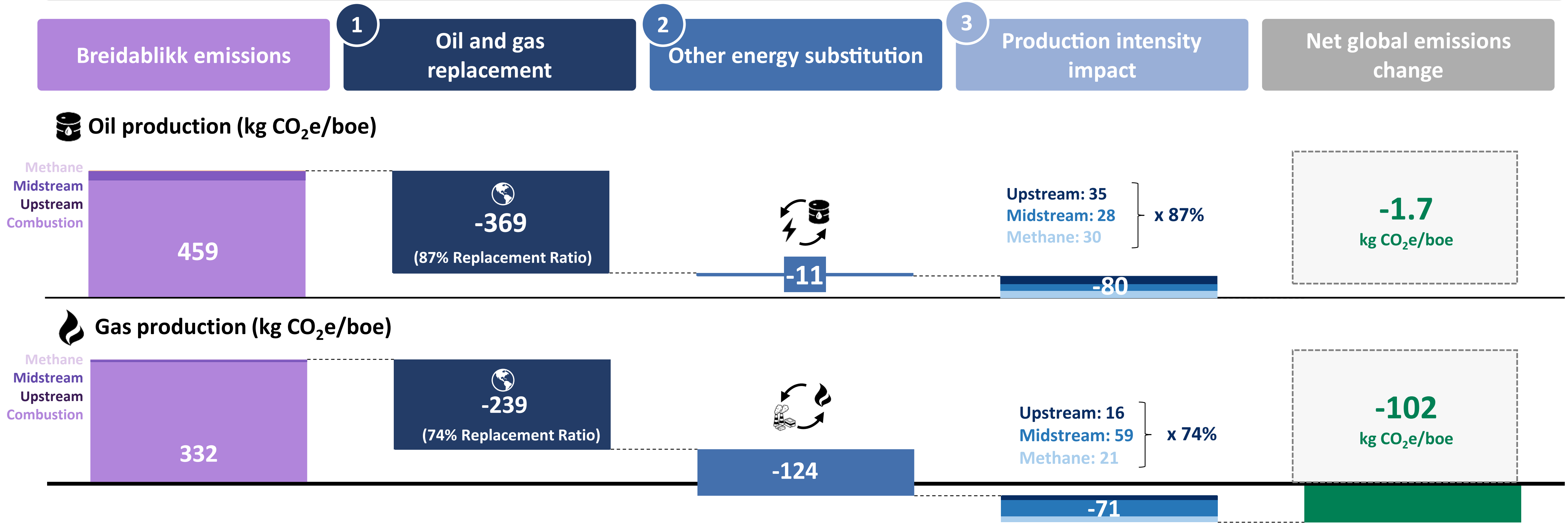
Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

Emission type X

Reference case

Gas production contributes less than 2% of total production emissions, but is contributing with 60% of Breidablikk's net global emission reductions

Net global emission impact per barrel from the Breidablikk field split by oil and gas



Weighted impact of Breidablikk's production is -4.3 kg CO_2e/boe

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

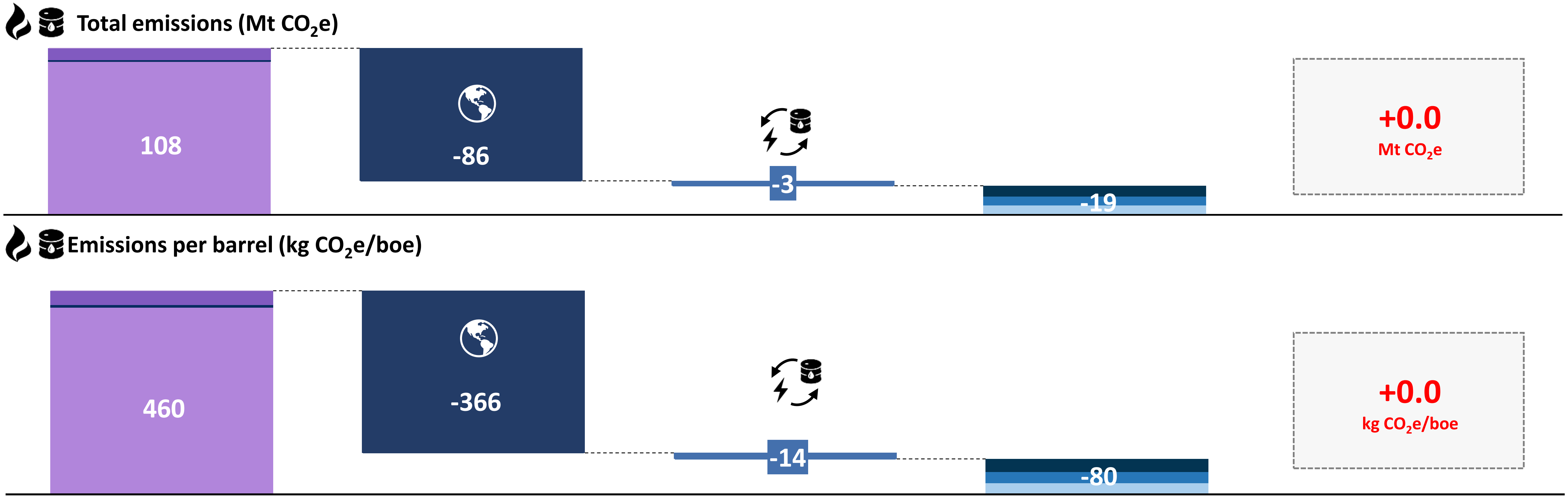
Framework

No electrification

Without electrification Breidablikk's production have a near zero effect on net global emission change

Global greenhouse gas emissions impact from Breidablikk's production without electrification

Breidablikk emissions | ① **Oil and gas replacement** | ② **Other energy substitution** | ③ **Production intensity impact** | **Net global emissions change**



Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

PDO

According to the PDO production of Breidablikk would decrease global emissions with 0.9 Mt CO_2e in total and -4.5 kg CO_2e/boe per barrel

Global greenhouse gas emissions impact from Breidablikk's oil production according to the PDO

Breidablikk emissions

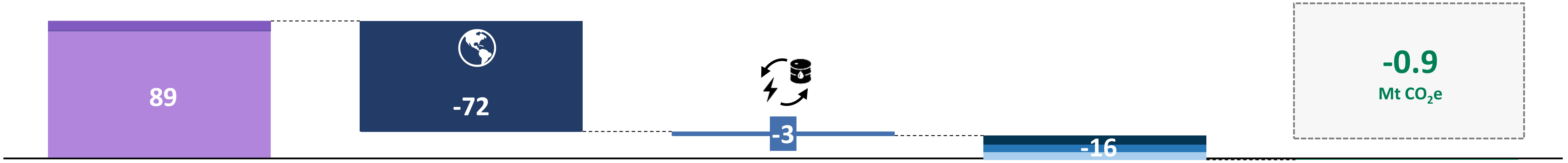
1 **Oil and gas replacement**

2 **Other energy substitution**

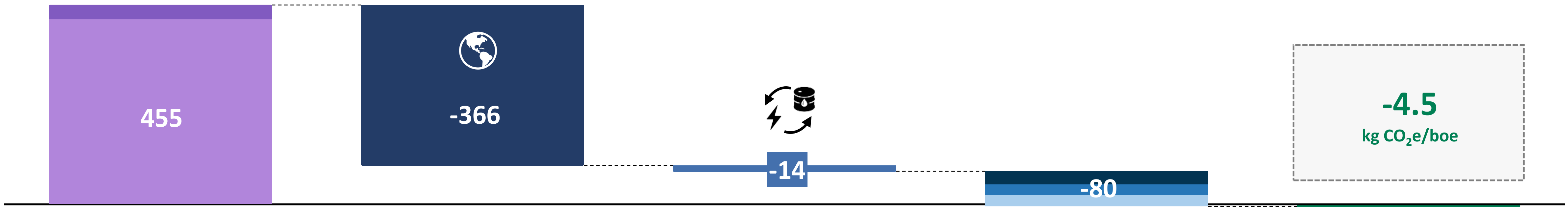
3 **Production intensity impact**

Net global emissions change

Total emissions (Mt CO_2e)

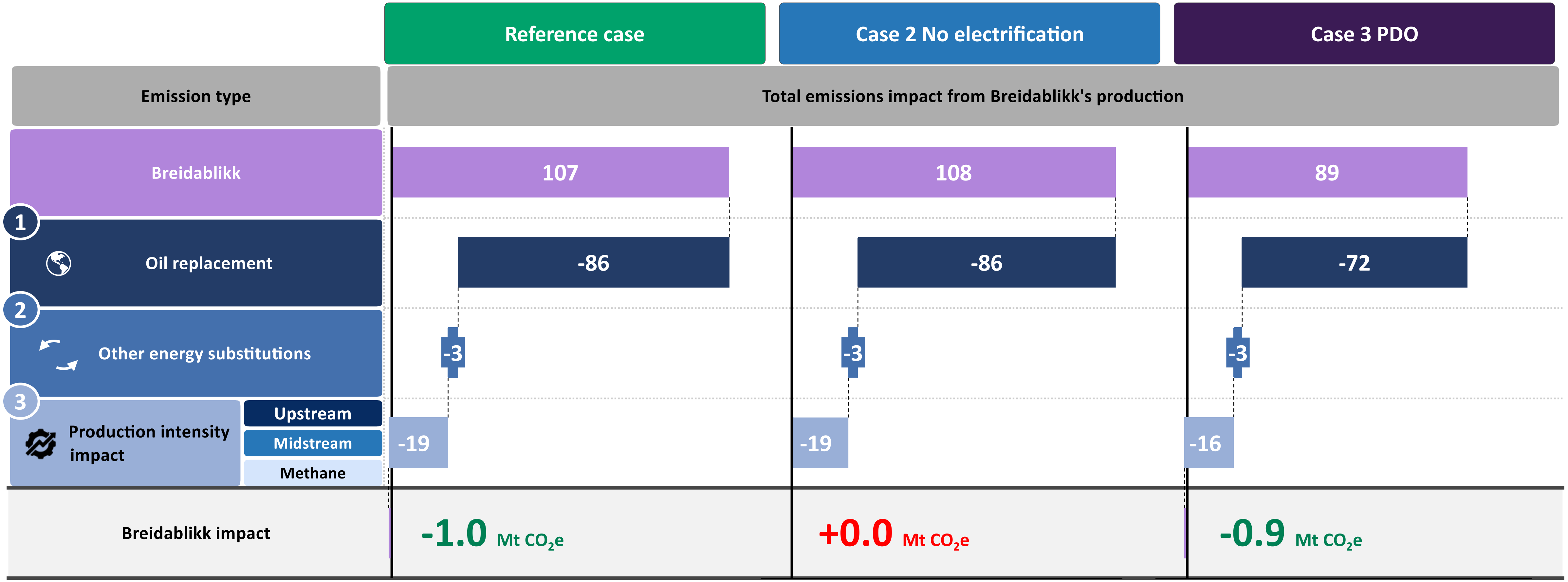


Emissions per barrel (kg CO_2e/boe)



Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

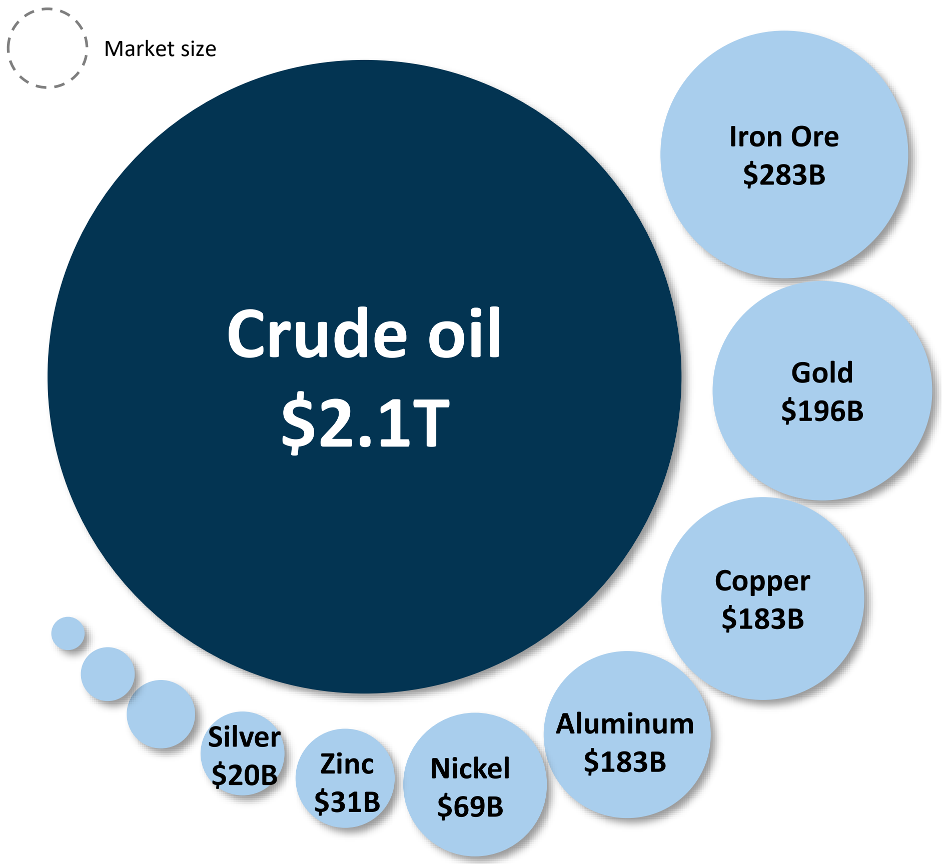
Breidablikk’s global net emissions impact is lowest in the reference case due to electrification bringing down upstream emissions



Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA’s “Announced Pledges Scenario”
Source: Rystad Energy research and analysis, Rystad Energy UCube, GasMarketCube; Equinor; IEA ; Climate Change Committee 6th Carbon Budget`

As a globally traded and highly liquid commodity, the oil market must be analyzed through the lens of worldwide supply and demand forces

The oil market is bigger than top 10 metal markets combined in terms of production value…



Source: Rystad Energy research and analysis, USGS Mineral Commodity Summaries 2023

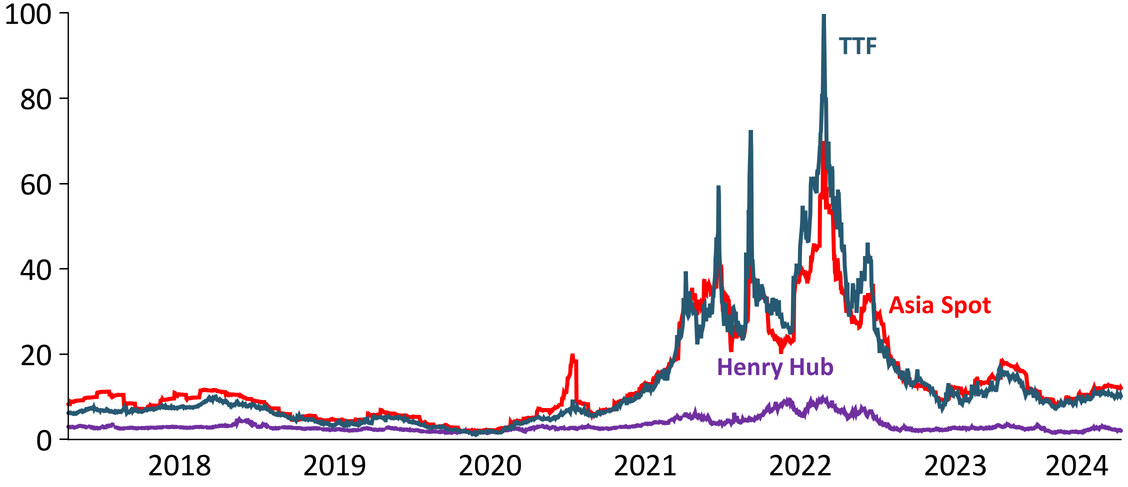
…ticking all the boxes characterizing global commodities

- ✓ **Universal demand:** Widespread demand across geographies
- ✓ **Standardized:** Standard quality and specifications
- ✓ **Large scale production:** Produced in large scale quantities
- ✓ **Market liquidity:** Large number of buyers and sellers
- ✓ **Price volatility:** Price sensitive to changes in global supply and demand conditions
- ✓ **Global trading infrastructure:** Well-established markets and trading platforms
- ✓ **Ease of transport and storage:** Relatively easy to transport and store
- ✓ **Economic significance:** Plays a significant role in the global economy

Unlike oil, natural gas markets are less integrated and dominated by regional forces

Natural gas markets are regionally priced, a reflection of the cost and logistical difficulty trading gas across borders…

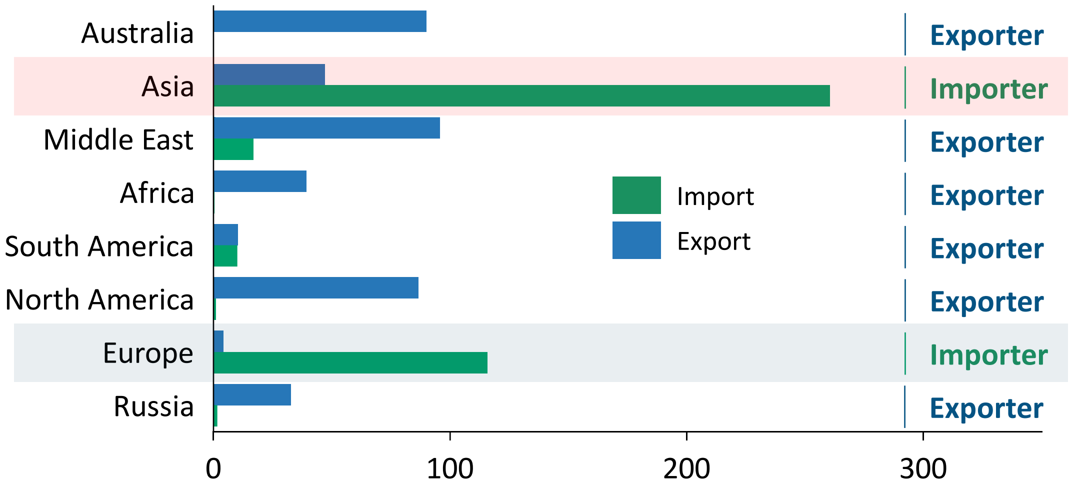
Gas price developments
USD/mmbtu



✗ **Global price:** Substantial price differences across regions

… however, LNG markets have a global element motivating the study of LNG supply elasticity in LNG importing regions

LNG trade by continent, 2024
Billion cubic meters (Bcm) LNG



✓ **Global price:** Substantial price contagion between regions with LNG as marginal price setter (i.e. Europe TTF and Asia Spot)

Source: Rystad Energy research and analysis; Rystad Energy GasMarketCube

Studying demand and supply elasticities of oil and gas products pose significant challenges on data quality; assessment of crude oil and natural gas markets as a whole used as a reasonable assumption

Product Examples

Crude Oil

- Gasoline
- Diesel
- Jet Fuel
- LPG
- Residual Oil
- Others

Natural Gas

- Methane
- Propane
- Ethane
- Butane
- Ammonia
- Others

Challenges incurred when studying products

❶ **Political policies:** dependent on political views on each oil/gas product, there may be taxes or subsidies etc. creating variations between products, geographies etc.

❷ **Substitutes:** products vary in how easily they can be substituted impacting demand elasticities

❸ **Ratio between products:** the composition of the mix of products produced per barrel of oil/gas varies over time

❹ **Limited data availability:** challenging to find sufficient data points to ensure "apples to apples" comparisons (e.g., limited IEA data points)

Crude oil and natural gas products not used in supply/demand analysis

Assumptions

Crude Oil is studied as a whole

Combustion average emissions from the combustion of crude oil are taken as the IPCC standard emissions factor for crude oil combustion

Crude Oil serves as input to all products, and should return similar results as studying each product independently and bringing it together

Natural gas is studied as a whole

Combustion average set to average natural gas emissions, using the IPCC standard emissions factor for natural gas combustion

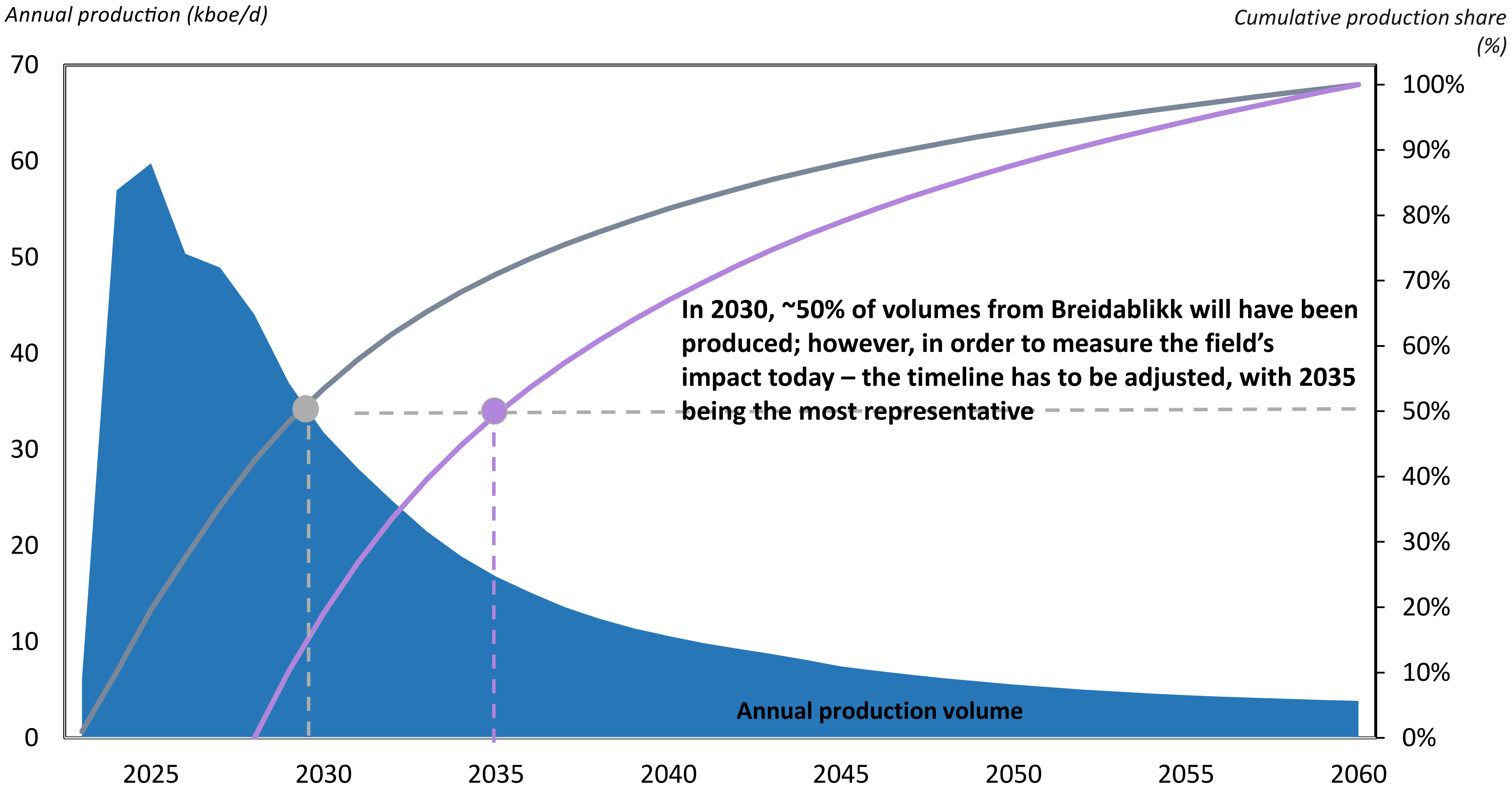
Natural gas serves as input to all products, and should return similar results as studying each product independently and bringing it all together

Source: Rystad Energy research and analysis

Reference case

For Breidablikk, 2035 represents the most representative year for the field's analysis

Breidablikk production profile



In 2030, ~50% of volumes from Breidablikk will have been produced; however, in order to measure the field's impact today – the timeline has to be adjusted, with 2035 being the most representative

- Studies of supply-side measures typically **focus on one analysis year**
- Any exaggerated effects on one side of the analysis year are compensated by exaggerated effects on the opposite side.
- Despite 2030 being the year when around 50% of Breidablikk's volumes will have been produced – the timeline for the field analysis has to be adjusted to today's point of view
- As a result, **2035 is the most representative year for the field's impact**

Sources: Rystad Energy research and analysis; Equinor

Content

Supply and demand elasticities drive displacement of other supply sources; 87% of oil and 74% of gas production from Breidablikk will displace production from other suppliers

1 O&G replacement

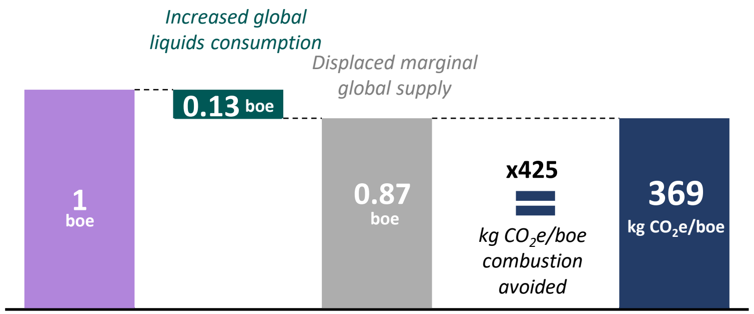
Approach

Assumptions

Oil production (kg CO_2/boe)

-369

(87% Replacement Ratio)



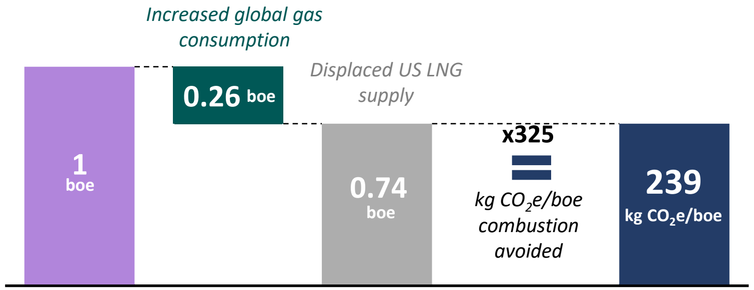
*Every barrel of oil produced at Breidablikk, will lead to **0.87 boe** of other supply not being produced globally over the longer term*

- Long-term crude oil demand is price inelastic with elasticity of -0.12 from academic literature review
- In the long-term supply is very responsive to changes in price with oil supply elasticity of 0.8 in 2035
- Global average oil combustion emissions of 425 kg CO_2e/boe

Gas production (kg CO_2/boe)

-239

(74% Replacement Ratio)



*Every boe of gas produced at Breidablikk will lead to **0.74 boe** of other supply not produced globally over the longer term*

- Long-term natural gas demand is partially elastic with elasticity of -0.64 from academic literature review
- In the long-term supply of natural gas is very responsive to changes in price with a supply elasticity of 1.8 in 2035
- Global average gas combustion emissions of 325 kg CO_2e/boe

Weighted oil and gas replacement impact of -366 kg CO_2e/boe

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

Increased production of oil and gas leads to a marginal increase in global oil and gas consumption and therefore emissions

Oil and gas replacement mechanism

Oil

1 Increased global oil supply ↑

Breidablikk production will increase oil production from Norway leading to increased Norwegian oil exports. With Norway exporting more oil, it increases the overall global oil supply.

2 Decreased global oil price ↓

Based on economic theory, an initial increase in global oil supply without an initial increase in demand, will lead to lower global oil prices

3 Supply withdrawal ↓

Lower oil prices lead to decreased supply as lower profitability prompts companies to reduce production, delay new projects, and scale back investment in exploration

3 Higher demand ↑

At a lower price, throughout the supply chain parties can now afford a greater quantity of oil, leading to increased oil demand

4 Marginal change in global oil consumption/emissions ↑

Dependent on the relative weightings of supply and demand price elasticities (replacement ratio), per barrel of oil there is a net change in world oil consumption, which in turn leads to a net change in end-use combustion emissions

Gas

1 Increased European gas supply ↑

Breidablikk production will increase domestic gas production in Norway reducing reliance on European gas imports, hence there will be more gas available in the European market

2 Decreased European LNG demand ↓

Increased domestic European gas supply will reduce the need for gas imports. As LNG is the marginal price setter for the European gas market, increased domestic supply will reduce European LNG import demand

3 Decreased global LNG price ↓

An initial decrease in demand without an initial decrease in supply will lead to lower market LNG price

4 Supply withdrawal ↓

Lower prices decrease global supply of LNG as reduced revenues lead producers to cut back on production and investment in new projects

4 Higher demand ↑

At a lower LNG price, it becomes cheaper for LNG importers to use natural gas compared to other primary energy sources, leading to an increase in demand for gas

5 Marginal change in global gas consumption/emissions ↑

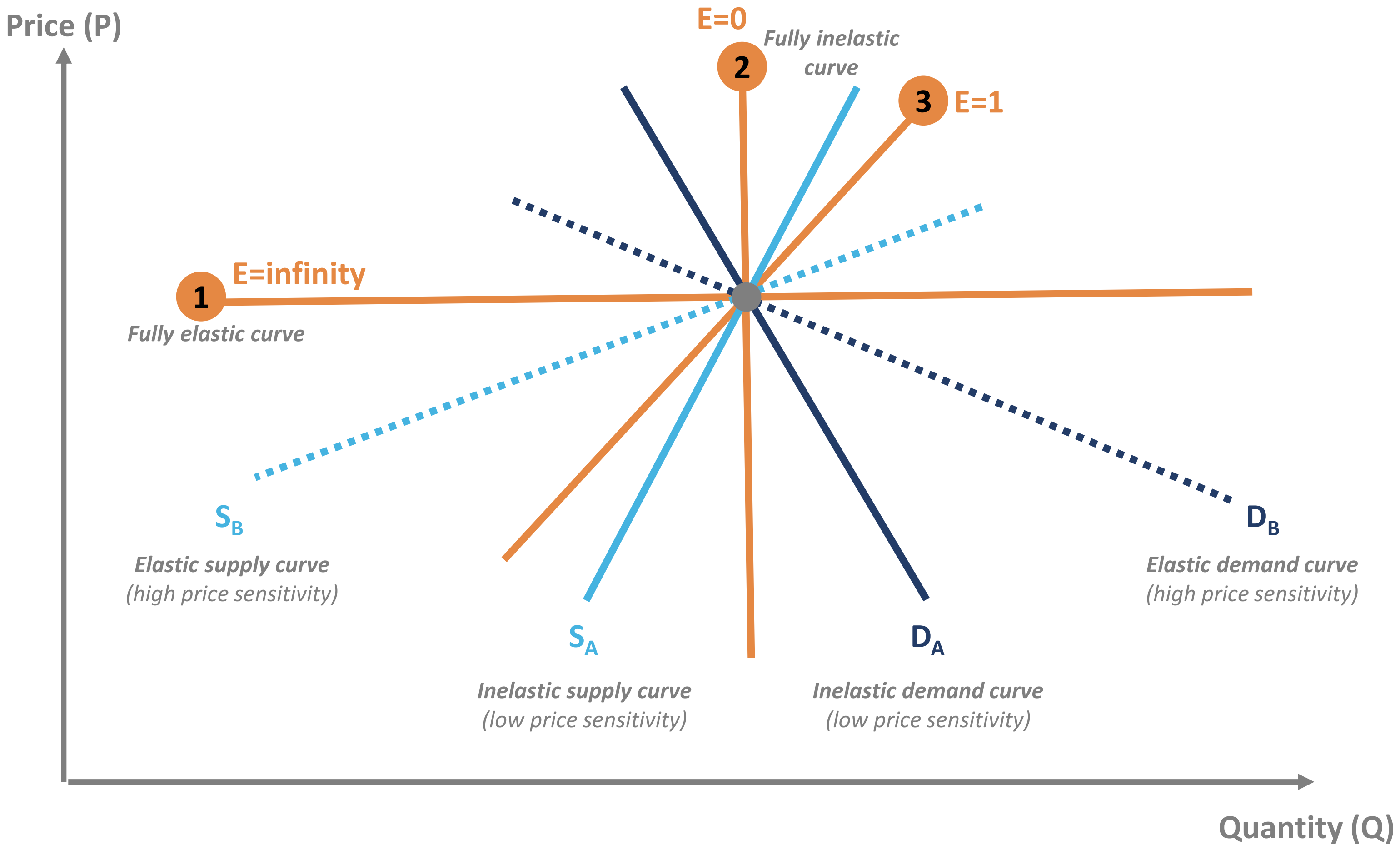
Dependent on the relative weightings of supply and demand price elasticities (replacement ratio), per boe of gas there is a net change in world gas consumption, which in turn leads to a net change in end-use combustion emissions

Source: Rystad Energy research and analysis

Content

Elasticities measure the quantity response of supply and demand for a given product to a change in price

Illustration of supply and demand elasticities



What is elasticity?

Demand or supply elasticity is a measure of price sensitivity, defined as the relative change in the quantity demanded or offered given a relative change in price. Demand elasticities are usually negative, while supply elasticities are positive

$$E = \frac{\Delta Q/Q}{\Delta P/P}$$

Percentage change in quantity

Percentage change in price

Three key elasticity scenarios

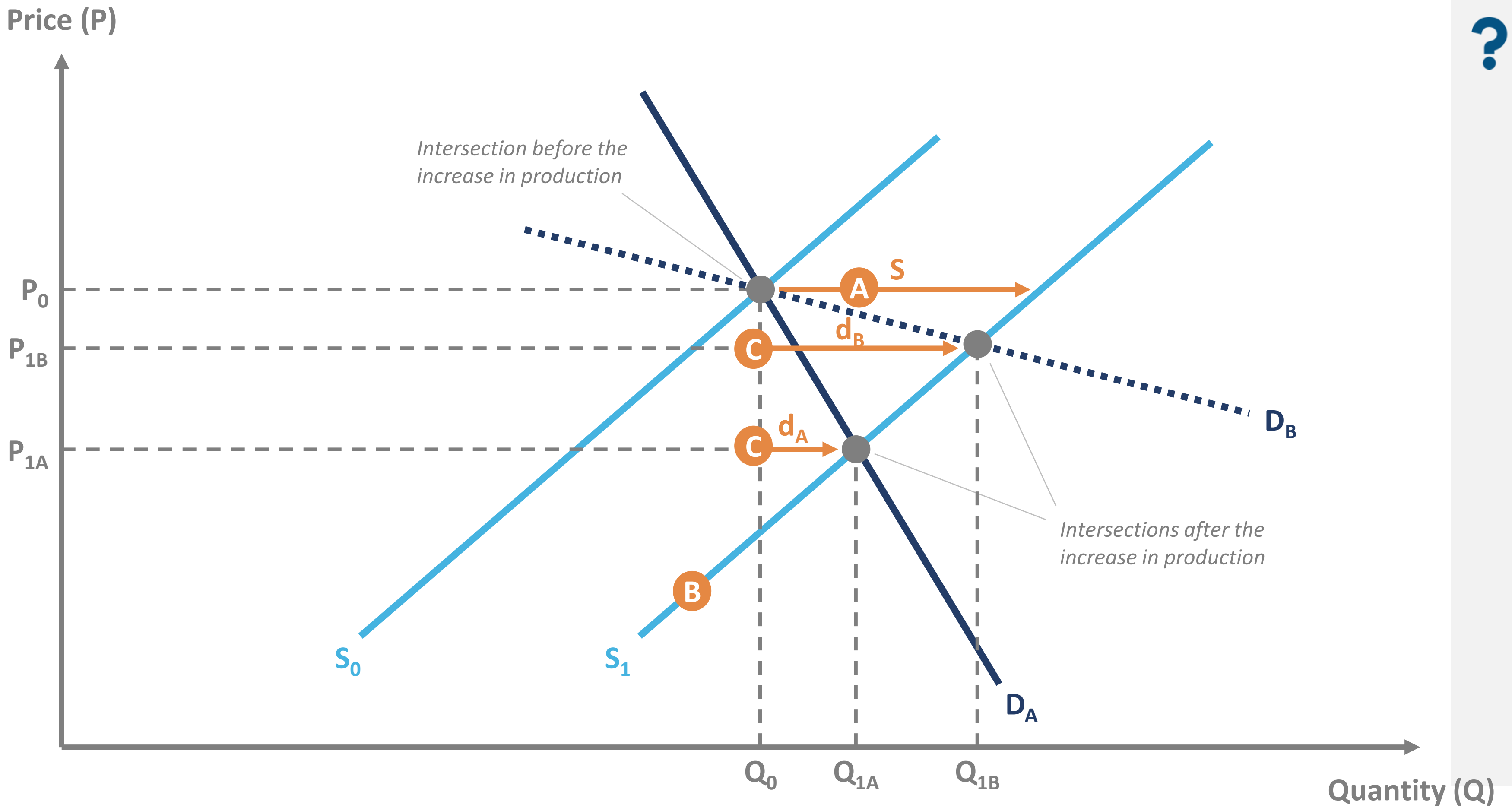
1	**E = 1**[1]	1% change in price gives 1% change in supply or demand. Equal %-wise increase of quantity and price is called unit elastic. Steeper curves are less elastic while slacker curves are more.
2	**E = 0**	A change in price does not lead to any change in supply or demand. Called completely inelastic. Illustrated by a vertical curve.
3	**E = infinity**[1]	The price is independent of the quantity offered or requested. Called fully elastic. Illustrated by a horizontal curve.

1) For demand elasticities, the values have the opposite sign

Source: Rystad Energy research and analysis

The more elastic the demand, the greater the demand response to an increase in production, all other things being equal

Illustration of supply and demand elasticities with increase in production



Intersection before the increase in production

Intersections after the increase in production

What is the relationship between demand elasticity and level of response?

When assessing market response, it is important to understand the relationship between demand elasticity and level of response

Example

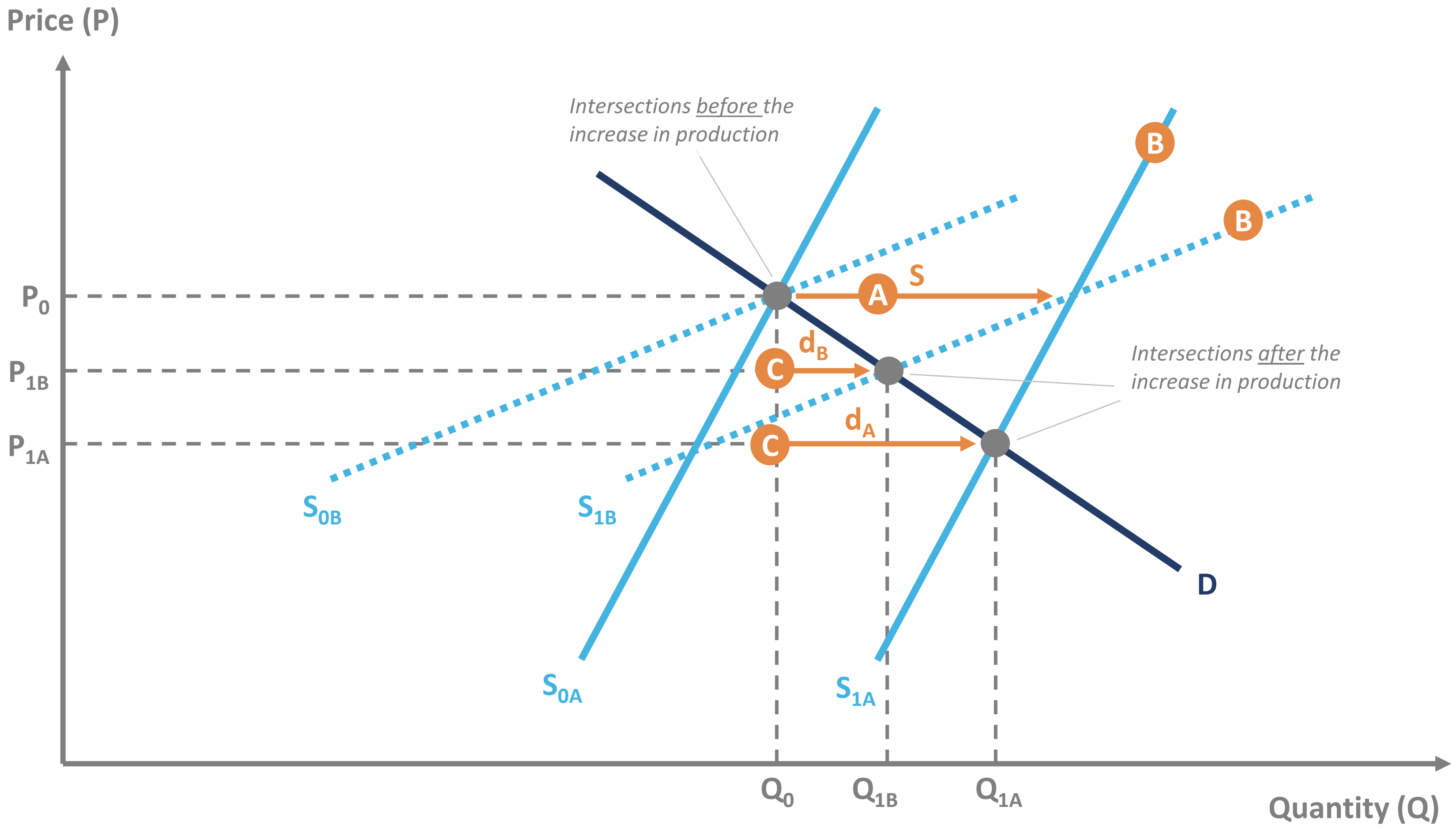
Have two demand curves, D_A is relatively inelastic, D_B is relatively elastic

Step A	Production increases with S, from Q_0 to Q_{1B}
Step B	Supply curve is shifted from S_0 to S_1
Step C	The greater the demand elasticity, the greater the demand response ($d_B > d_A$). Similarly, the quantity demanded increases relatively more, in the most elastic scenario.

Source: Rystad Energy research and analysis

Similarly, the more elastic supply, the greater the demand response to an increase in production, all other things being equal

Illustration of supply and demand elasticities with increase in production



Source: Rystad Energy research and analysis

What is the relationship between supply elasticity and level of response?

When assessing market response, it is important to understand the relationship between supply elasticity and level of response

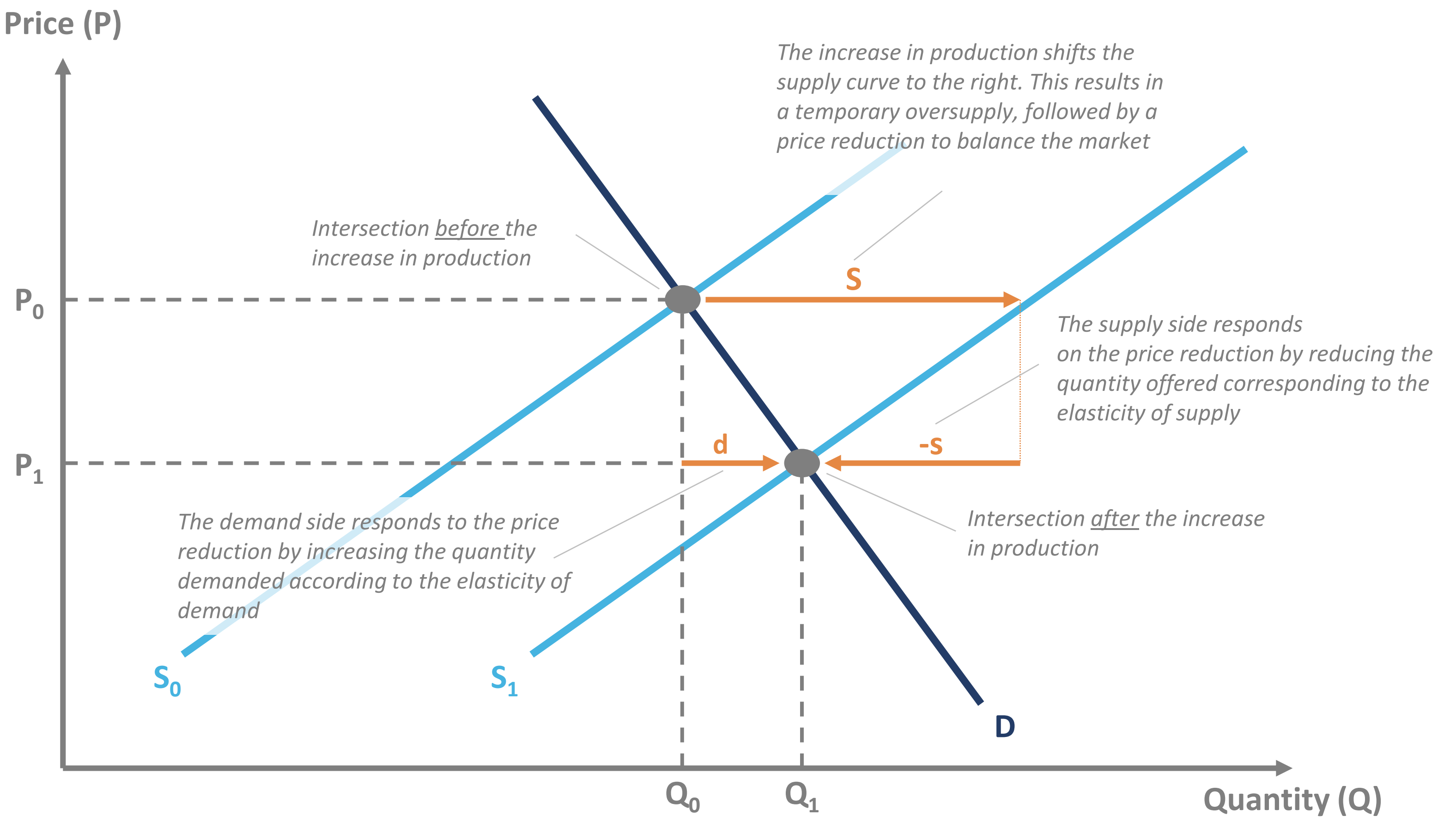
Example

Have two supply curves, S_A is relatively inelastic, S_B is relatively elastic

Step A	Production increases with S, from Q_0 to Q_{1A}
Step B	Supply curves are shifted from S_{0A} to S_{1A} and from S_{0B} to S_{1B}
Step C	The greater the supply elasticity, the smaller the demand response ($d_B < d_A$). Similarly, the quantity is relatively smallest in the least elastic scenario.

The relationship between supply and demand response is similar to the ratio of corresponding elasticities

Illustration of supply and demand elasticities with increase in production



The increase in production shifts the supply curve to the right. This results in a temporary oversupply, followed by a price reduction to balance the market

Intersection before the increase in production

The supply side responds on the price reduction by reducing the quantity offered corresponding to the elasticity of supply

The demand side responds to the price reduction by increasing the quantity demanded according to the elasticity of demand

Intersection after the increase in production

How much does an increase in production increase consumption?

The relationship between supply and demand elasticities dictates the supply and demand response to an increase in production.

Example

The increase in production S results in a displacement of supply from other sources $(-\mathrm{s})$ *and a demand increase* (d)

Relationship

$$d = S * \frac{|E_D|}{|E_D| + E_S}$$

where:

S is the supply increase
E_D is the demand elasticity
E_S is the supply elasticity
d is the demand increase

Source: Rystad Energy research and analysis

Step 1

Oil and gas markets are characterized by low demand elasticity and high supply elasticity

Key questions for understanding the elasticity of demand and supply

Does the price of oil affect the use of oil? Do you use more petrol/diesel for your car when the price is low? Do you fly more when the price is low? Are you buying more goods when shipping costs are lower?	✗	No, to a small extent	Low elasticity in oil demand
Does the price of gas affect the use of gas? Do power generators switch from coal to gas when the price is low? Do you heat less at home when the price is high? Do you cook more when prices are low?	—	Yes, to some extent	Some elasticity in gas demand
Does the price of oil and gas affect the production of oil and gas? Do you reduce investments when prices fall? Do you increase drilling activity when prices increase?	✓	Yes, to the highest degree	High supply elasticity

Source: Rystad Energy research and analysis

Content

Oil and gas supply elasticity measured as a function of supply and demand scenarios

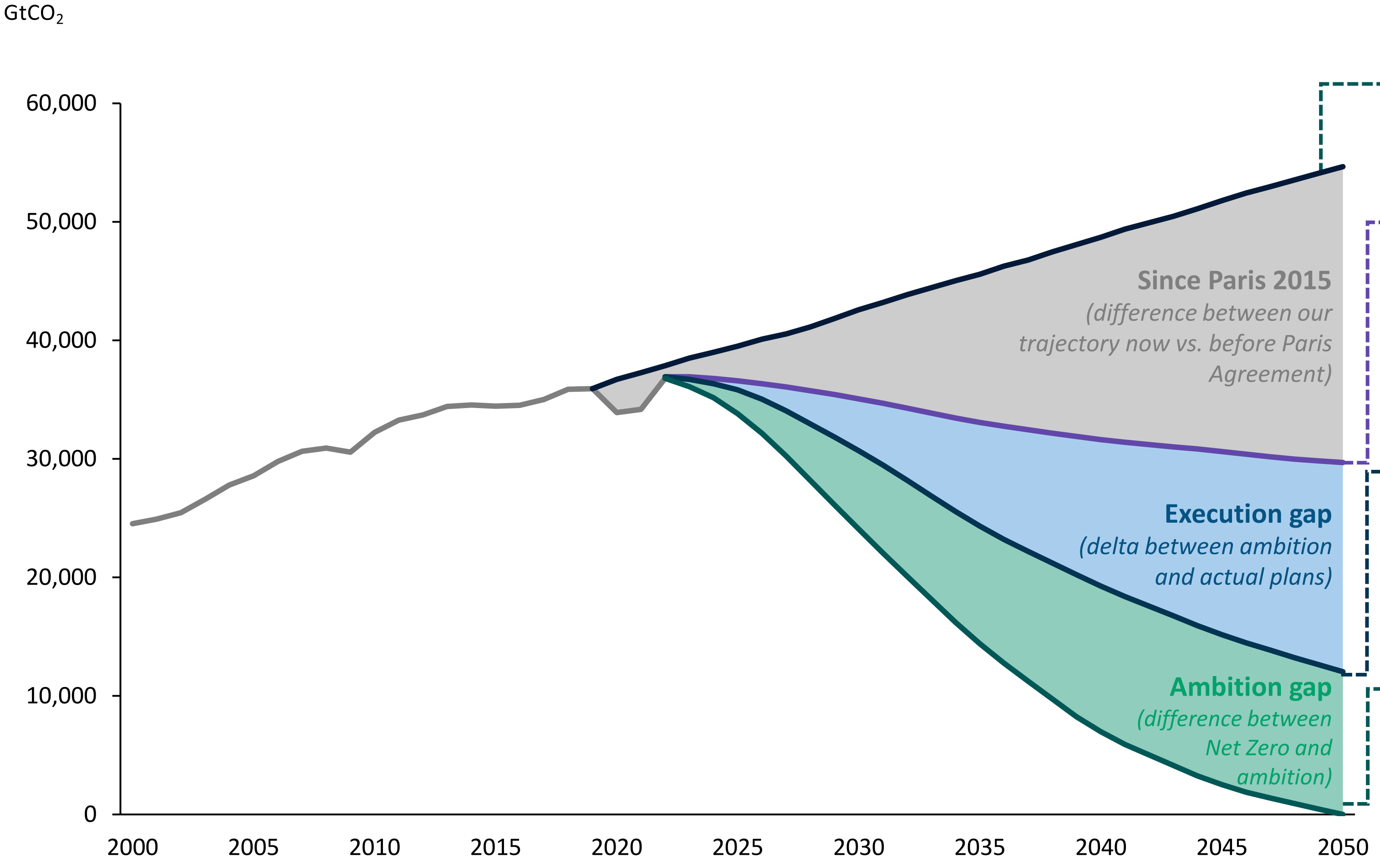
Supply scenario

Short-*term* *(0-1 years)* New capacity cannot be developed and produce beyond what already exists in the market	**Medium-term** *(2-5 years)* Long enough time for discovered resources to be developed	**Long-*term*** *(5+ years, i.e. after 2030)* Long enough time for undiscovered resources to be sought out and developed
Not applicable ***Breidablikkikk is not expected to produce within the next 0-1 years***	***Not applicable*** ***Time period not representative for full assessment of Breidablikk's impact***	***Focus of the report*** ***When evaluating the net emissions impact of Breidablikk production (2023-2060), long-term supply elasticity is the most relevant***

Source: Rystad Energy research and analysis

With demand scenarios being defined according to IEAs three key scenarios towards 2050

Global CO_2 Emissions by scenarios, 2023 - 2050



Source: Rystad Energy research and analysis, IEA

IEA with three key scenarios

Description scenarios

Trajectory before Paris Agreement

Expected trajectory before Paris Agreement

Stated Policies

Scenario reflecting current policy settings based on a sector-by-sector and country-by-country assessment of the energy-related policies that are in place as of the end of August 2023, as well as those that are under development

Announced Pledges

Scenario assuming all climate commitments made by governments and industries around the world as of the end of August 2023, will be met in full and on time

Net Zero by 2050

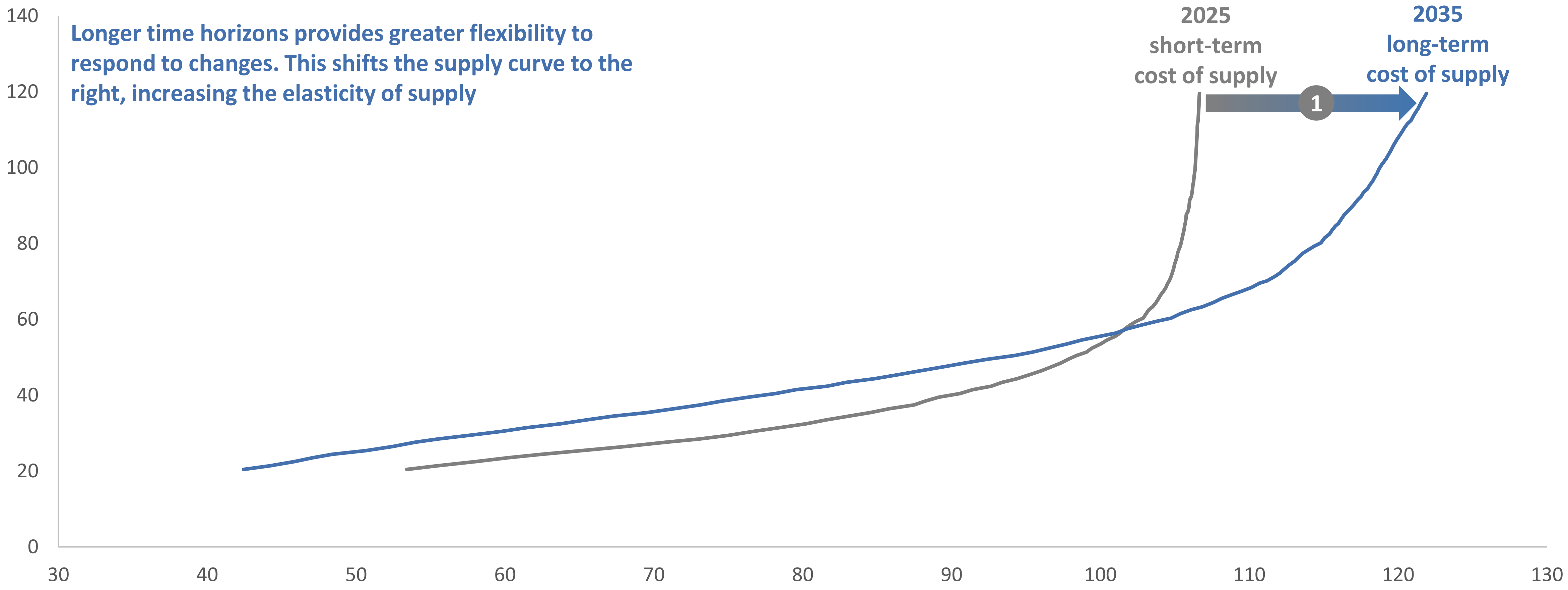
Scenario sets out a pathway for the global energy sector to achieve net zero CO_2 emissions by 2050. Universal access to electricity and clean cooking are achieved by 2030.

Content

Supply of oil is more price elastic in the long-term

Dynamic supply curves for liquids split by year[1]

Breakeven price - USD/bbl (y-axis); Production - million barrels per day (Mbpd)

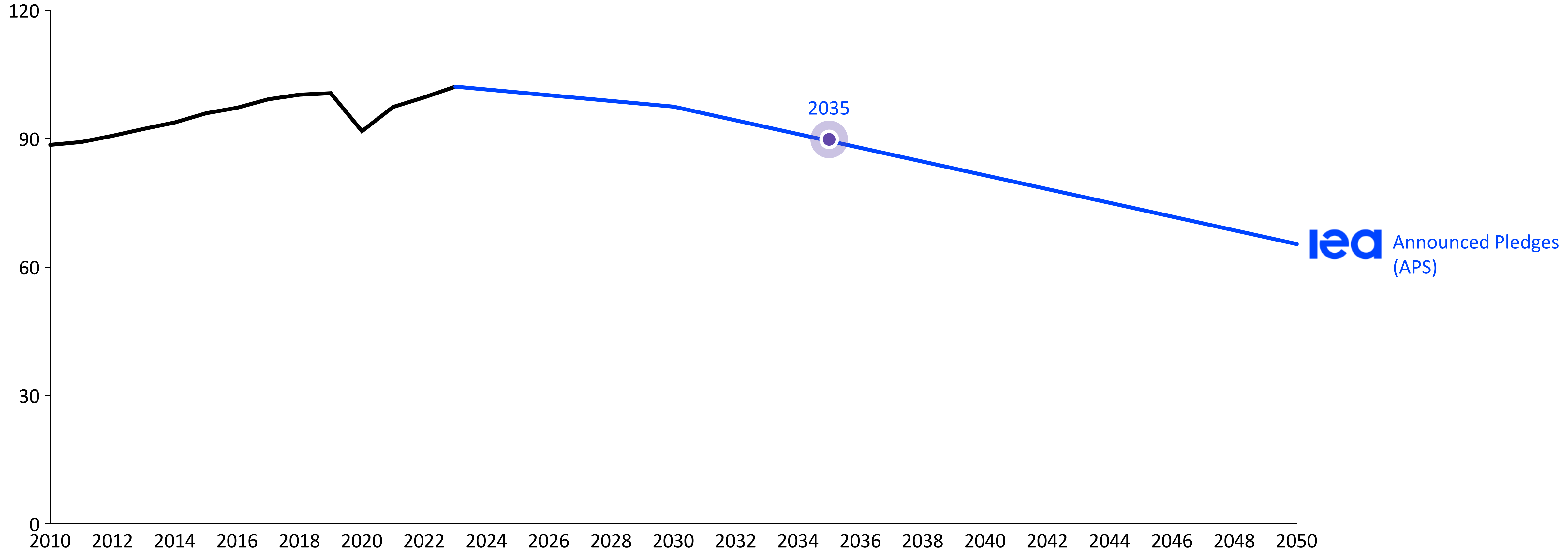


1) For each relevant year, dynamic supply curves are calculated by assuming flat real break-even prices from today (2024) until the current year
Source: Rystad Energy research and analysis; Rystad Energy UCube

IEA World Energy Outlook liquids demand scenarios used to read the dynamic supply curves

Liquids demand outlook by IEA scenario

Million barrels per day (Mbpd)

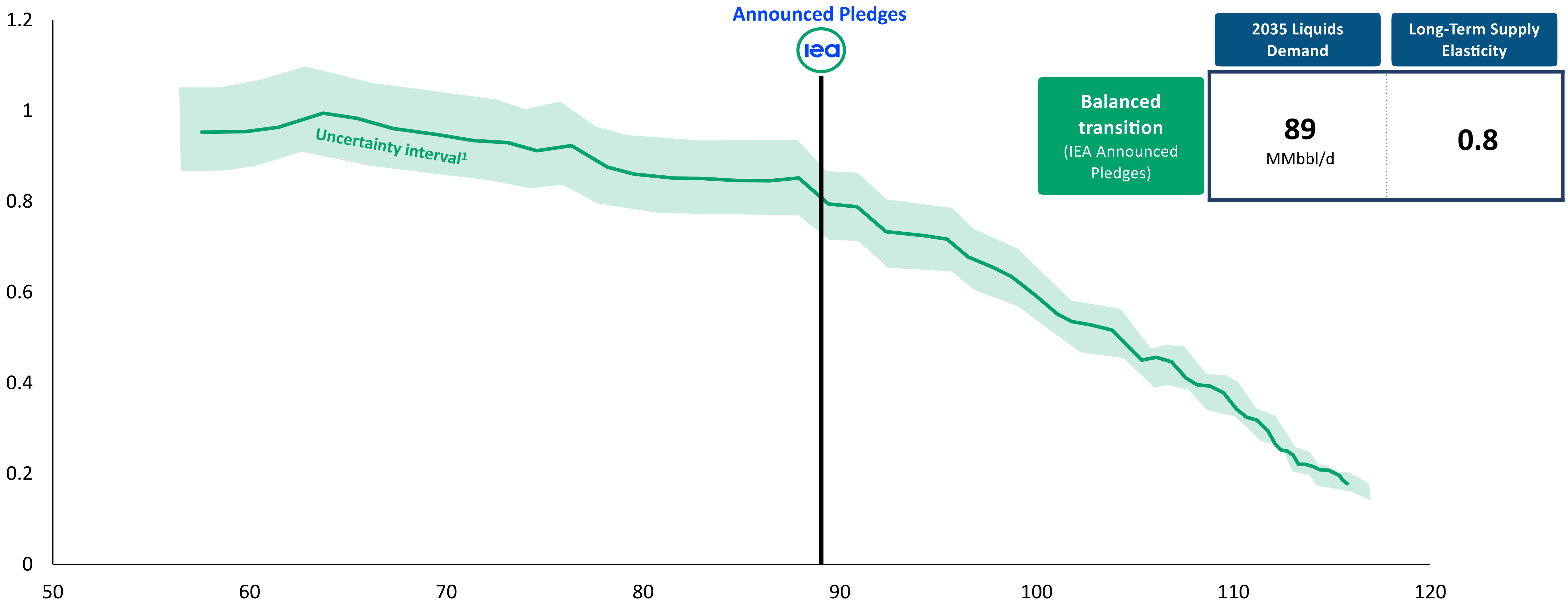


Source: Rystad Energy; IEA

Long-term supply elasticity of 0.8 under Announced Pledges

Estimated oil supply elasticity based on dynamic supply curves for 2035 under IEA Announced Policies demand scenario

Supply elasticity (y-axis); Liquids demand: Million barrels per day (x-axis)



	2035 Liquids Demand	Long-Term Supply Elasticity
Balanced transition (IEA Announced Pledges)	**89** MMbbl/d	**0.8**

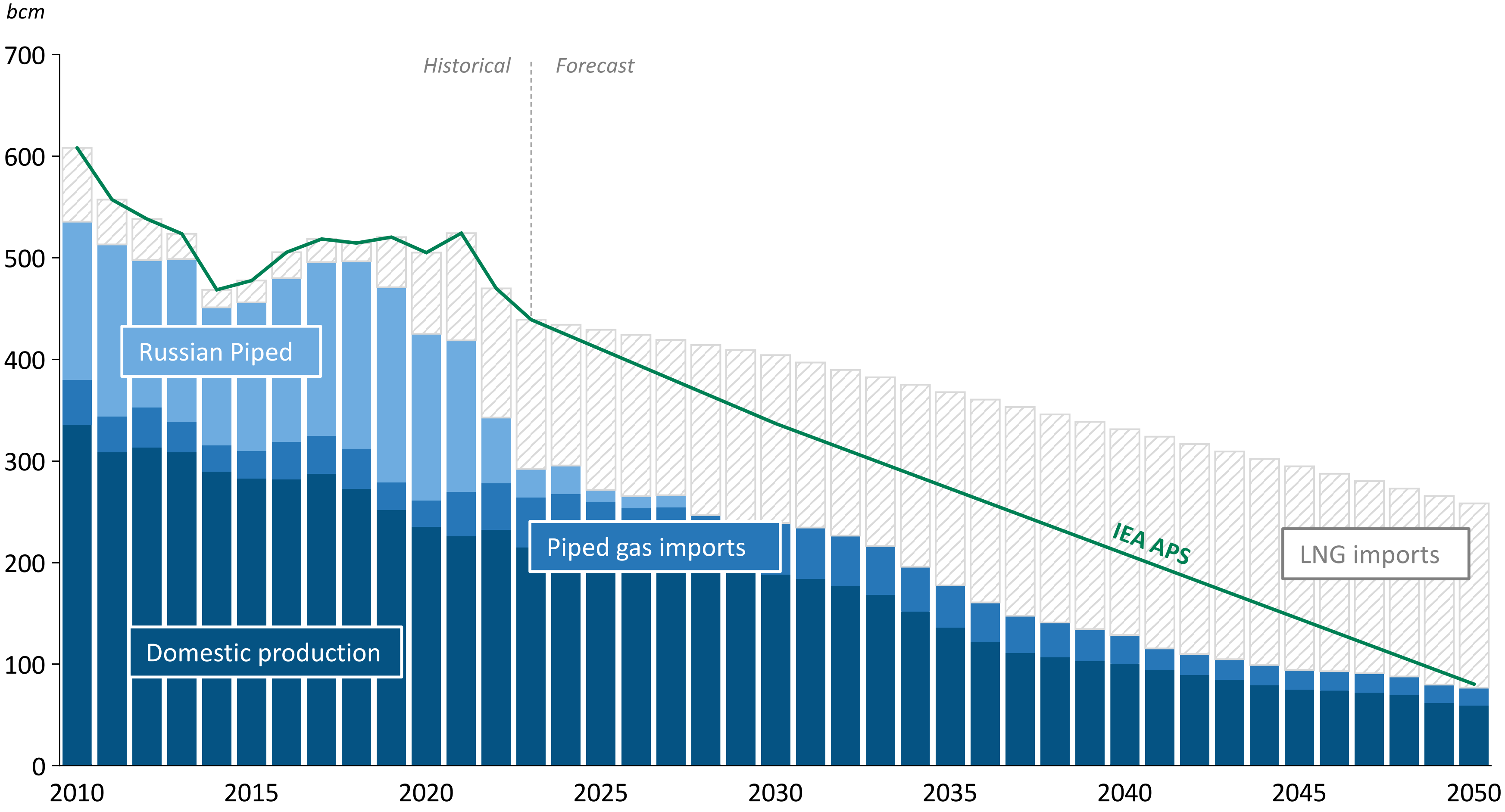
1) The uncertainty fan is made by varying the window size used in the midpoint elasticity formula. This varies between 1 and 10 USD/bbl in each direction. For each production level, the highest and lowest possible supply elasticity is extracted. Average relative distances between these derived curves and the main curve form the basis of the upper and lower bounds.

Source: Rystad Energy research and analysis, Rystad Energy UCube; IEA

Content

Breidablikk gas production will displace LNG imports to Europe

European gas market balance

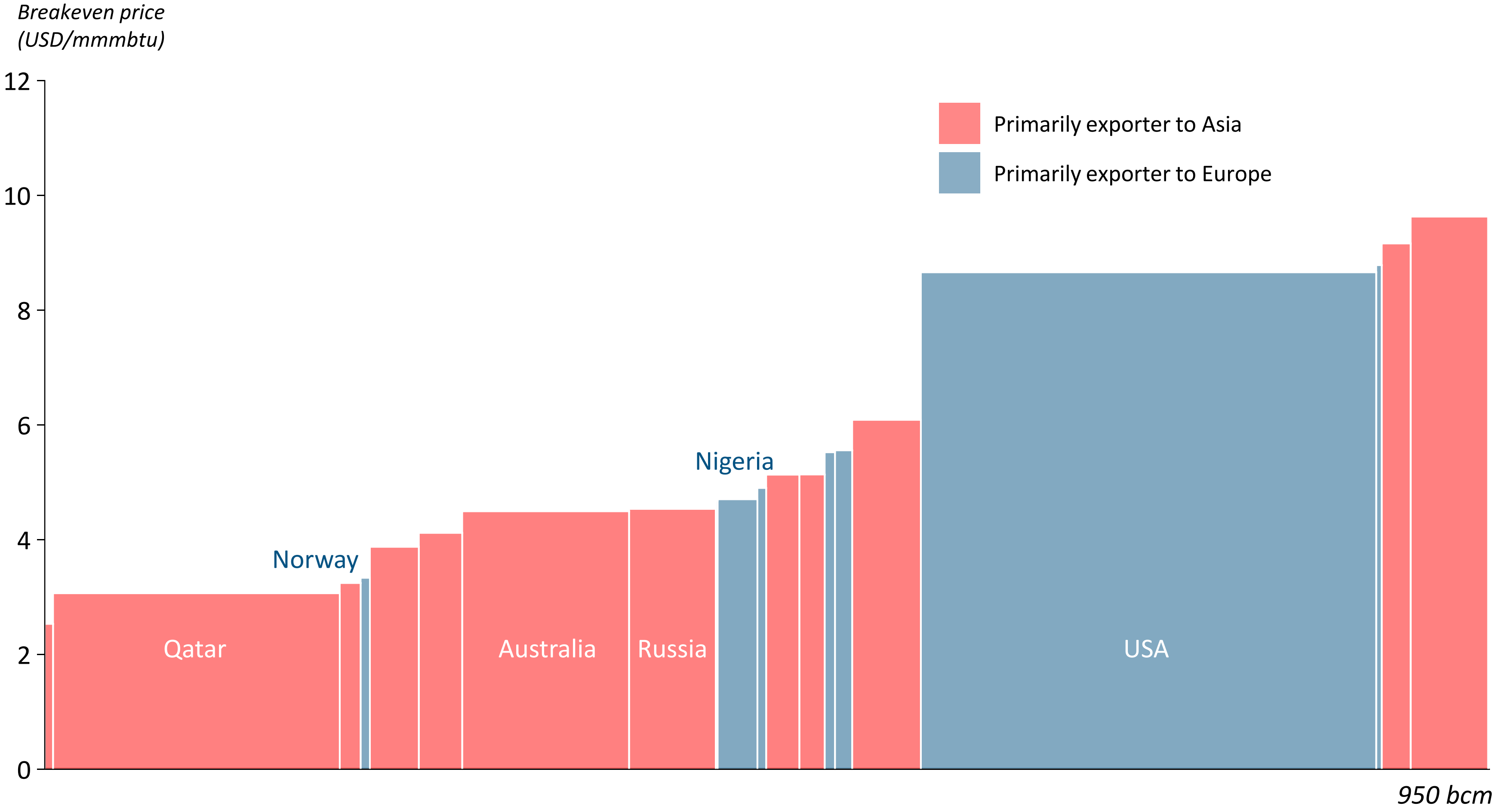


Source: Rystad Energy research and analysis; Rystad Energy GasMarketCube

- Up until 2045, **Europe is not self-sufficient** in gas under IEAs APS scenario
- **European gas demand not fulfilled by domestic production** and must be covered by pipeline gas imports and LNG
- Going forward, the phase-out of Russian pipeline gas, will increase the need for LNG imports
- As LNG is more expensive than pipeline gas, **increased domestic production from Breidablikk will displace LNG**
- Analysis of Breidablikk gas production impact must focus on the **global LNG market serving as a marginal supply of gas to Europe**

The US is the most likely swing producer of LNG to Europe (1/2)

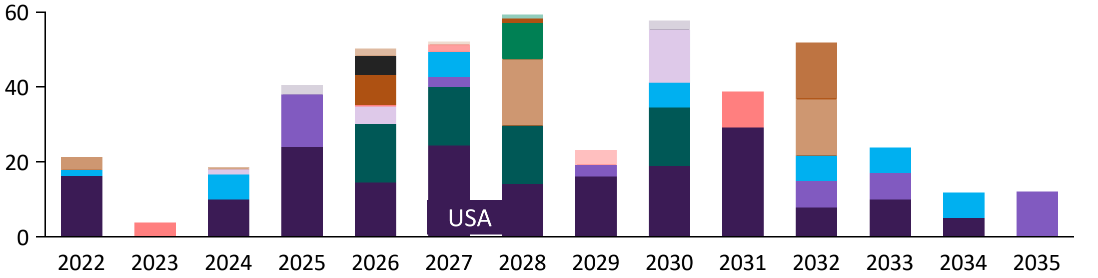
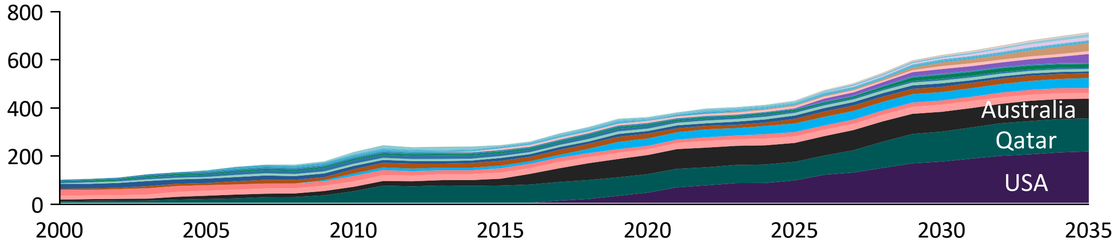
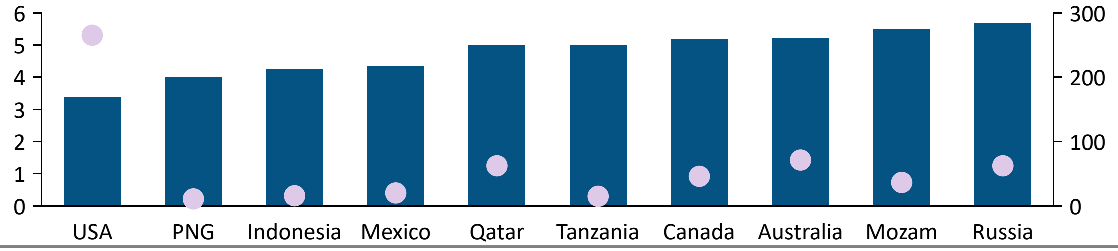
Instantaneous supply curves for LNG by export country in 2035[1]



- Most likely export region for each country is mainly driven by **geographical proximity** to various markets and consequently **minimization of transport costs**
- The US is expected to be by far the **largest supplier of LNG globally** in 2035
- US LNG, close to being the most expensive will be the **marginal supplier of LNG** at least to Europe

1) Based on existing capacity as well as capacity under construction today (2024). Weighted average breakeven prices and total LNG production per country are shown based on named liquefaction facilities.
Source: Rystad Energy research and analysis; Rystad Energy GasMarketCube

The US is the most likely swing producer of LNG to Europe (2/2)

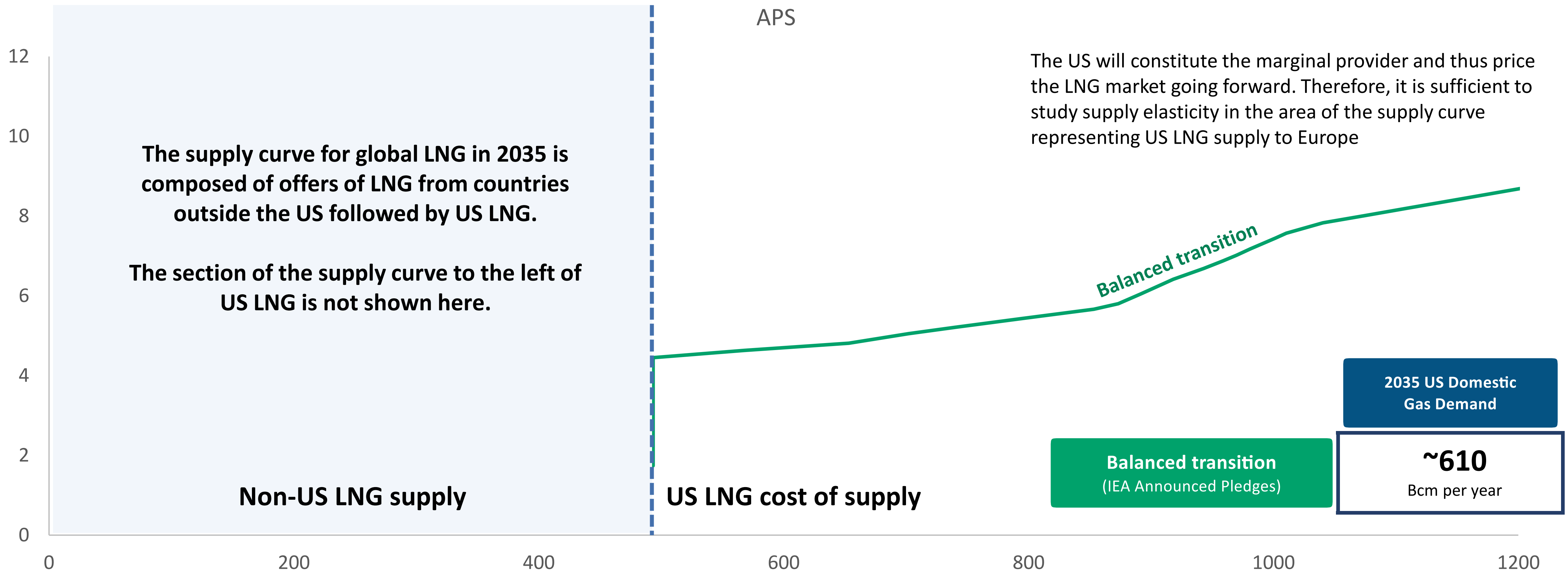
Three supporting reasons why the US Will Become Europe's LNG Swing Producer in the 2030s Beyond the Supply Curve		
Theme	**Illustration**	**Comment**
Largest planned capacity additions	*Million tonnes of LNG capacity (y-axis), start-up year (x-axis)* 	- The US shale revolution has made large and highly competitive natural gas resources available. - The shale revolution has turned the US natural gas deficit into a surplus. - The US has further ambitions to increase exports.
Largest exporter of LNG globally	*Million tonness LNG production (y-axis), year (x-axis)* 	- The US became the world's largest LNG exporter in 2022. - The United States has some of the most favorable shipping and quoting costs of LNG to Europe.
World leader in construction speed	*Construction time (bar chart, left y-axis), new LNG capacity (scatter chart, right y-axis)* 	- From 2014 to 2035, the United States will develop more than twice as much LNG capacity as any other country - The US has some of the shortest lead times for LNG facilities, it has been communicated that LNG facilities can be built in less than 3 years.

Note: Papua New Guinea (PNG)
Source: Rystad Energy research and analysis, Rystad Energy GasMarketCube

Gas market supply elasticity is estimated on the US section of the LNG supply cost curve

Dynamic supply curve for global LNG supply in 2035[1]

Breakeven price - USD/kcf (y-axis); Global LNG demand - bcm (x-axis)



The supply curve for global LNG in 2035 is composed of offers of LNG from countries outside the US followed by US LNG.

The section of the supply curve to the left of US LNG is not shown here.

The US will constitute the marginal provider and thus price the LNG market going forward. Therefore, it is sufficient to study supply elasticity in the area of the supply curve representing US LNG supply to Europe

Balanced transition
(IEA Announced Pledges)

2035 US Domestic Gas Demand

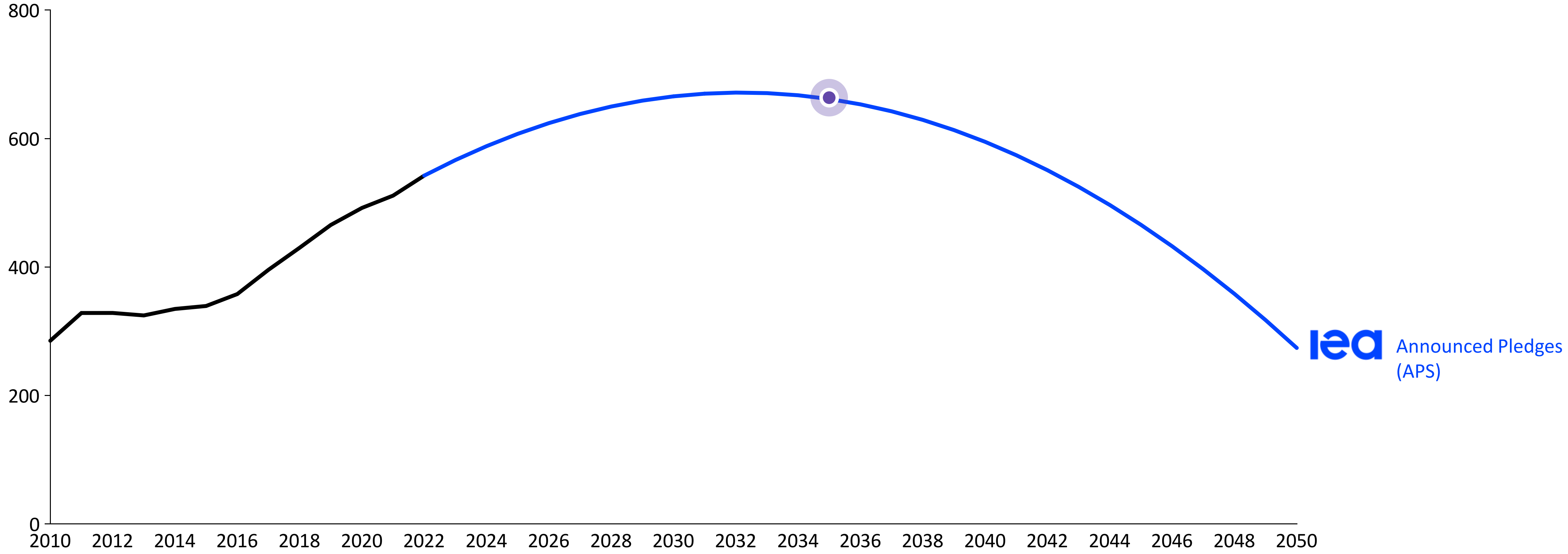
~610
Bcm per year

1) Average transport costs based on global LNG trade is assumed
Source: Rystad Energy research and analysis, IEA

IEA World Energy Outlook LNG demand APS scenario used to read the dynamic supply curves

LNG demand outlook by IEA APS scenario

Billion cubic meters (Bcm) LNG per year

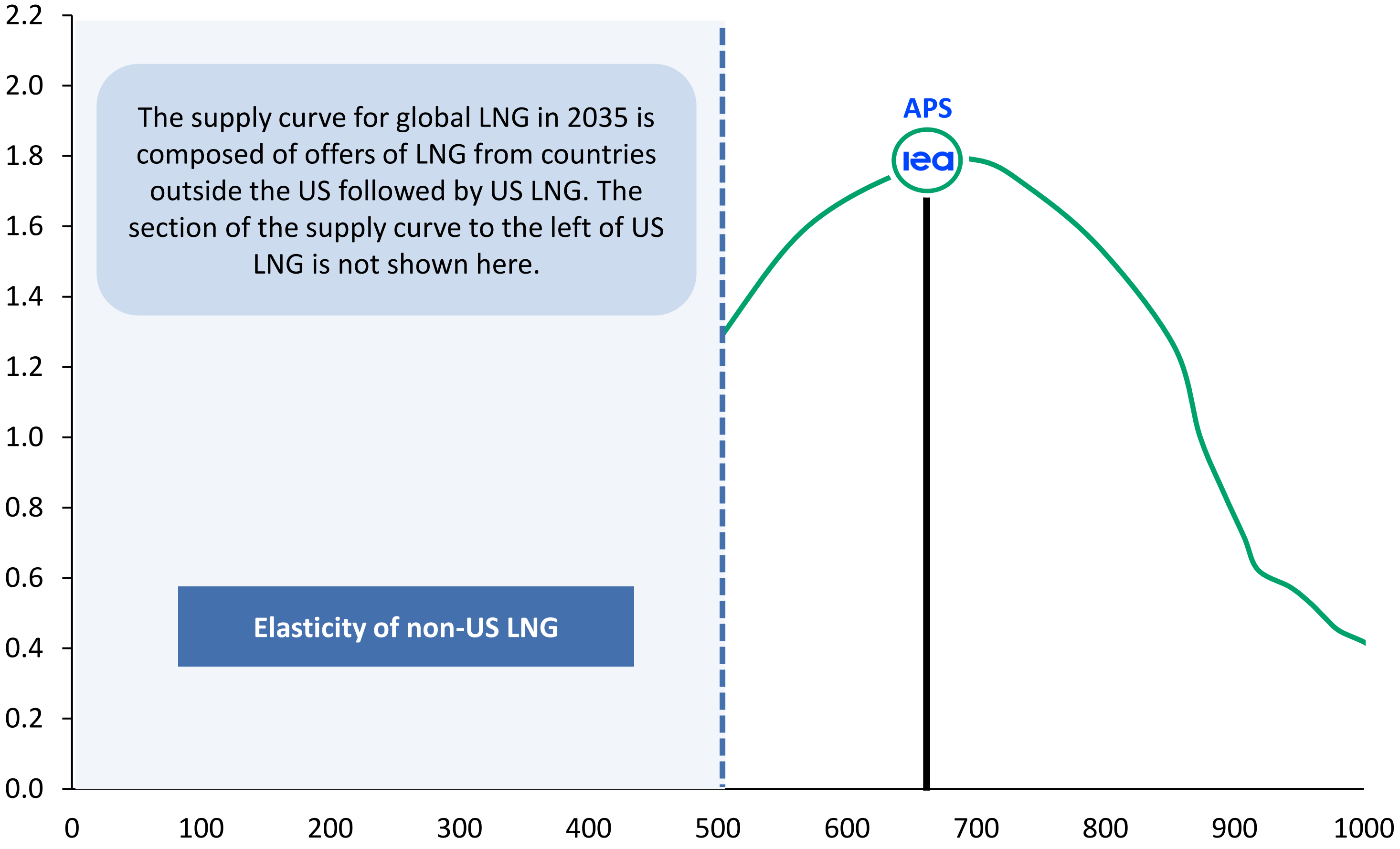


Source: Rystad Energy research and analysis, IEA

Supply elasticity of 1.8 for gas markets in under the IEA APS scenario

Dynamic supply curve for global LNG supply in 2035*

Supply elasticity (y-axis); Global LNG demand - bcm (x-axis)**



The supply curve for global LNG in 2035 is composed of offers of LNG from countries outside the US followed by US LNG. The section of the supply curve to the left of US LNG is not shown here.

Source: Rystad Energy research and analysis, Rystad Energy GasMarketCube, UCube; IEA

Supply elasticity curves for LNG vary based on demand scenarios. Faster transitions result in decreased US gas production increasing the availability of US gas for LNG production. This increases the elasticity of the US LNG supply.

	2035 LNG Demand	Long-Term Supply Elasticity
Balanced transition (IEA Announced Pledges)	**~660** Bcm per year	**1.8**

Content

Several studies on demand elasticity are not relevant or representative and thus excluded

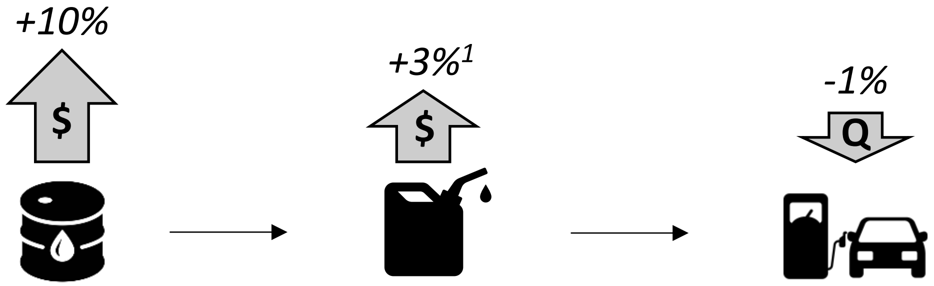
Category		Oil Inclusion Criteria	Gas Inclusion Criteria
	Elasticity definition	**Long-term crude oil price elasticity** Excludes short-term elasticities, on income or other variables, as well as on derivatives such as gasoline	**Long-term gas price elasticity** Excludes short-term elasticities, on income or other variables, as well as LNG.
	Recognition	**Published Work** Either in a reputable journal with peer review, or by a recognized organization such as the IEA or IMF	**Published Work** Either in a reputable journal with peer review, or by a recognized organization such as the IEA or IMF
	Year of publication	**2008 or later** To provide the most up-to-date estimates	**2008 or later** To provide the most up-to-date estimates
	Era investigated	**From 1970** Studies with data prior to 1970 are excluded, as these are considered to be of little relevance to the current and future market	**No hard requirements** Studies with newest data are prioritized
	Geography studied	**Global Focus, Non-Oil Exporting Countries** Studies on individual countries or regions dominated by oil exporting countries are excluded	**Global focus** Studies on individual countries are excluded although studies on signifcant regions such as Europe and the USA (being the only acception to individual country rule) are included

Source: Rystad Energy research and analysis

Using gasoline price elasticities of demand for crude oil will lead to an overestimate

Market dynamics of crude oil compared to gasoline

Consumers are more price sensitive to changes in petrol prices than markets are to changes in oil prices, a smaller percentage variation in petrol prices leads to the same demand effect as a larger percentage variation in oil prices



Crude oil price

If crude oil prices increase by 10% ...

Gasoline price

… fuel prices increase by only 3%* due to fixed taxes…

Oil & Gasoline demand

… Suppose this leads to a fall in demand by 1% for both gasoline and crude oil (value purely illustrative). Then by the E_D formula, gasoline has a price elasticity of demand at 1/3 compared to crude oil which has 1/10.

$$E_D = \frac{\% \Delta Quanity}{\% \Delta Price}$$

Therefore, gasoline is more price elastic

Key reasons leading to the invalidation of gasoline-related studies

1 Fixed fees

- Gasoline will always be more expensive than oil due fixed costs from taxes, transport etc.
- Therefore, as a percentage of price gasoline fluctuations will be less sensitive to price changes than crude oil, leading to a higher elasticity given the further assumption that the % change in demand is roughly 1:1.

2 Contentious elasticity relation

- Some academics attempt to study the price elasticity of crude oil with gasoline data, to account for this they typically will divide the gasoline E_D by a constant, but the exact value of this constant has been argued at different values by various academic reports.
- For example, Hamilton (2009) uses a value of 2 based of a 2:1 percent oil-gasoline price relationship, but by this same logic Wood et al. (2022) would suggest a constant closer to 3
- This coefficient will also vary significant by region as different countries have varying tax policies (effecting price relation) and different consumer behaviors (effecting quantity relation)

3 Tax changes

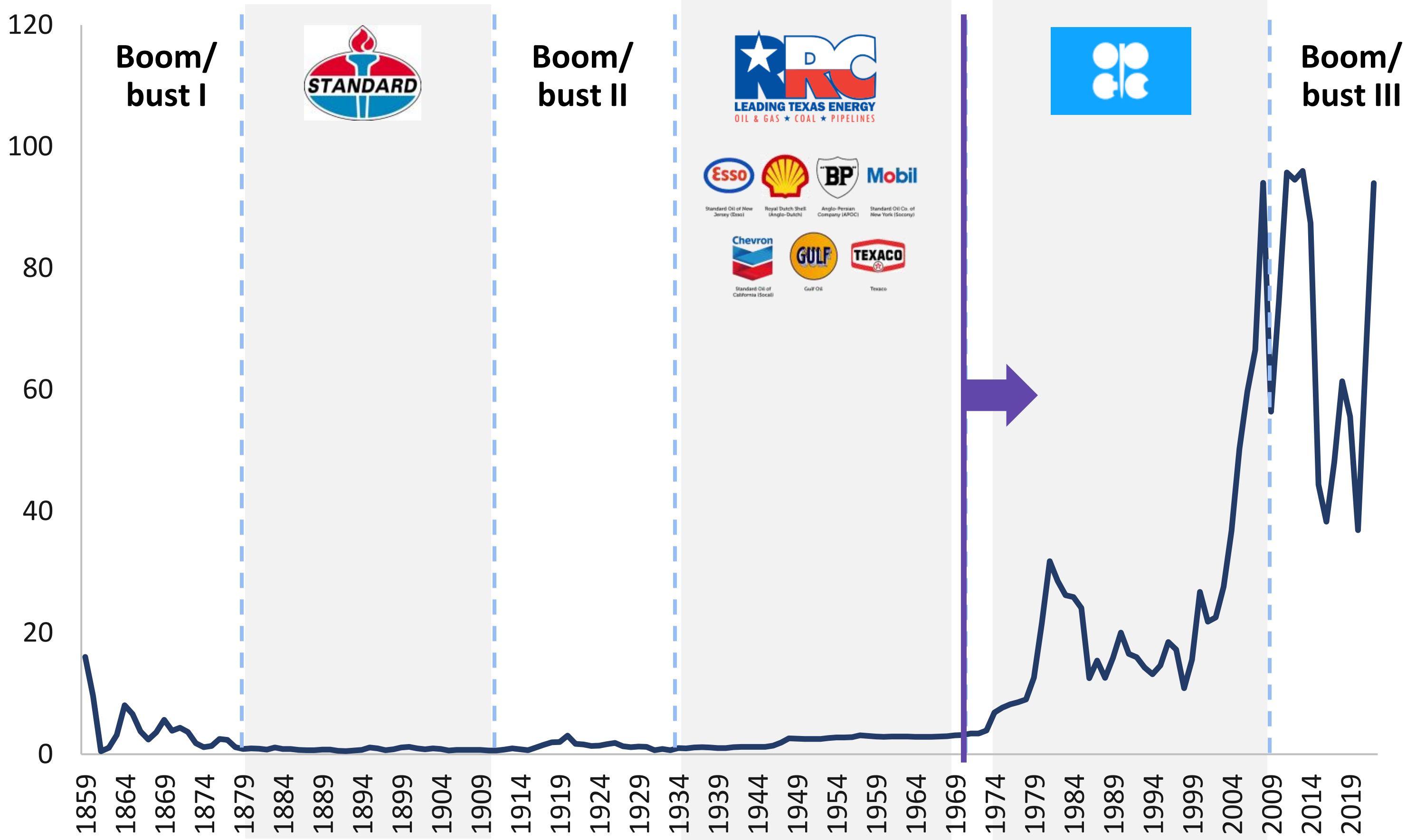
- When there is an announced increase in tax on gasoline, in the period before implementation consumers are more inclined to purchase a higher amount of gasoline than they normally would and less in the immediate period after, this has been studied in academic literature[2].
- This leads to artificially high calculated gasoline elasticities for studies calculated around these periods

1) Wood et al. (2022); 2) See, among others, Coglianese et al. (2017)
Source: Rystad Energy research and analysis, refrenced reports

Structural changes to the oil market after the 60s make data pre-1970 less relevant

Purchase price for US Crude oil[1]

Nominal USD/bbl



Difference in the oil market before 1970

The oil market was structurally different before 1970. The U.S. oil market was controlled by the Railroad Commission of Texas (RRC) and the Middle East market was subordinate to the Seven Sisters. Together, the cartels controlled a majority of global production, which resulted in a more stable oil price.

Misestimation of demand elasticity

By using data series starting before 1970, one will misestimate the elasticity of demand. This is because the market was largely regulated before 1970, which meant that supply and demand did not determine the price.

Newer data is more relevant for the future

Data series starting after 1970, and preferably after 2009, best describe the current and most likely future oil and energy market.

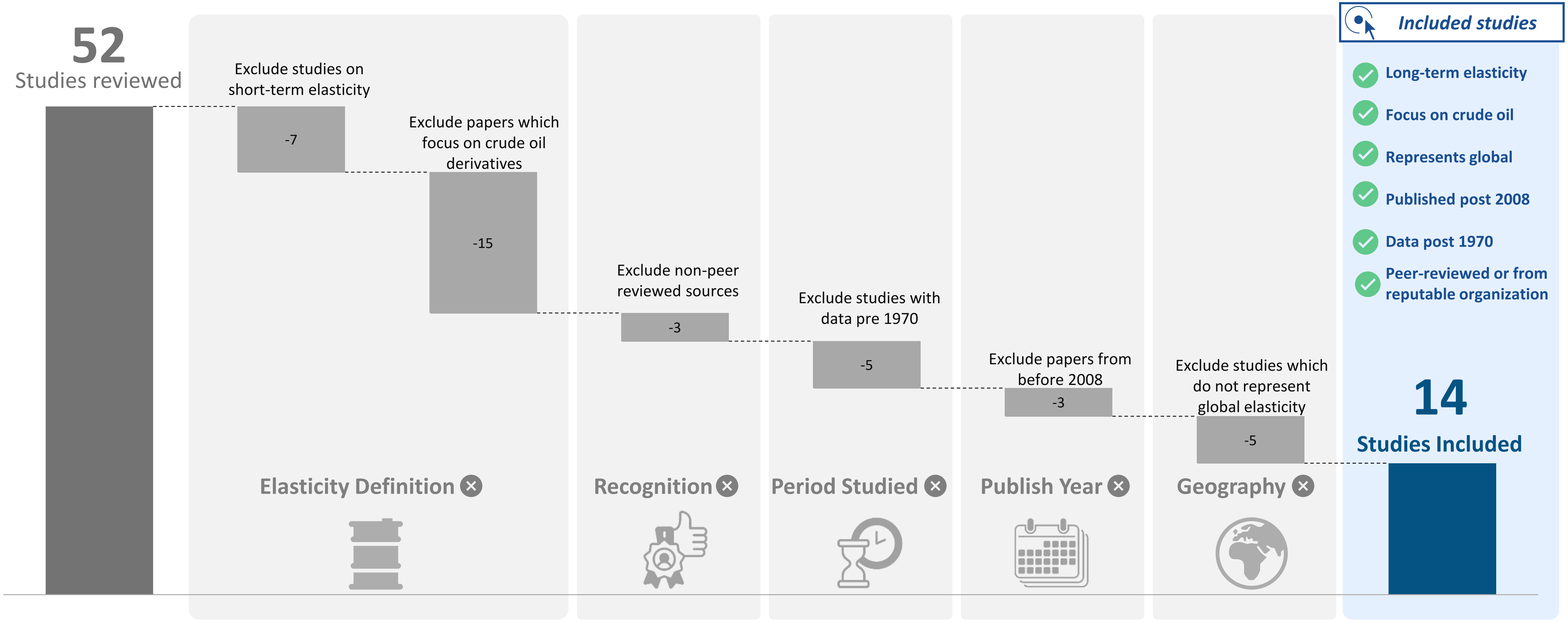
1) US crude oil annual price proxy

Source: Rystad Energy research and analysis

Content

All 14 studies included in the assessment meet key criteria

Methodology to identify relevant literature on long-term demand elasticity of crude oil



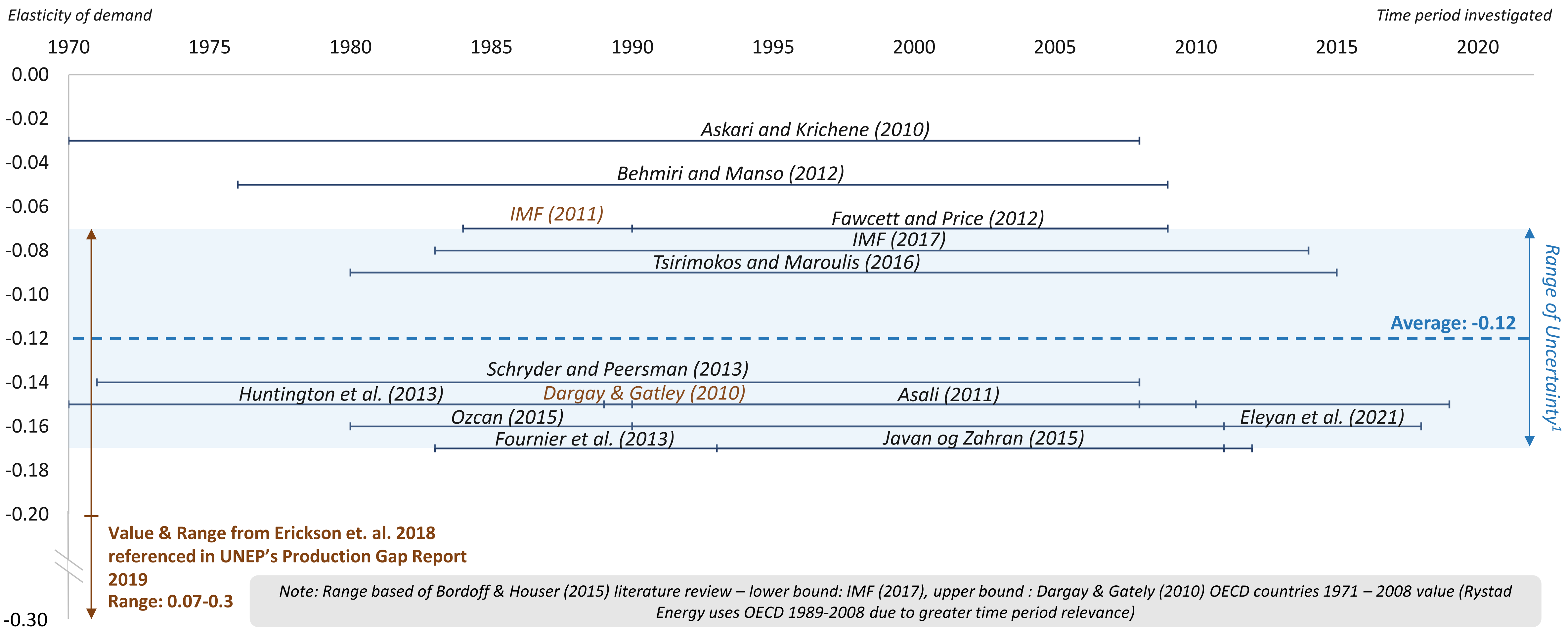
Included studies

- ✓ **Long-term elasticity**
- ✓ **Focus on crude oil**
- ✓ **Represents global**
- ✓ **Published post 2008**
- ✓ **Data post 1970**
- ✓ **Peer-reviewed or from reputable organization**

Note: Non-exhaustive list of studies
Source: Rystad Energy research and analysis

The research literature gives an average long-run price elasticity of demand for oil of -0.12

Long-run price elasticity of demand of accepted literature



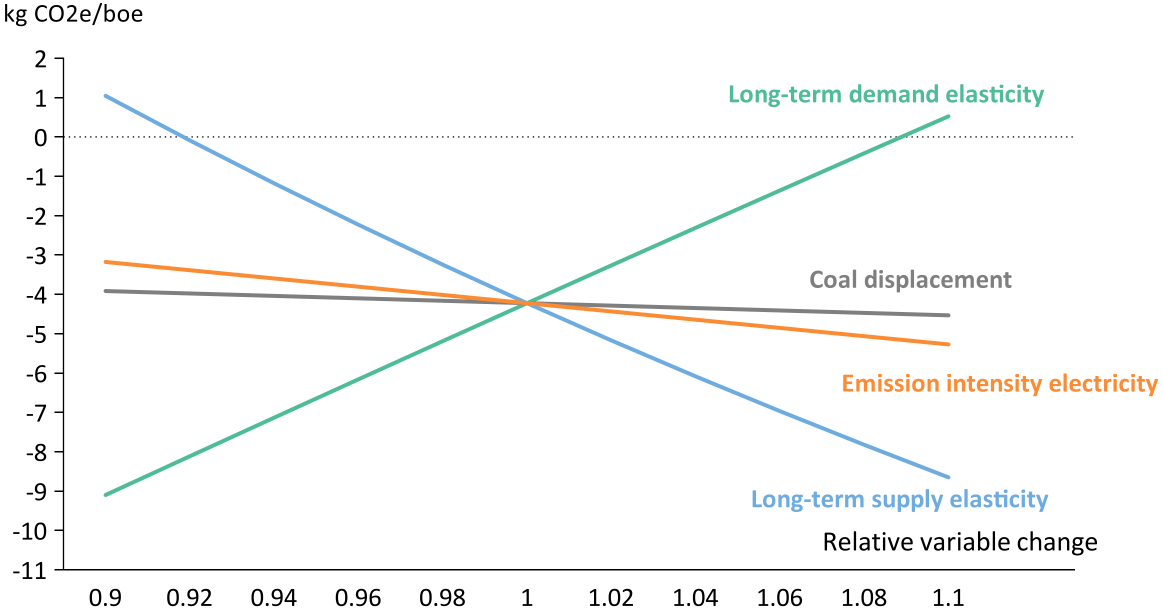
Note: Range based of Bordoff & Houser (2015) literature review – lower bound: IMF (2017), upper bound : Dargay & Gately (2010) OECD countries 1971 – 2008 value (Rystad Energy uses OECD 1989-2008 due to greater time period relevance)

1) Plus or minus one standard deviation from the selected group mean

Source: Rystad Energy research and analysis

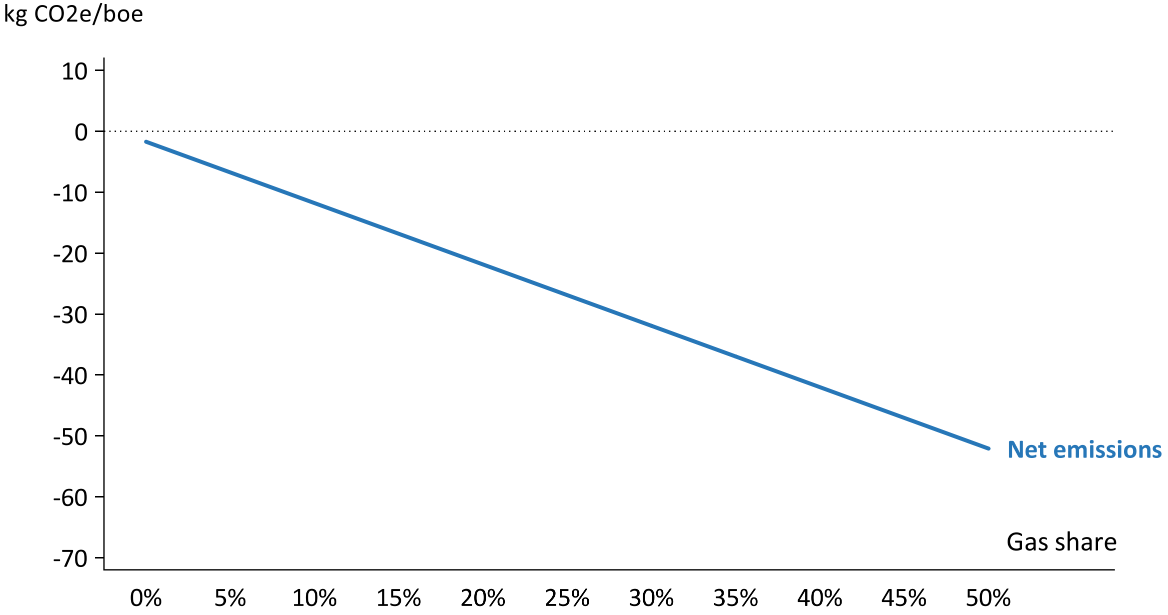
The analysis is most sensitive to assumptions regarding the long-term supply & demand elasticity, with gas share also being a very impactful parameter.

Sensitivities for Breidablikk's net emission impact per boe to parameter assumptions



- Assumptions regarding long-term supply and demand elasticity are the most impactful parameters as they affect how many boe of oil are displaced.
- A 1% increase in oil displacement will lead to a reduction in net global emissions of **4.2 kg CO_2e/boe**.
- Coal displacement is an important factor for fields with a high share of gas, for Breidablikk this is not as important. The assumptions for the emission intensity of electricity, which is displaced by increased oil use, are more important.

Sensitivities for Breidablikk's net emission impact per boe to gas share



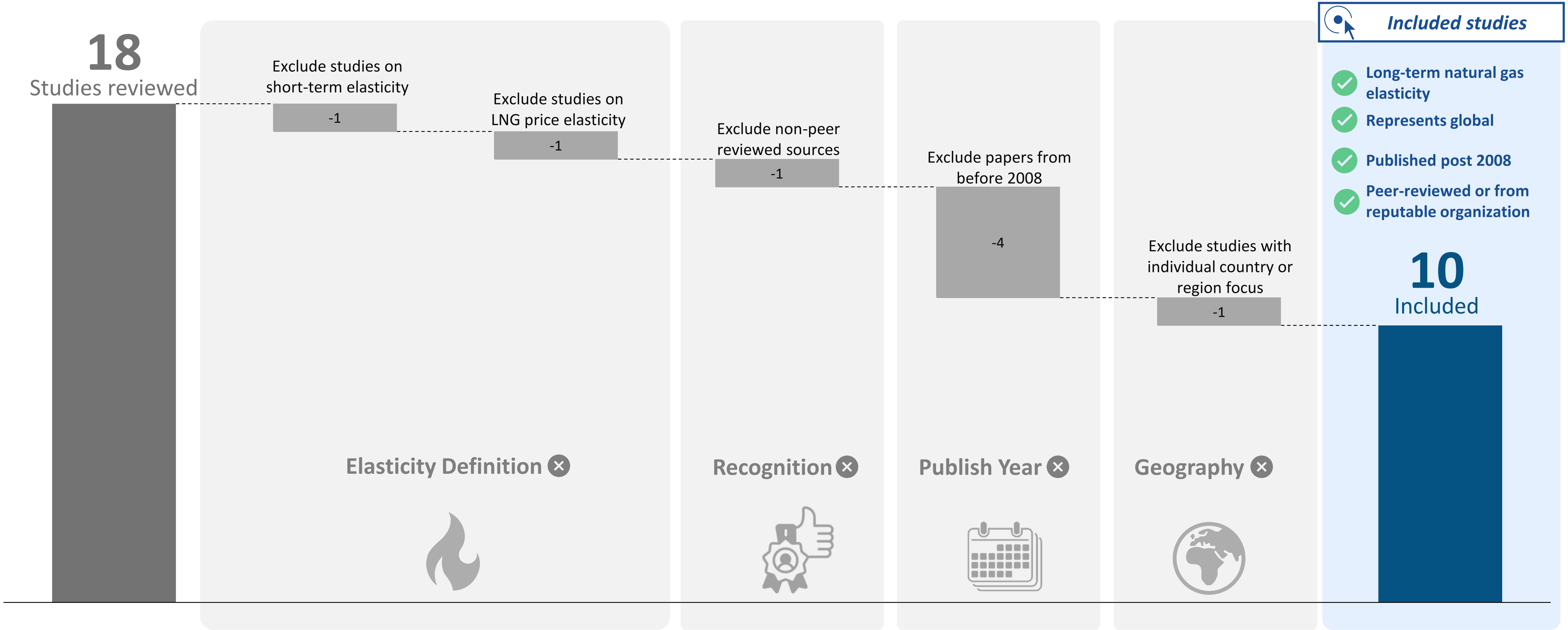
- Net global emissions are highly sensitive to Breidablikk's gas share.
- A 1% increase in gas share will reduce net global emission of **1 kg CO_2e/boe**.
- A 50% gas share will reduce net global emissions of **52 kg CO_2e/boe**.

Source: Rystad Energy research and analysis

Content

All 10 studies included in the assessment meet key criteria for gas

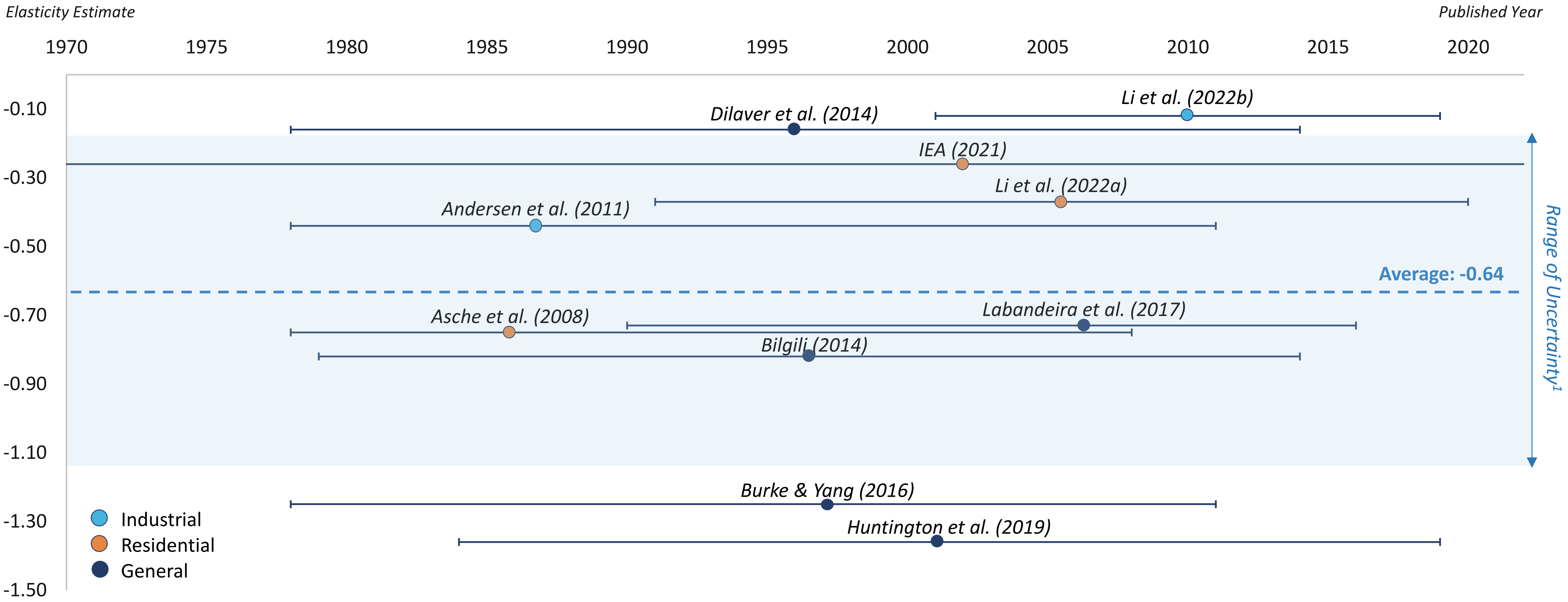
Methodology to identify relevant literature on long-term demand elasticity of gas



Note: Non-exhaustive list of studies
Source: Rystad Energy research and analysis

From the relevant literature, average long run PED for natural gas is -0.64

Long-run price elastcity of demand of accepted literature for natural gas and period of study



1) Plus or minus one standard deviation from the selected group mean
Source: Rystad Energy research and analysis, referenced research articles

Content

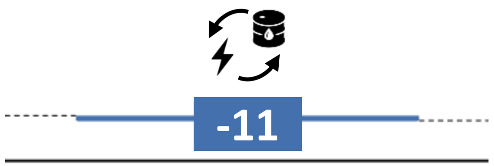
Increased oil and gas consumption from Breidablikk production displaces emissions from EV’s electricity demand and coal-fired power generation respectively

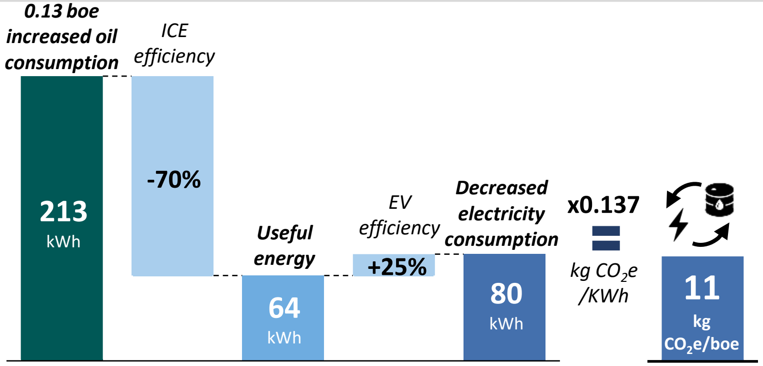
2 Other energy substitution

Approach

Assumptions

Oil production (kg CO_2/boe)

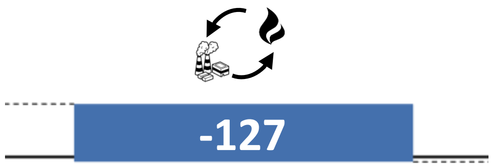


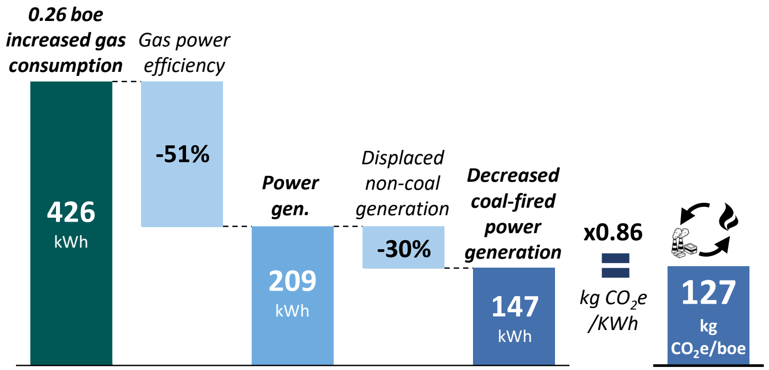


Each boe of oil produced at Breidablikk will displace ***11 kg CO_2e*** *of global emissions from EV electricity demand*

- Useful energy is substituted on 1:1 basis, whereby increased oil consumption decreases EV electricity demand
- Global average power mix emissions intensity of 0.137 kg CO_2e/kWh in 2035 as in IEA APS scenario

Gas production (kg CO_2/boe)





Every boe of gas produced at Breidablikk will displace ***127 kg CO_2e*** *of global emissions caused by coal-power generation*

- Useful energy is substituted on 1:1 basis, whereby increased gas consumption displaces other forms of power generation
- Political ambitions to decarbonize the power mix and decreased gas costs drives coal-fired power generation displacement. Assume 70% of power generation substitution is coal and 30% non-coal, as ~ 70% of LNG volumes is imported to countries with coal-fired electricity generation and stated ambition to phase out
- Global average coal-fired power generation emissions intensity of 0.86 kg CO_2e/kWh

Weighted oil and gas energy substitution impact of -14 kg CO_2e/boe

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA’s “Announced Pledges Scenario”
Source: Rystad Energy research and analysis; Equinor

Increased consumption of oil and gas displaces emissions from electricity and coal-fired power generation respectively

Other energy substitution mechanism

Oil

1 Lower oil prices ↓

A marginal increase in oil supply will result in a marginal decrease in oil prices

2 Lower petrol prices ↓

Lower oil prices mean lower petrol prices

3 Slower electric car transition ↓

A lower petrol price will lead to a marginally slower transition to electric cars globally

4 Decreased power demand ↓

As the transition to electric cars will be slower, there will be marginally lower demand for power

5 Crowded-out emissions from power generation ↑

Substitution of electric cars leads to a decrease in electricity demand and a displacement of emissions from the power that would have gone into powering them.

Gas

1 Lower gas price ↓

A marginal increase in the supply of natural gas will result in a marginal decrease in oil prices

2 Higher gas demand ↑

A marginal decrease in gas prices will result in a marginal increase in gas demand.

3 Increased gas generated power ↑

When gas prices fall, gas becomes more attractive as a power source than its substitutes – the world will then use more gas power.

4 Decreased substitute power production ↓

Given that the world has a given power demand, an increase in gas-fired power will mean that other power production will be displaced.

5 Displaced emissions from substitute power ↑

The displacement of other energy sources also entails a displacement of associated emissions, given that the power displaced is not emission-free.

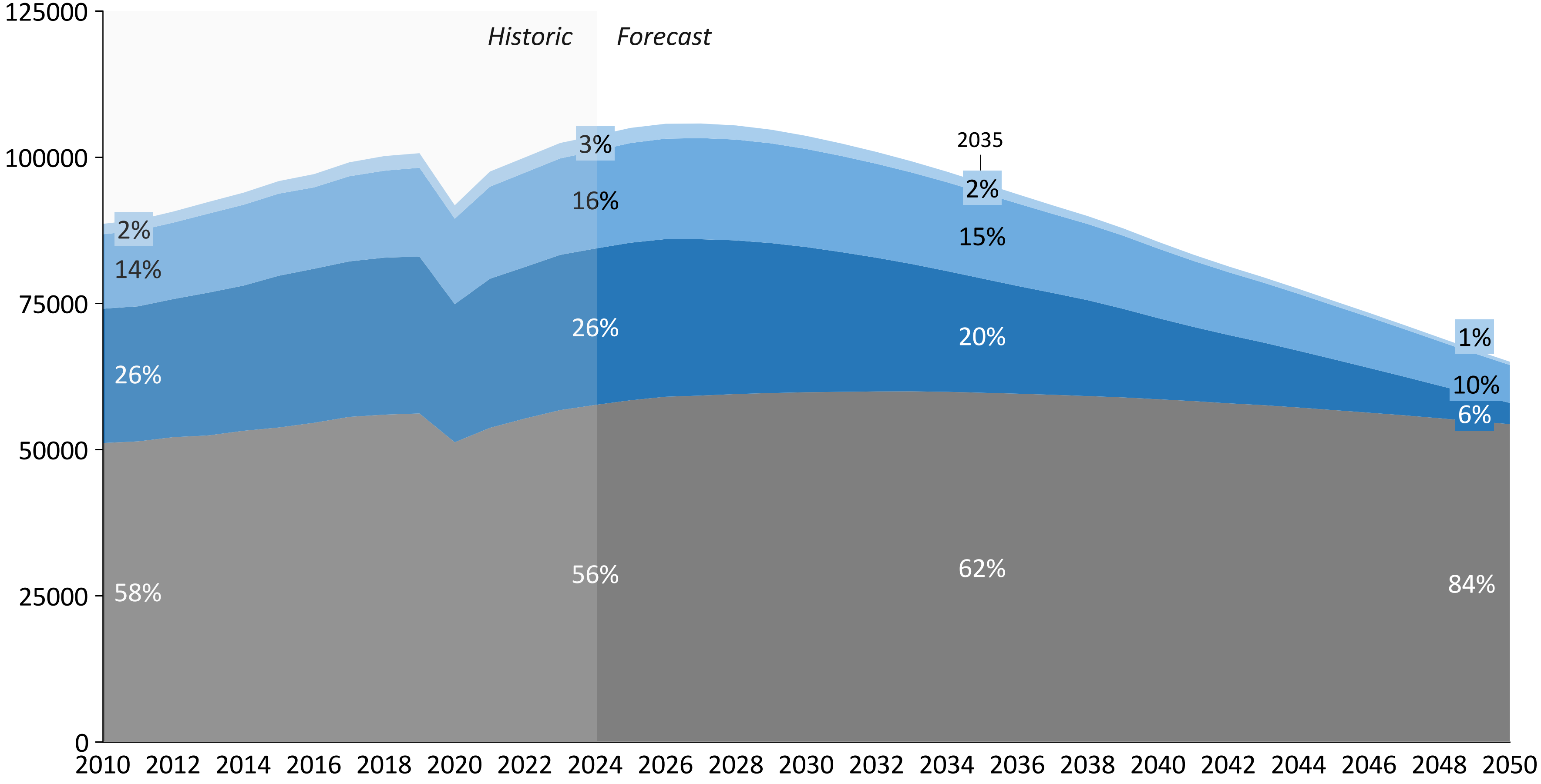
Source: Rystad Energy research and analysis

Content

Oil demand outside the road transport sector is expected to remain nearly constant until 2050

Crude oil demand by sector, 2010 - 2050

kbbl/d & demand share



Buses

*Electrification and the switch to other renewable fuels drive a **-4% annual growth** from 2024 to 2035.*

Trucks

*Have made the least progress in electrification but are projected to see **falling demand at -1% annually** from 2024 to 2035.*

Cars

*Electrification and improved fuel efficiency are expected to moderate demand growth, with a **projected annual growth rate of -3%** from 2024 to 2035.*

Other

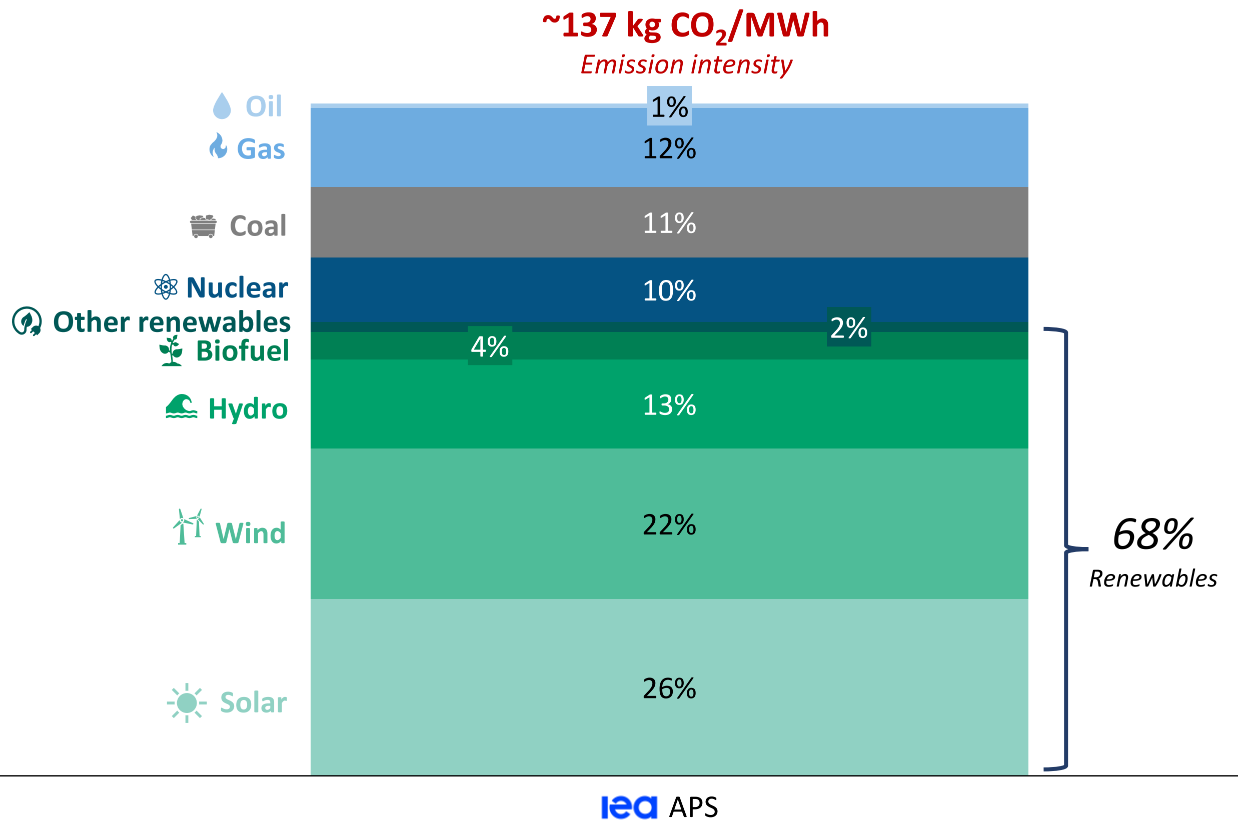
*This sector is expected to experience varied growth rates depending on the adoption of alternative fuels and technologies, with an overall projected **growth rate of around 0.3% annually** from 2024 to 2035.*

Source: Rystad Energy research and analysis, Rystad Energy Long term oil demand model dashboard

Coal and gas have a moderate share of the global power mix in 2035 in IEAs APS scenario

Global power mix in IEAs APS scenario, 2035[1]

TWh



APS (Announced Pledges Scenario) entails a scenario where all governments stick to and achieve their announced pledges

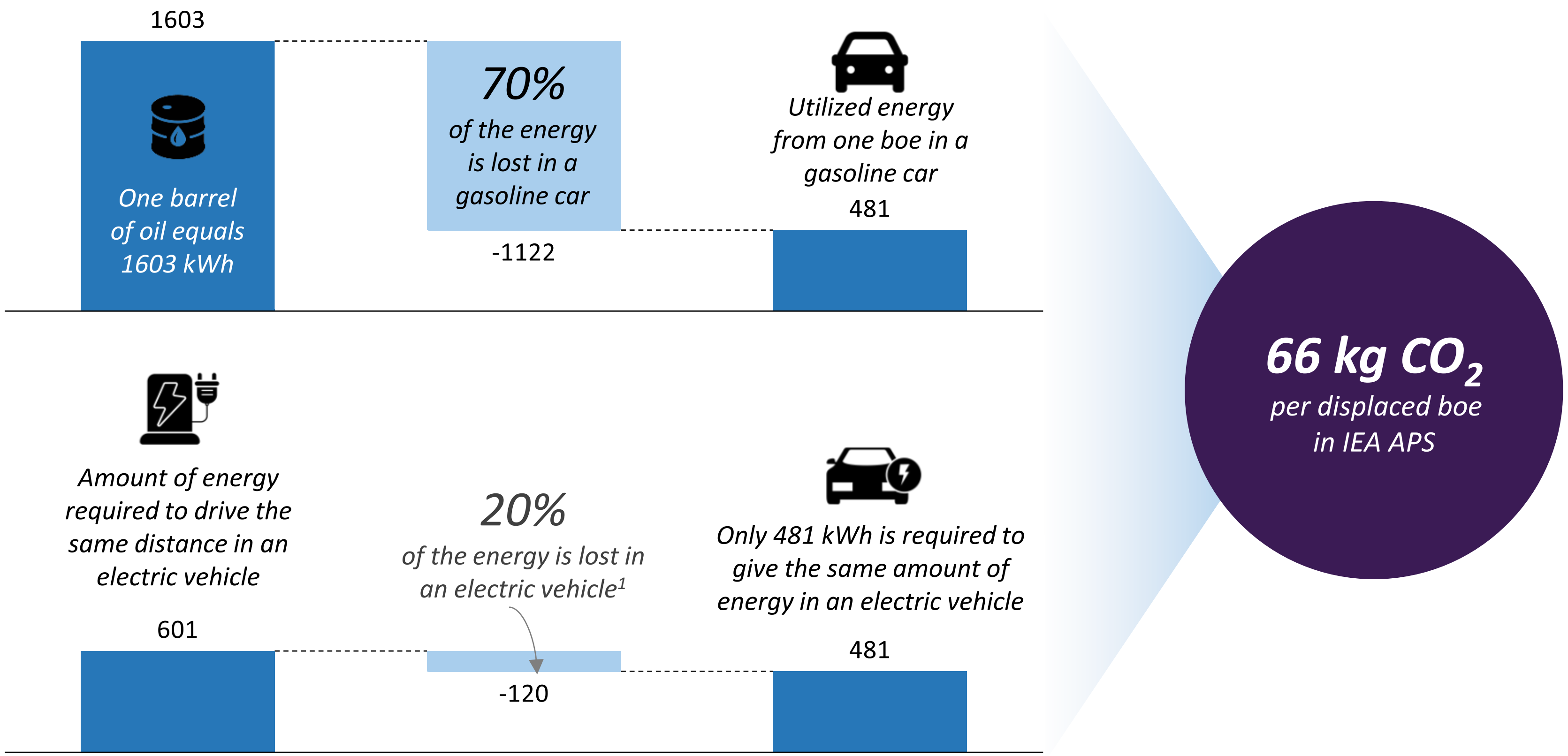
1) Using an assumption of CO_2 intensity(kg/kWh) at 0.86, 0.47 and 0.64 for coal, gas and oil, respectively. The emission intensity is zero for the other energy sources.

Source: Rystad Energy research and analysis; IEA; EPA

Each barrel of increased oil demand from Breidablikk production can displace 66 kg CO_2e from the production of 481 kWh globally

Energy from a barrel of oil in a gasoline car, and the amount of energy required to drive the same distance in an electric vehicle

kWh



- By increasing oil production, it is fair to assume that it will displace power. In the transportation sector, a lower oil price will reduce the adoption of electric vehicles, all else equal.
- Here it is assumed an average efficiency of 30% for gasoline cars and 80% for electric vehicles. Hence, the amount of energy required to drive a given distance with a gasoline car is significantly higher than with an electric.
- The displaced electricity will reduce CO2 from power production. The amount of CO2 displaced is dependent on the scenario. In line with IEAs APS scenario 0.137 kg CO2 per kWh is displaced. This corresponds to 66 kg CO2 displaced per barrel of oil produced.

[1] Hjelkrem et al. (2020). The efficiency is adjusted to reflect the energy use of an average gasoline and electric vehicle.

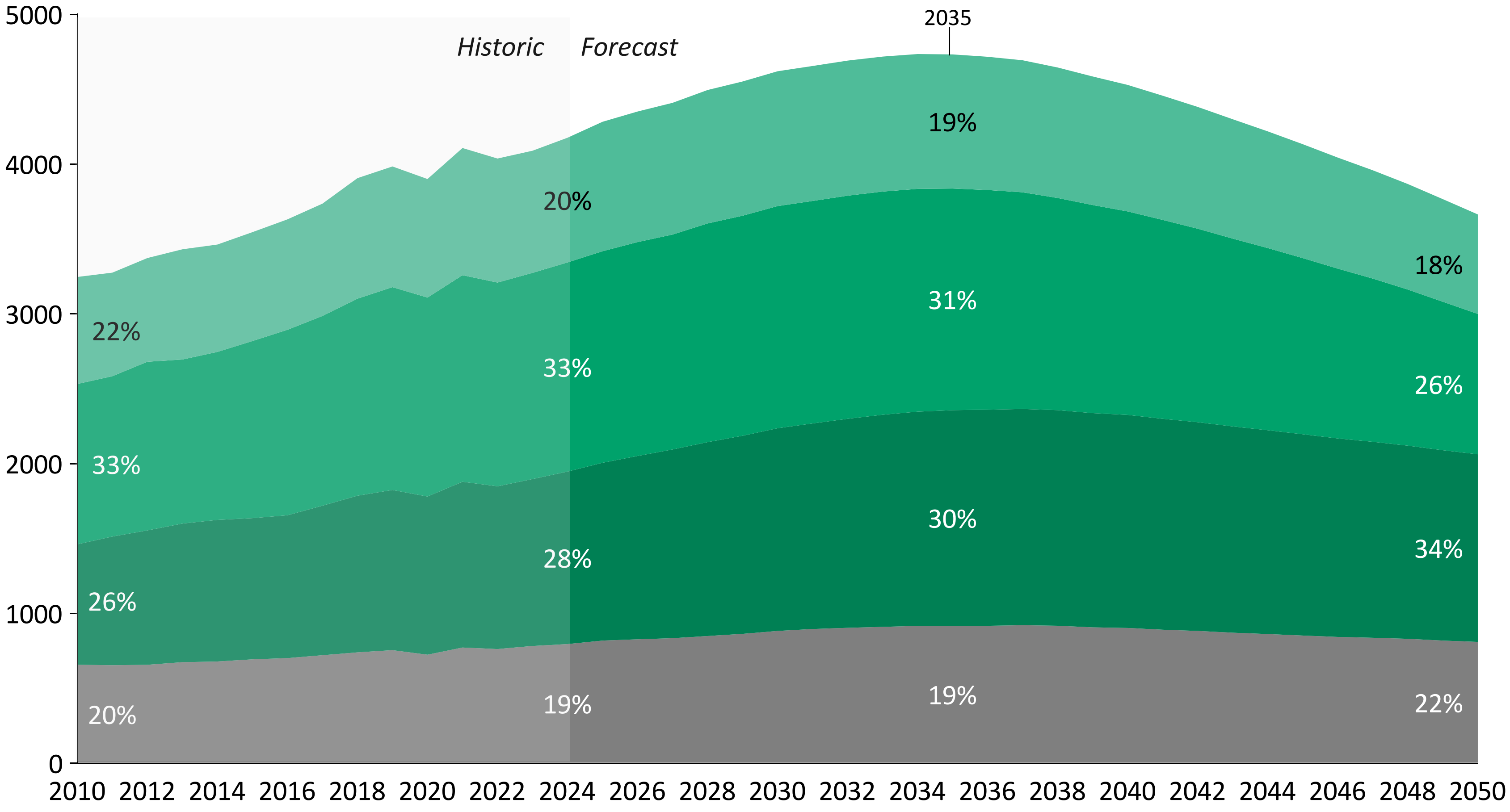
Source: Rystad Energy research and analysis; IEA

Content

The demand mix for gas is expected to remain fairly constant going forward, with industrial use seeing a slight increase relative to other sectors

Natural gas demand by sector, 2010 - 2050

Billion cm & demand share



Buildings

Includes gas delivered via pipelines for heating and cooking in buildings.

Power Generation

Gas-fired power plants that cover baseload and provide necessary balancing in the power grid.

Industrial sector

Includes gas used in the production of steel, cement, hydrogen, and other materials.

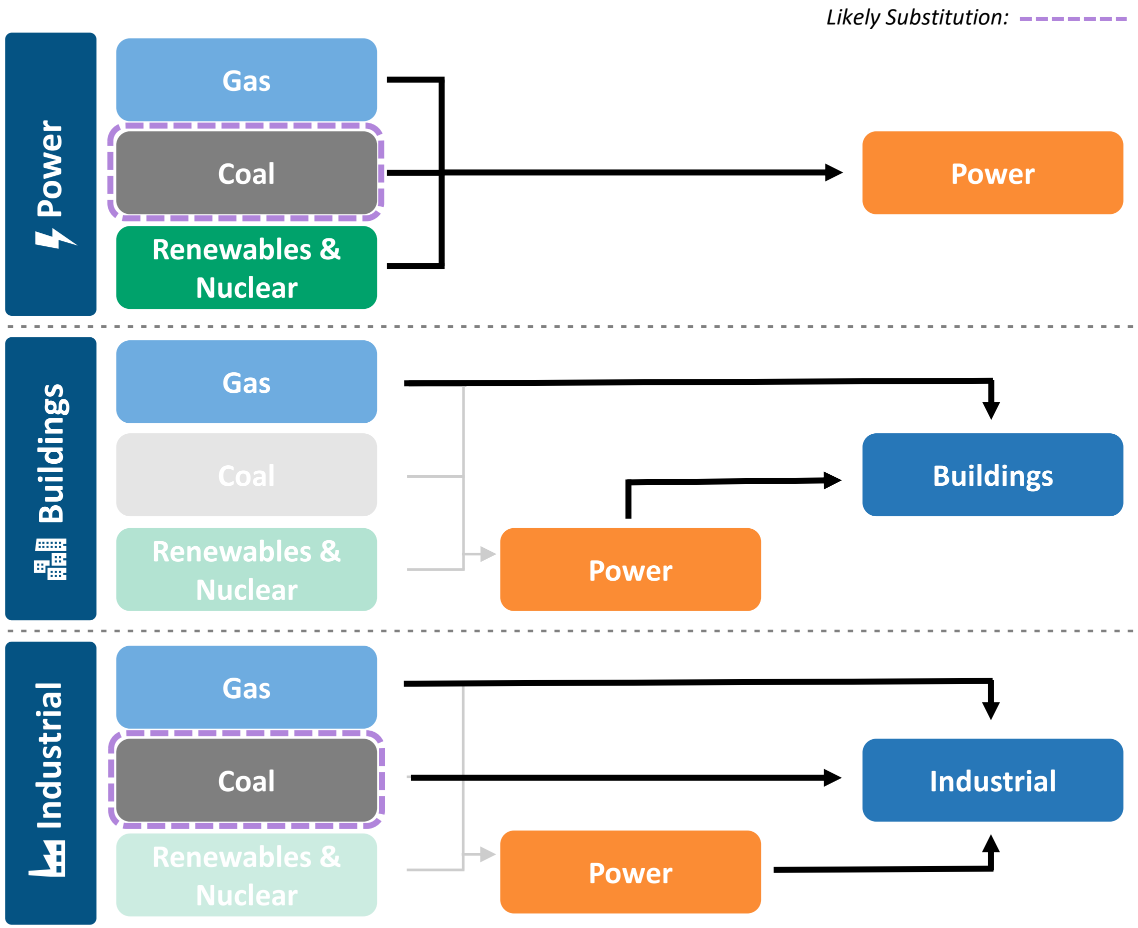
Other Segments

Includes losses in processing, transport, and other minor uses.

Source: Rystad Energy research and analysis; Rystad Energy GasMarketCube

Increased gas supply from Breidablikk will crowd out emissions-intensive coal consumption

Simplified energy system relevant to gas



Likely Substitution: - - - - -

Power

Gas

Coal

Renewables & Nuclear

Power

- An increased gas supply will likely displace either coal, renewable or nuclear-powered electricity generation with gas-fired power.
- Coal is more expensive than other energy sources, making a shift to gas likely. Although coal will remain significant in the 2035 energy mix, existing global gas capacity can absorb additional use without new investments, making coal-to-gas substitution feasible.

Buildings

Gas

Coal

Renewables & Nuclear

Power

Buildings

- Breidablikk gas will lead to 2 key effects, all else equal. On one hand, gas prices will decrease marginally. On the other hand, this price decrease will also be reflected in electricity production, and because gas, along with coal, serves as a marginal electricity producer, this will decrease electricity prices.
- While gas and electricity prices may decrease, their relative price relationship remains stable. Hence a shift in demand between them is unlikely, keeping the distribution of the demand largely unchanged.

Industrial

Gas

Coal

Renewables & Nuclear

Power

Industrial

- For power to be a likely alternative to gas it requires industries to electrify their operations however, for many industries this is unlikely in the short & medium term.
- In the short term, switching from coal to gas is technically and economically feasible, so increased gas supply and lower prices will likely cause coal displacement. In the medium to long term, while lower gas prices may reduce electricity costs, as with buildings, a stable gas-price relationship makes further substitution unlikely.

Source: Rystad Energy research and analysis

New natural gas supply will likely displace coal therefore the development of renewables will hardly be affected

Why renwables are unlikely to be effected by increased natural gas production

1 Gas price competiveness vs coal

- By increasing the global gas supply due to Breidablikk production, from a purely economic theory standpoint natural gas prices will decrease.
- From historical data, a decrease in gas prices corresponds to a decrease in coal demand, and vice versa. This suggests that gas-coal switching is an embedded mechanism into the global energy system.

2 Favourable politcial policies

- Many regions have political targets for increasing the share of renewable energy. In line with this, an increasing number of renewable projects receive subsidies or enter into PPA agreements.
- At the same time, fossil power plants are exposed to rising fuel prices and expanding carbon taxes, enhancing the price competitiveness of renewable energy compared to fossil power.

3 Politcial ambitions of LNG Importers

- Breidablikk gas supply will lead to a global decrease in LNG prices and lead to higher gas demand in LNG-importing countries.
- Most of these countries have both their power mixes and political measures aligned with goals for 2035 that support the displacement of coal.

Impact of 3 key factors

- Within electricity production, buildings, and industry, gas is largely the only relevant substitute for coal. However, in the power sector, new gas supply risks displacing new renewable capacity.
- As analyzed, from a cost and political perspective, renewables displacement is unlikely. In most scenarios, there is still coal in the power mix that can be displaced by 2035. Additionally, there is sufficient unused capacity in gas power plants so that new gas supply can be absorbed without incurring new investment costs regarding building new gas-fired facilities.

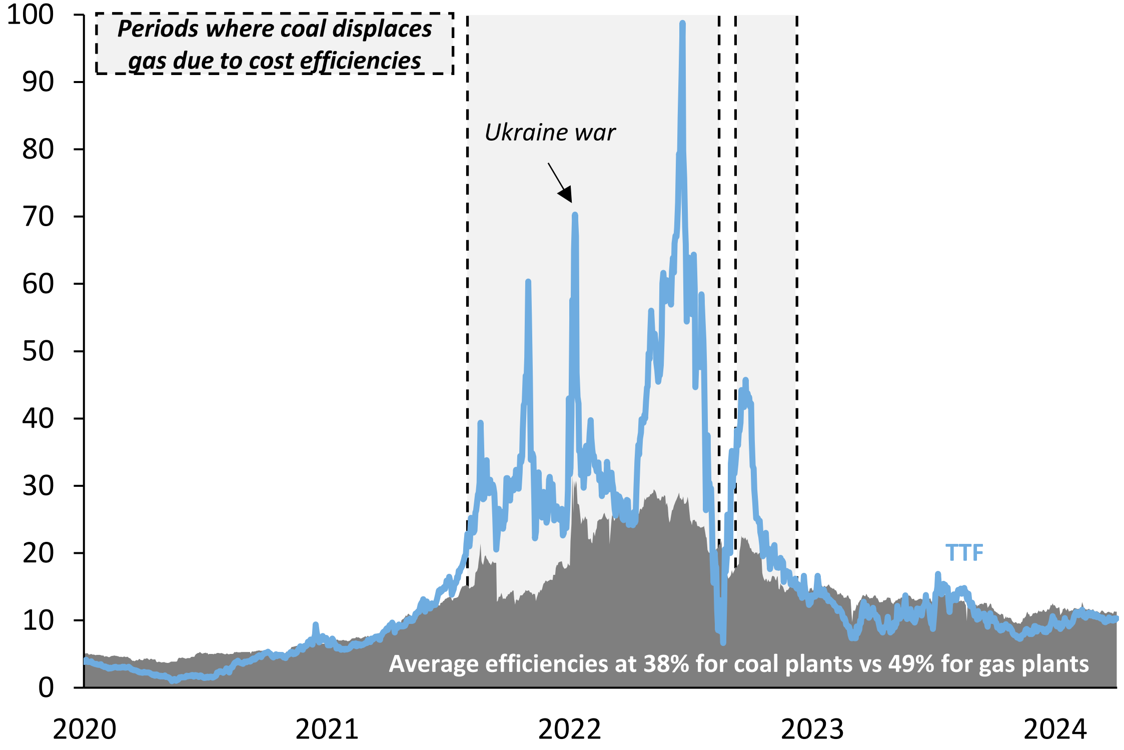
Source: Rystad Energy research and analysis

Breidablikk production will contribute to lower global gas prices, increasing the displacement of coal in the energy system

European gas prices vs coal-switching price in Europe

USD per million British thermal units (MMBtu)

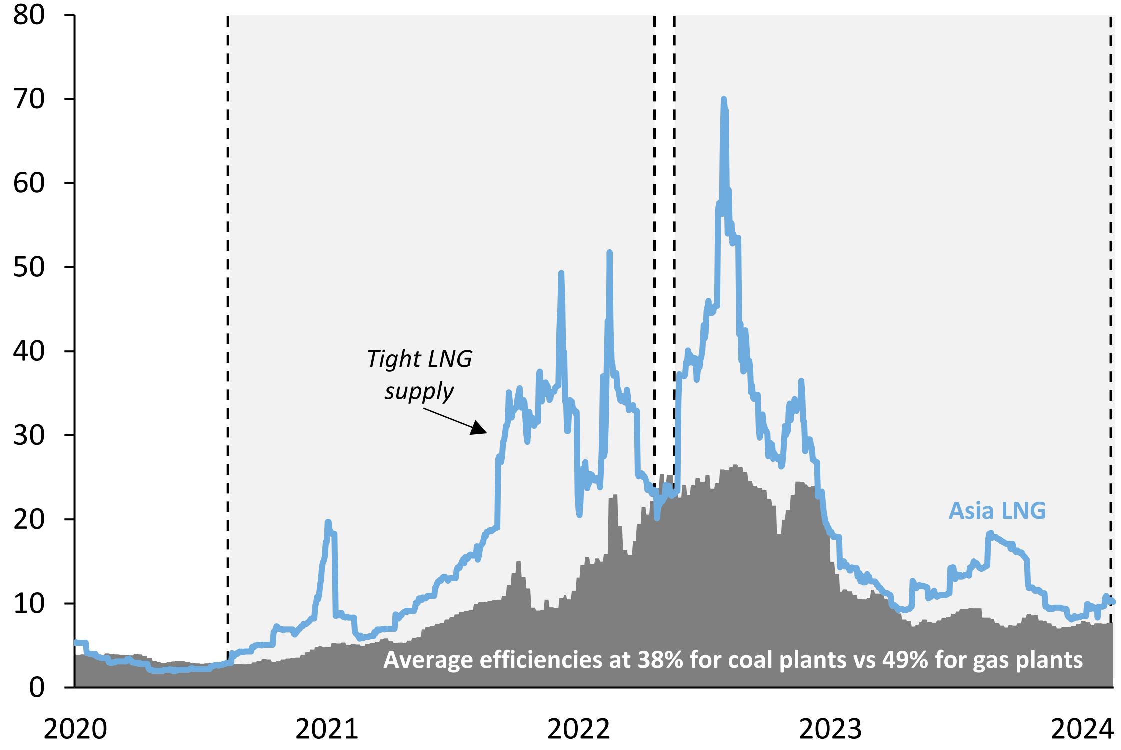
The switching point between coal and gas is determined by the relative cost between the gas price (TTF) and the coal price (ARA), and the corresponding switching points. In Europe, gas was the optimal power source 60% of the time, in the relevant time period.



Asian LNG prices versus coal-switching price

USD per million British thermal units (MMBtu)

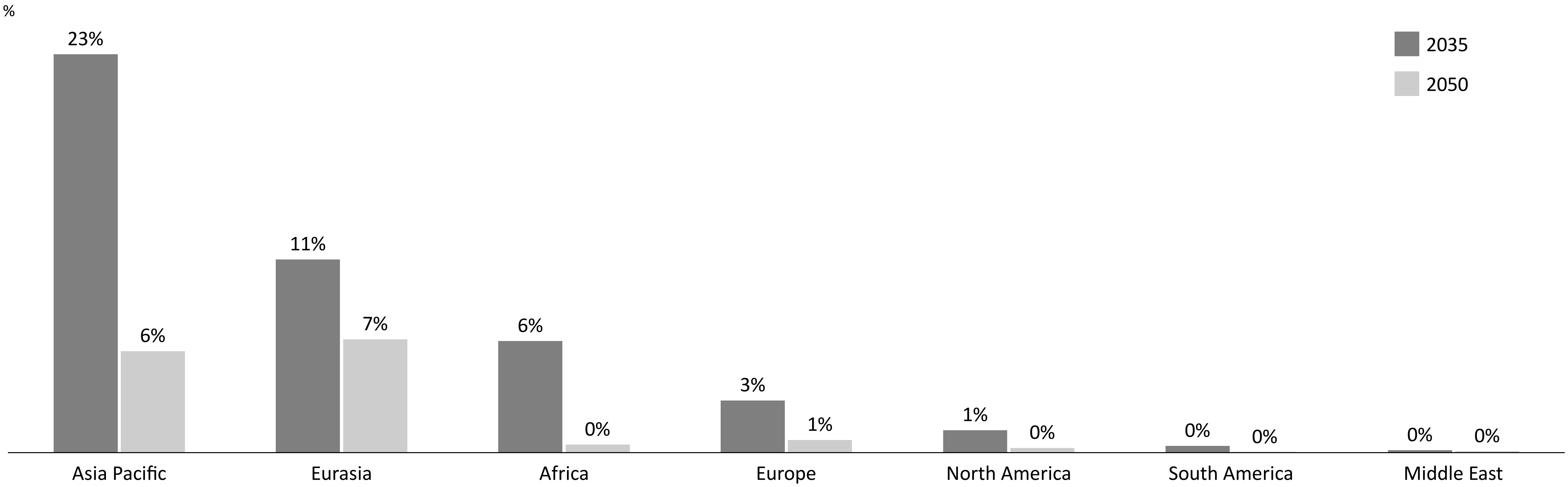
The switching point between coal and gas is determined by the relative cost between the gas price (Asia LNG) and the coal price (Newcastle CIF), and the corresponding switching points. In Asia, coal was the optimal power source 84% of the time, in the relevant time period.



Source: Rystad Energy research and analysis; Rystad Energy GasMarketCube; Bloomberg; Refinitiv

Coal phase-out is accelerating, but coal power still makes up a large proportion of the Asian power mix in 2035

Share of coal in the power mix in different regions, IEA APS scenario



- In 2035, Coal makes up more than 20% of the power mix in the Asia Pacific region, representing a significant share of power generation that can be displaced by other energy sources
- Asia also accounts for majority of LNG demand outside of Europe, with lower gas prices incentivizing a faster substitution away from coal-fired power generation.

Source: Rystad Energy research and analysis; IEA

Furthermore, various academic literature and media reports observe gas-coal displacement

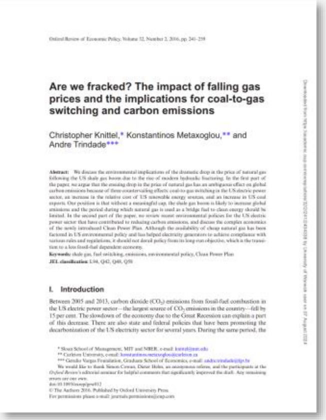
Decreasing natural gas prices

Acedemic studies have observed that low natural gas prices in the 2010s directly lead to a significant shift away from coal-fired generation and towards gas-fired generation.

Examples

Are we fracked? The impact of falling gas prices and the implications for coal-to-gas switching and carbon emissions

Knittel et al. (2016)



Oxford Review of Economic Policy, Volume 32, Number 2, 2016, pp. 241–259

Are we fracked? The impact of falling gas prices and the implications for coal-to-gas switching and carbon emissions

Christopher Knittel,* Konstantinos Metaxoglou,** and Andre Trindade***

I. Introduction

The Effects of Fuel Prices, Environmental Regulations, and Other Factors on U.S. Coal Production, 2008-2016

Coliganese et al. (2018)

The Effects of Fuel Prices, Environmental Regulations, and Other Factors on U.S. Coal Production, 2008–2016

ABSTRACT

We decompose the decline in coal production from 2008 to 2016 into the contributions of several sources. In particular, we estimate the effects of declining natural gas prices and the introduction of new environmental regulations along with several other factors, using both monthly state-level data and annual information on coal plant closings. We estimate that the declining price of natural gas relative to coal is responsible for 92 percent of the total decline in coal production over this period and that environmental regulations account for an additional six percent, with other factors making small and offsetting contributions.

Keywords: Energy transition, Electricity, Environmental regulation

1. INTRODUCTION

From 2008 to 2016, U.S. coal production fell 37 percent, from 1,172 million short tons to 739 million short tons (EIA, 2017). During this period, carbon dioxide (CO_2) emissions from coal-fired power plants fell by 718 million metric tons, although some of those reductions were offset by increased CO_2 emissions from natural gas for power generation. The decline in coal CO_2 emissions drove a 23 percent reduction in total power sector CO_2 emissions 2008 to 2016.

55

Increasing natural gas prices

Recent reports from media sources have linked high post-pandemic natural gas prices to rising coal-fired energy generation.
(note: there is a lack of acedemic reports on this topic as of yet due to its recency)

Examples

Carbon-heavy but cheaper coal to replace gas in European power mix this winter

Reuters (2024)

Carbon-heavy but cheaper coal to replace gas in European power mix this winter

By Forrest Crellin and Vera Eckert

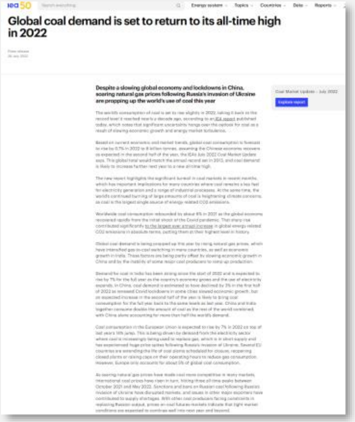
Summary
- Coal power to get cheaper than gas, carbon prices also retreat
- Winter coal margins favoured by carbon prices trends
- Gas seen rising on tight LNG, looming Russia stop, Norway curbs

PARIS/FRANKFURT, July 10 (Reuters) - A rise in European wholesale gas prices over the past several months could encourage more utilities to switch to coal for electricity generation this coming winter, even as countries try to push the carbon-intense fuel out of the power mix.

While many European countries, such as France, Britain and Italy, have already either phased out coal completely or have limited scope for large-scale gas-to-coal switching, it remains a key part of the power mix in Europe's number one energy consumer Germany, and much of eastern Europe.

Global coal demand is set to return to its all-time high in 2022

IEA (2022)



Global coal demand is set to return to its all-time high in 2022

Despite a slowing global economy and lockdowns in China, soaring natural gas prices following Russia's invasion of Ukraine are propping up the world's use of coal this year

Source: Rystad Energy research and analysis, referenced reports

Favourable politcial policies and increased fossil fuel costs can further increase the competiveness of renewables

Key drivers of reduced renewables costs

1. **Political objectives** for an increased share of renewables in their energy mix
2. **Subsidies** that reduce costs directly through employment, technological development etc.
3. **PPA agreements**[1] which reduce costs indirectly through fixed, long-term income and thus lower risk and return requirements for projects

Key drivers of increased fossil fuel costs

1. Level of volatility in **fuel prices** can lead to uncertainty and increase the return requirements to ensure a positive net present value in turbulent markets
2. **Carbon taxes** in several regions reduce the competiveness of fossil energy sources
3. **Investment costs** for new capacity will increase the capital requirements and the unit cost of generating non-renewable power

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1) Power Purchase Agreements (Agreements made in advance to purchase a pre-detirmined amount of energy for a fixed priced)

Source: Rystad Energy research and analysis, NREL, IEA

Around 70% of LNG in 2035 will be exported to regions where the displacement of coal is likely

The additional supply of gas from Breidablikk injected into world markets will impact global LNG prices, the increased gas demand will be driven by LNG importers. The table below assesses whether the marginal increase in world gas supply from Breidablikk is more likely to displace coal or another non-gas energy source based of assessing top world LNG importers by 3 key criteria.

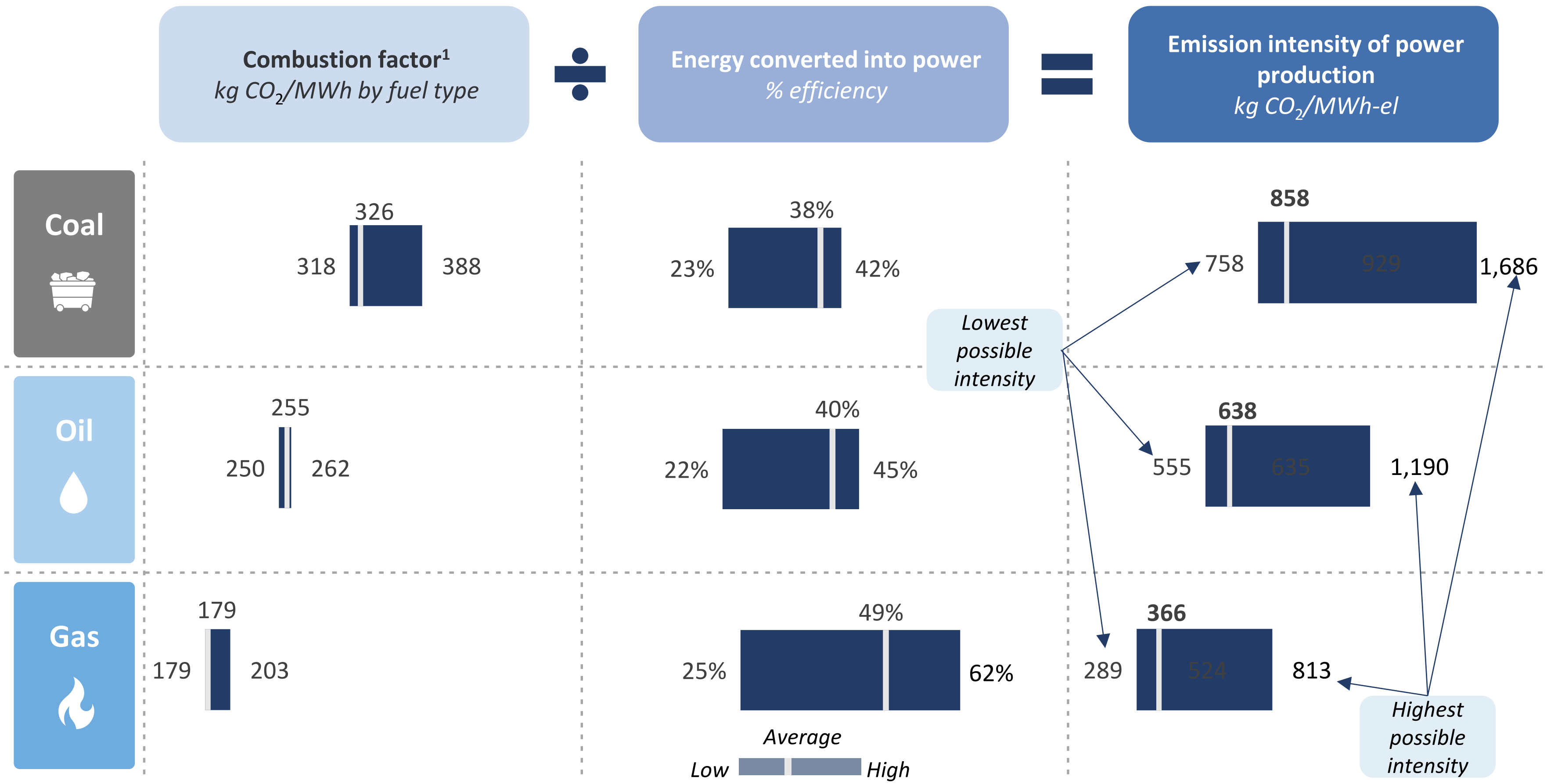
LNG Importer	LNG Import Share (2035)	Remaining Coal Power	Free Gas Capacity	Political Renewable Focus	Displaced Energy Source	Comment
China	22%	✓	✓	✓	✓ **Coal**	*Clear ambitions for increasing renewables share in their energy mix as demonstrated by commitment to offshore wind*
EU	19%	✓	✓	✓	✓ **Coal**	*Aims to grow renewables share in energy mix from 23% in 2022 to at least 42.5% in 2030*
Japan	8%	✓	✓	✓	✓ **Coal**	*Announced government policies aim to significantly increase nuclear power generation*
South Korea	7%	✓	✓	✓	✓ **Coal**	*High capacity factors in offshore wind power generation are a key driver of renewable development*
Thailand	4%	✓	✓	✓	✓ **Coal**	*Plans to increase the share of renewable energy from 20% to 51% by 2027 in their Power Development Plan*
Pakistan	4%	✓	✓	✓	✓ **Coal**	*Plans to shift to 60% renewable energy and ban all coal imports*
Malaysia	3%	✓	✓	✓	✓ **Coal**	*Government aims for 40% renewable energy by 2035 as announced in the national energy policy (NEP)*
Taiwan	3%	✓	✓	✓	✓ **Coal**	*Increasing natural gas production by converting coal-fired boilers to natural gas fired*
	$\sum$ LNG Import Share $\approx$ 70%					
India	6%	✓	✓	✗	✗ **Unsure**	*Does not plan to decrease coal reliance to deal with high projected future energy demand caused by rapid urbanization*
Bangladesh	4%	✓	✓	✗	✗ **Unsure**	*Uncertain targets and plans in renewable energy makes coal displacement unlikely*
Indonesia	3%	✓	✓	✗	✗ **Unsure**	*Recent continued growth in coal exports, currently being the largest exporter gloablly and therefore is unlikely to reduce coal dependence*
Others	16%	✗	✗	✗	✗ **Unsure**	*No displacement of coal is assumed as a conservative estimate for the rest of the world*

Source: Rystad Energy research and analysis; Rystad Energy PowerCube

Coal is more than twice as CO_2 intensive as gas on average

Emission intensities for fossil fuels

kg CO_2 per kWh



- For coal, the average combustion factor is set to the coal mix used in power generation
- For oil and natural gas, it is set to an unweighted average of the combustion factors of various forms.
- Average efficiencies are weighted on a global level, while the extremes are based on observed high and low efficiencies of individual power plants worldwide.

1) Extremes are determined by nine different qualities of coal, three different oil distillates plus crude oil, and natural gas and ethane.

Source: Rystad Energy research and analysis; Guidehouse (International comparison of fossil power efficiency and CO_2 intensity - Update 2018); EPA (Greenhouse Gas Inventory Guidance: Direct Emissions from Stationary Combustion Sources)

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Displaced oil supply has >2x and gas supply >10x the emissions intensity compared to volumes from Breidablikk

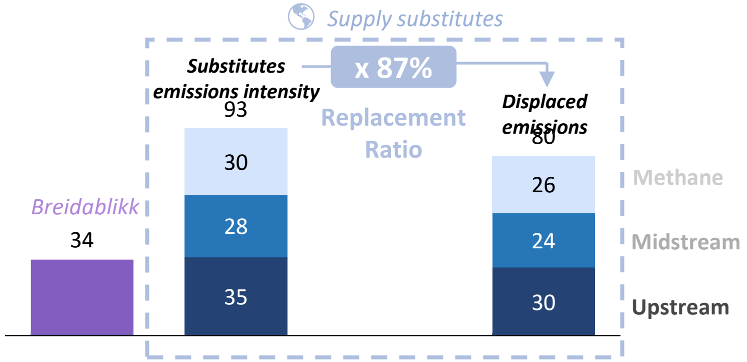
3 Production intensity impact

Approach

Assumptions

Oil production (kg CO_2/boe)

Upstream: 35
Midstream: 28
Methane: 30
x 87%

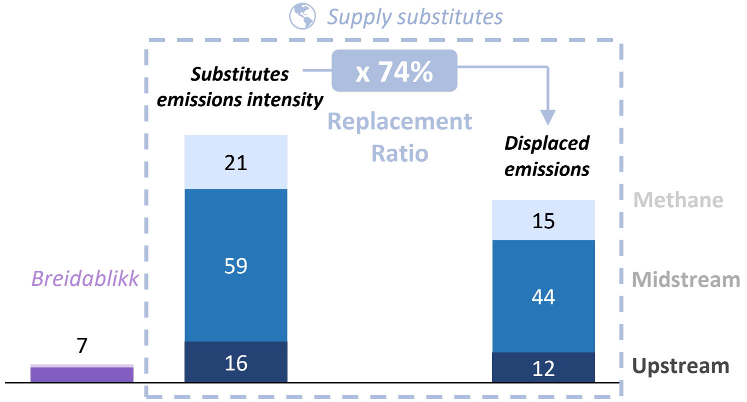


*Each barrel of oil produced at Breidablikk will displace **80 kg CO_2e** of global production emissions from substitute sources of oil production*

- Breidablikk oil production substitutes marginal global oil supply as more expensive oil supply will be displaced by Breidablikk oil production
- Average upstream, midstream, and methane intensities for global oil production with breakeven above 50 USD/boe are used
- Only upstream methane emissions are included

Gas production (kg CO_2/boe)

Upstream: 16
Midstream: 59
Methane: 21
x 74%



*Every boe of gas produced at Breidablikk will displace **71 kg CO_2e** of global production emissions from substitute sources of gas production*

- US LNG is the marginal supplier to European market
- Breidablikk gas production will displace US LNG as it is more expensive than pipeline imports
- Emissions intensity of US LNG delivered in Europe is used
- Both upstream and midstream methane emission sources are considered

Weighted oil and gas production impact of **-80 kg CO_2e/boe**

Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

Increased production of oil and gas leads to a marginal increase in global oil and gas consumption and therefore emissions

Production intensity impact mechanism

Oil

1 Decreased other oil supply ↓

Breidablikk's oil supply will lead to an increase in Norwegian oil exports, affecting the global oil market dynamics as calculated in step 1 (oil replacement.) For every barrel of oil produced by Breidablikk, it will displace a given percentage of a barrel of oil elsewhere, with this value given by the replacement ratio which is a function of supply and demand elasticities

2 Reduced emissions from decreased oil production ↓

The displaced barrels would have directly contributed to global emissions via upstream and midstream operations, also considering methane leakages. Therefore, since these are no longer produced, there is a relative decrease in GHG emissions. The magnitude of this effect is dependent on the global average oil production emissions profile compared to that of Breidablikk production.

Gas

1 Decreased other gas supply ↓

Breidablikk gas production will lead to an increase in European gas supply availability. As US LNG is the marginal price setter for the European gas market, increased European supply will reduce the LNG import demand, effecting the global LNG market dynamics as calculated in step 1 (oil and gas replacement.) For every boe of gas produced by Breidablikk, it will displace a given percentage of a boe of US LNG, with this value given by the replacement ratio which is a function of supply and demand elasticities

2 Reduced emissions from decreased gas production ↓

The displaced boe of gas would have directly contributed to global emissions via upstream and midstream operations, also considering methane leakages. Therefore, since these are no longer produced, there is a relative decrease in GHG emissions. The magnitude of this effect is dependent on the US gas/LNG emissions profile compared of to that of Breidablikk production.

Source: Rystad Energy research and analysis

Three key parameters used as input to calculate total scope 1 and 2 emissions for oil

	Geography	Total emission intensity kg CO_2e / boe	=	Upstream kg CO_2 / boe	+	Midstream kg CO_2 / boe	+	Methane[1] kg CO_2e / boe
Oil	**Breidablikk**	**33** The total emission intensity for Breidablikk in 2035.		**0,4** Upstream intensity for Breidablikk. Using the reference case in 2035.		**33** Oil refinement emissions intensity calculated based om Breidablikk's API values is used for midstream.		**<1** Methane intensity for Breidablikk 2035.
	 **Norway**	**34** The total average emission intensity for Norway in 2035.		**14** Average upstream emission intensity for Norway in 2035.		**20** Average midstream emission intensity for Norway in 2035.		**<1** Methane intensity for Norway in 2035.
	Global	**93** For Global oil production, estimated 2035 numbers are used with a breakeven price above 50 USD. This is the production that is assumed displaced.		**35** Upstream intensity for Global oil production with breakeven price above 50 USD, in 2035.		**28** Midstream intensity for average Global oil refining for oil production with breakeven above 50 USD, in 2035.		**30** Methane intensity for Global oil production in 2035. Values are obtained from IEA Methane tracker 2023, decreasing in line with GMP[2].

Note: The average upstream emission intensity for Norway 2035 is estimated assuming no new electrification of fields. 1) GWP-100 with a factor of 29.87 is used to calculate Methane in CO_2 equivalents; 2) Global Methane Pledge
Source: Rystad Energy research and analysis; Rystad Energy UCube; Rystad Energy EmissionCube

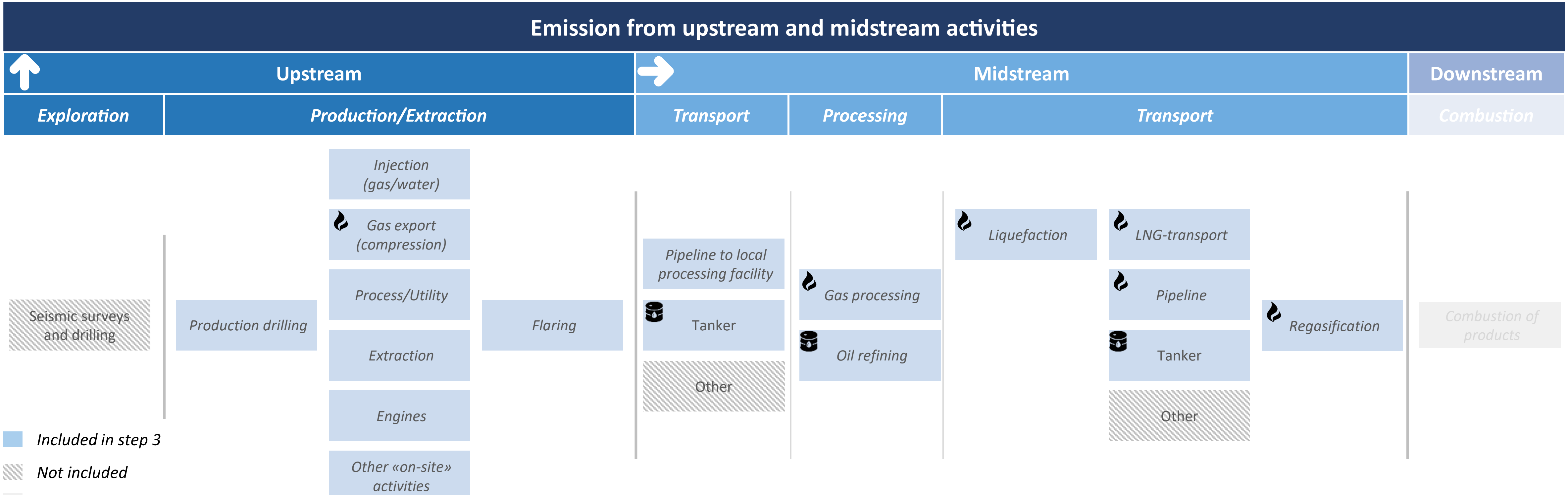
Three key parameters used as input to calculate total scope 1 and 2 emissions for gas

	Geography	Total emission intensity kg CO_2e / boe	=	Upstream kg CO_2 / boe	+	Midstream kg CO_2 / boe	+	Methane[1] kg CO_2e / boe
Gas	**Breidablikk**	**5** The total emission intensity for Breidablikk in 2035.		**0,4** Upstream intensity for Breidablikk. Using the reference case in 2035.		**5** Midstream intensity for Breidablikk in 2035.		**<1** Methane intensity for Breidablikk.
	Norway	**11** The total average emission intensity for Norway in 2035.		**8** Average upstream emission intensity for Norway in 2035.		**3** Average midstream emission intensity for Norway in 2035.		**<1** Methane intensity for Norway in 2035.
	Global	**96** Production from the Breidablikk field would displace LNG from the US as this is the marginal supplier to Europe.		**16** Upstream intensity for LNG produced in the US in 2035.		**59** Estimated midstream intensity for LNG transported from the US to Europe in 2035.		**21** Methane intensity for US LNG, including production and transportation emissions in 2035. Values are obtained from IEA Methane Tracker 2023, decreasing in line with GMP[2].

[1] GWP-100 with a factor of 29.87 is used to calculate Methane in CO_2 equivalents; [2] Global Methane Pledge

Source: Rystad Energy research and analysis; Rystad Energy UCube; Rystad Energy EmissionCube

In step 3 all significant CO_2 emission activities from upstream and midstream are included



Emission from upstream and midstream activities

Upstream

- **Exploration**
  - Seismic surveys and drilling
- **Production/Extraction**
  - Production drilling
  - Injection (gas/water)
  - 🔥 Gas export (compression)
  - Process/Utility
  - Extraction
  - Engines
  - Other «on-site» activities
  - Flaring

Midstream

- **Transport**
  - Pipeline to local processing facility
  - 🛢 Tanker
  - Other
- **Processing**
  - 🔥 Gas processing
  - 🛢 Oil refining
- **Transport**
  - 🔥 Liquefaction
  - 🔥 LNG-transport
  - 🔥 Pipeline
  - 🛢 Tanker
  - Other
  - 🔥 Regasification

Downstream

- **Combustion**
  - Combustion of products

🟦 *Included in step 3*

▨ *Not included*

⬜ *Included in step 2*

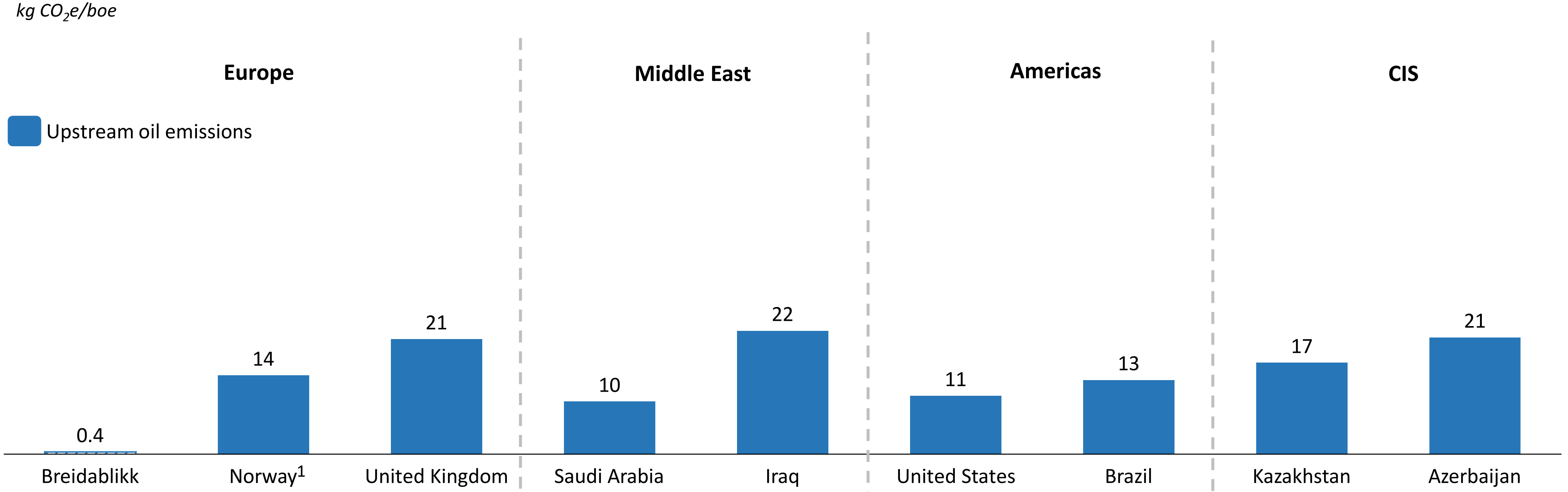
🛢 *Oil-specific*

🔥 *Gas-specific*

Source: Rystad Energy EmissionCube

Breidablikk emissions from upstream activities compete favorably with imported sources to Europe

Weighted average upstream CO_2 emission intensity detail for oil delivered to Europe by supply source - 2035



Breidablikk is estimated to be well below average in Norway in 2035. Norway currently has the lowest intensity with a high share of electrification.

Iraq's high emissions are largely due to extensive flaring, a consequence of poor infrastructure.

The US has low upstream emissions, where the primary source is the extraction process.

Emissions from the two main exporting countries to Europe from CIS are relatively low compared to other sources.

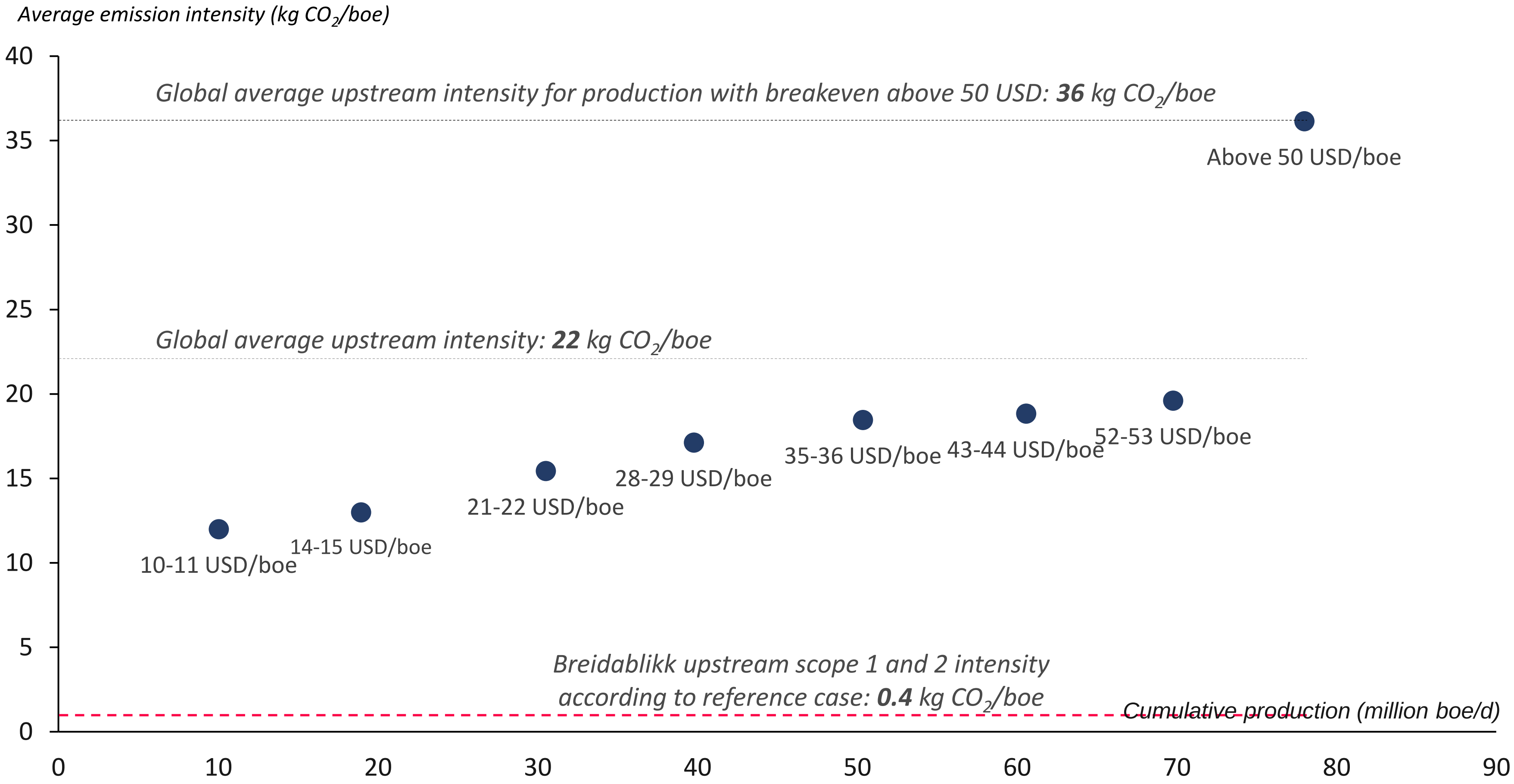
Note: Using the assumption of electrification for Breidablikk.; 1) Weighted average upstream emission intensity for Norway without Breidablikk, the estimate for 2035 assumes no new electrification projects in Norway.
Source: Rystad Energy research and analysis; Rystad Energy UCube; Equinor

Reference case

Step 3

Oil fields with higher breakeven prices are on average also more emission intensive

Average upstream oil CO_2 emission intensities for different groups in 2035, sorted by breakeven price



- The graph shows the distribution between volumes, breakeven prices, and upstream emission intensity for crude oil production.
- The groups along the x-axis are summed to the closest 10 mboe/d from lowest to highest breakeven prices. This means that each group produces approximately 10 mboe/d, and the values on the y-axis show the corresponding CO2 emission per boe.
- In an efficient market, production increases will displace producers with higher breakeven prices. Accordingly, it is reasonable to assume that production from Breidablikk would displace barrels of oil with higher emission intensity and breakeven prices.

Source: Rystad Energy research and analysis; Equinor

LNG imports exhibit the highest emission intensity due to additional processing steps required for utilization

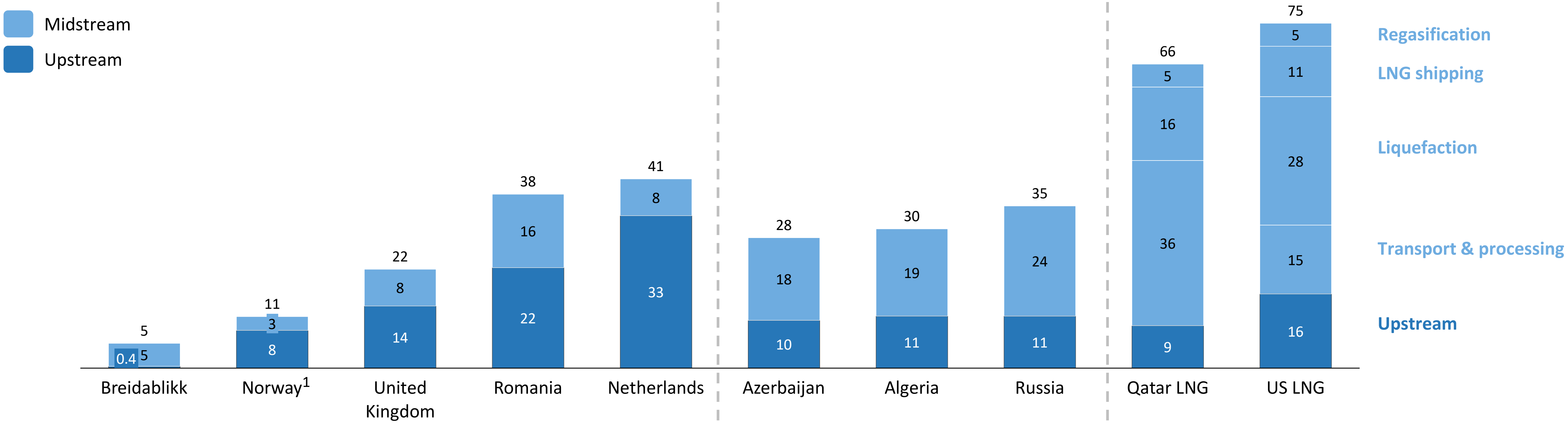
Weighted average emission intensity along the value chain for gas delivered to the Europe by supply source in 2035

kg CO_2e/boe

Domestic supply
Primarily from UK, Netherlands, Norway and Romania

Other pipeline imports
Primarily from Algeria and Azerbaijan

Spot LNG imports
Primarily from US and Qatar



The Breidablikk emissions are expected to be significantly lower than the weighted average emissions for Norway as it is a subsea tieback

On average other pipeline gas import alternatives to Europe are not that much higher in terms of emission intensity.

LNG is significantly more emission intensive due to all the extra steps required.

Note: Emissions for transport & processing for Qatar LNG is 0 as it is realized at the liquefaction facility; 1) Weighted average upstream emission intensity for Norway without Breidablikk
Source: Rystad Energy research and analysis; Rystad Energy GasMarketCube; Rystad Energy EmissionCube

In the production intensity impact step methane emissions for oil and gas production as well as LNG transport is included

Methane emissions along the value-chain of oil and gas

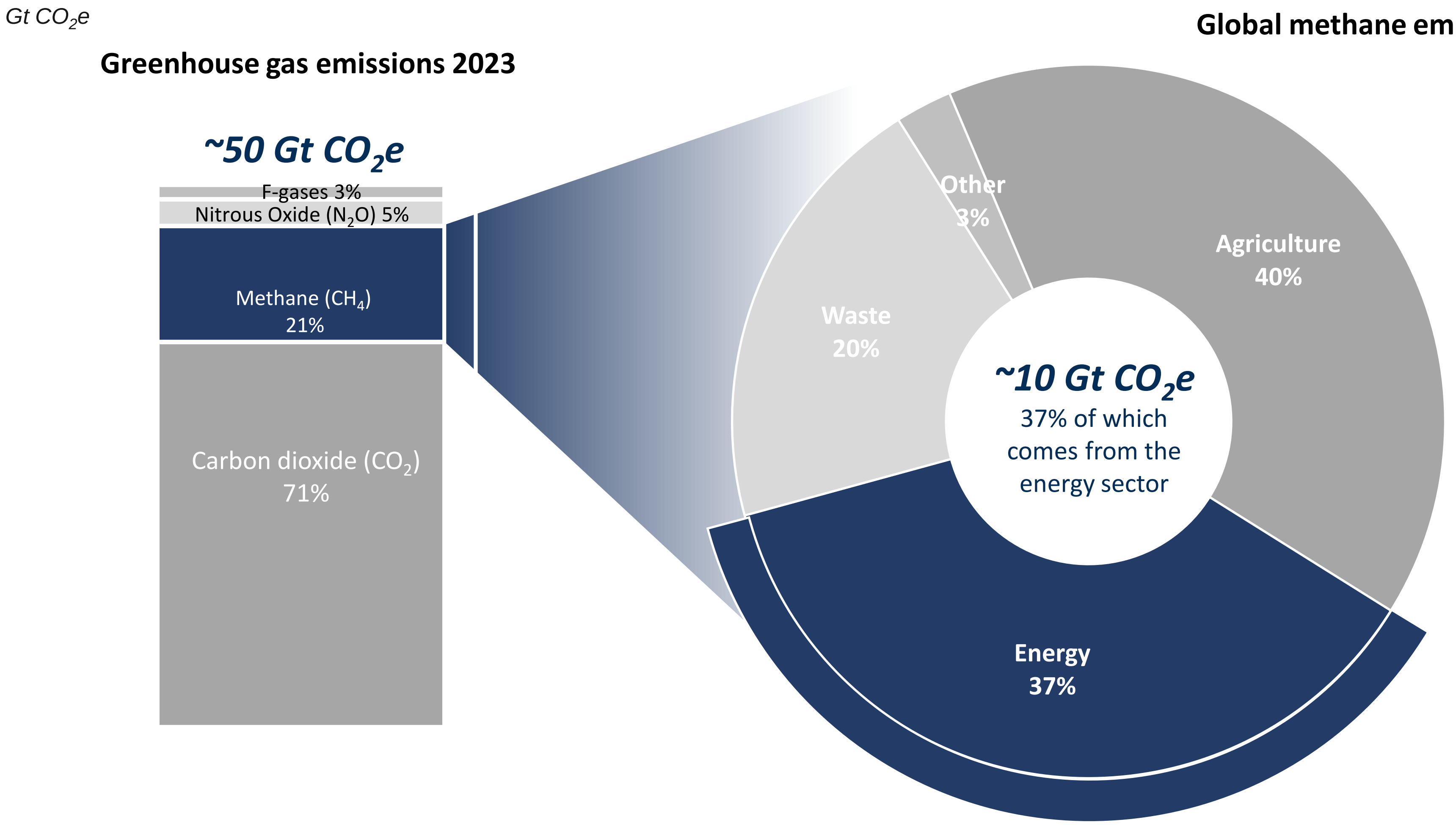
	Production / extraction	*Transmission[1], processing and LNG-production*	*Long-distance transport*	*Distribution to end-user*
Oil	✓	X	X	X
	Included, based on numbers from IEA Methane Tracker. Emissions are primarily related to venting, leakage and flaring of associated gas.	*Not included*	*Methane emissions from long-distance transport of oil on tankers and pipelines is not included*	*Not included*
Gas	✓	X	✓	X
	Included, based on numbers from IEA Methane Tracker. Emissions are primarily related to venting and leakage.	*Not included*	*Included in analysis of methane emissions from LNG-shipping*	*Not included*

1) Includes transmission from production to processing and further transport to liquefaction plants.
Source: Rystad Energy research and analysis; IEA

Step 3

Methane makes up a significant share of global greenhouse gas emissions

Global greenhouse gas emissions - 2023



Greenhouse gas emissions 2023

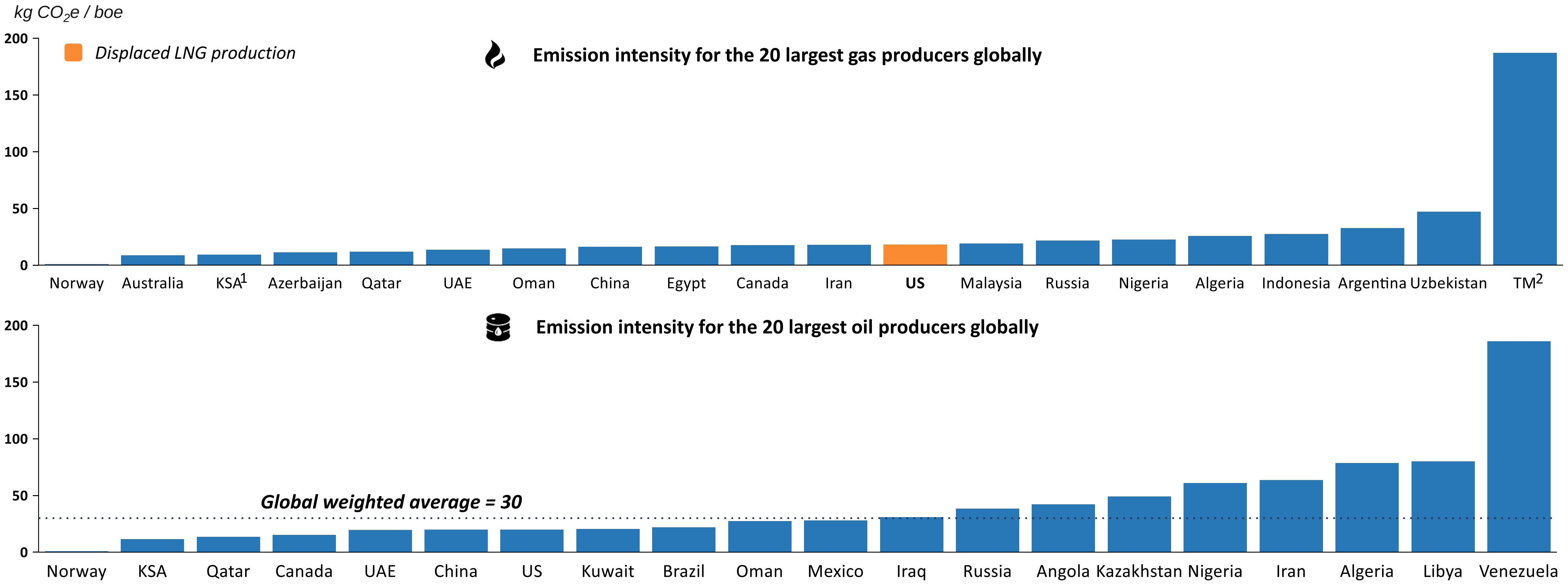
Global methane emissions 2023

Oil & Gas	**62%**
Coal	**31%**
Bioenergy	**7%**

Source: Rystad Energy research and analysis; IEA; European Commission

Large variations in methane intensity from the top 20 largest oil and gas producers globally

Average methane intensity in 2035 for upstream oil and gas production



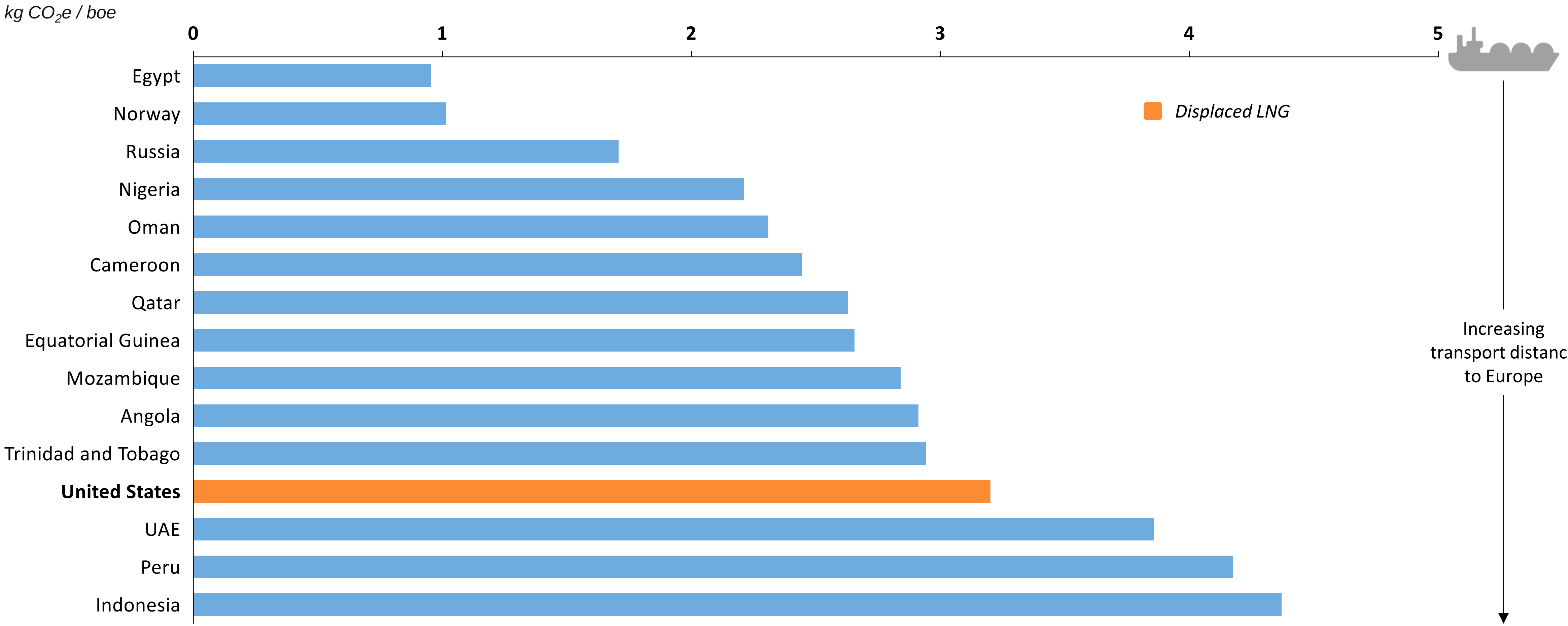
Emission intensity for the 20 largest gas producers globally

Emission intensity for the 20 largest oil producers globally

Note: Estimated average data for 2035 1) KSA – Kingdom of Saudi Arabia; 2) TM - Turkmenistan
Source: Rystad Energy research and analysis; IEA

LNG entails extra greenhouse gas emissions due to methane leakages during transport

Average methane intensity in 2035 for midstream transportation of LNG



Note: Estimated average data for 2035
Source: Rystad Energy research and analysis; Roman-White et al; IPCC; KonKraft; Marcogas; Wuppertal Institute; IPCC

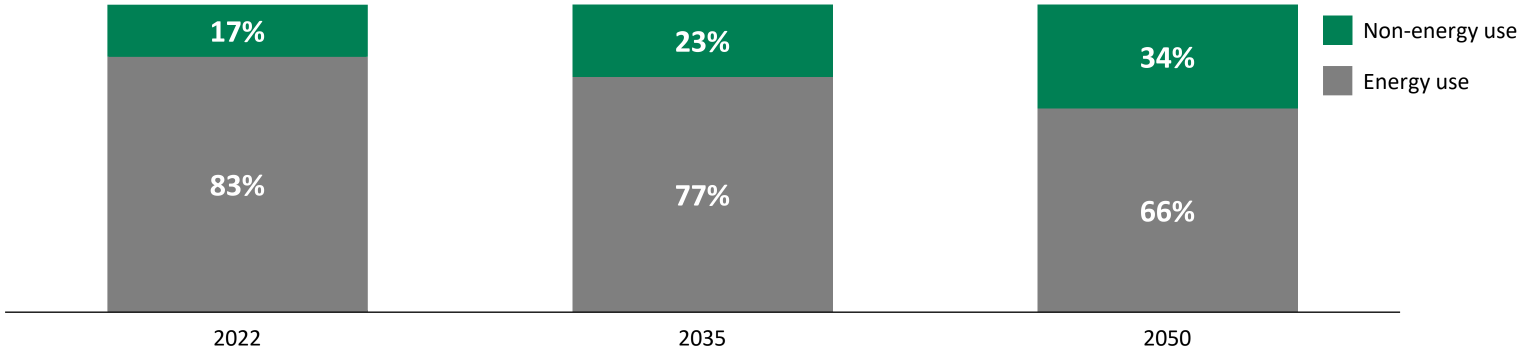
Content

Reference case

Accounting for non-energy related oil demand the total global emission impact from Breidablikk's oil production would be 22.8 Mt CO_2e lower

IEA oil demand split by energy and non-energy usage under the abalanced scenarios (IEA APS)[1]

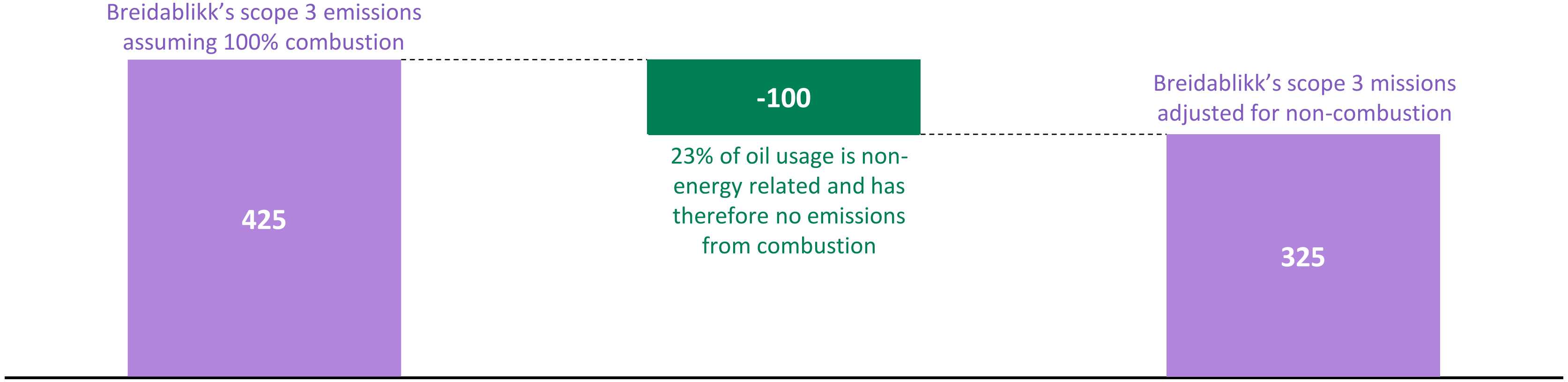
%



Impact of non-energy oil use on Scope 3 emissions

Total emissions from Breidablikk's oil production adjusted by non-energy demand impact

kg CO_2e/boe



- In 2035 **23 %** of oil demand will stem from non-energy related usage i.e. plastics according to IEAs APS scenario
- This results in only 77% of oil being combusted with per barrel emissions of 425 kg CO_2/boe
- When accounting for this the downstream Scope 3 emissions of Breidablikk is therefore reduced by **100 kg CO_2e/boe**

1) Under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Sources: Rystad Energy research and analysis; Equinor

Breidablikk's oil production reduces global emissions by 2.9 Mt CO_2e when accounting for non-energy use according to reference case

Global greenhouse gas emissions impact from Breidablikk's oil production adjusted for non-energy use

Breidablikk emissions[1]

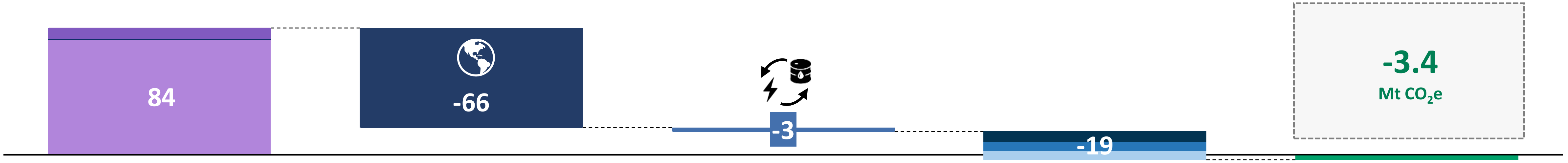
① **Oil replacement**[1]

② **Other energy substitution**[2]

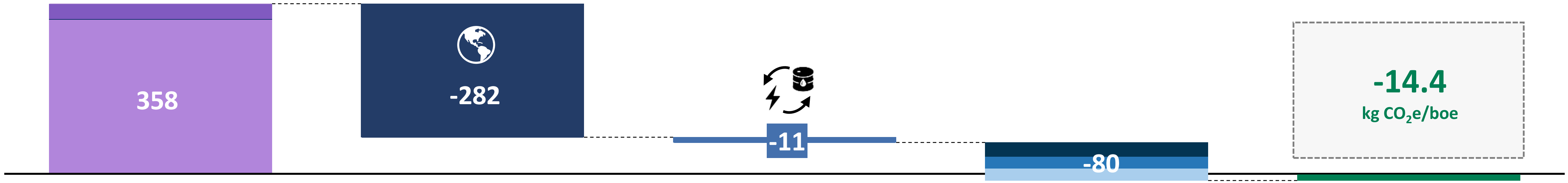
③ **Production intensity impact**

Net global emissions change

Total emissions (Mt CO_2e)



Emissions per barrel (kg CO_2e/boe)



1) Scope 3 emissions reduced by 23% to adjust for displaced for non energy oil demand; 2) Only 77% of new oil production displaces other energy
Note: Emissions impact calculated under a balanced transition scenario corresponding to IEA's "Announced Pledges Scenario"
Source: Rystad Energy research and analysis; Equinor

RystadEnergy

Content

RystadEnergy

Content

Table of included studies for long-term elasticity of oil demand (1/3)

Title	Author	Elasticity	Time Period	Geography	Comment
Oil prices and the global economy	IMF (2017)	-0.08	1983-2014	Global	The study evaluates a model for examining the oil market. The model includes factors such as changes in global GDP, technological improvement, and changes in the supply of oil. Key findings include that short-term oil price movements are not necessarily a good basis for understanding long-term development.
WEO (World Economic Outlook)	IMF (2011)	-0.07	1990-2009	Global	A report that is published twice a year. In the April 2011 edition, the long-term and short-term oil price elasticity of demand (PED) for OECD, non-OECD, and the largest oil-exporting countries is estimated using panel data.
An oil demand and supply model incorporating monetary policy	Askari & Krichene (2010)	-0.03	1970-2008	Global	The study investigates the drivers of the global oil market, including oil PED, using a simultaneous equations system. The study finds that the oil price has little impact on oil demand and identifies income and monetary policy as the most important drivers.
The U.S. dollar exchange rate and the demand for oil	Schryder & Peersman (2013)	-0.14	1971-2008	65 Countries	The demand effect of oil price and dollar exchange rate variations is examined in 65 oil-importing countries, including 23 OECD countries and 42 non-OECD countries, using a panel dataset.
World oil demand in the short and long run: a cross-country panel analysis	Fawcett & Price (2012)	-0.07	1984-2009	53 Countries	A report from the Bank of England that investigates oil demand in 53 countries of which constitute for 75% of global oil demand. The report uses panel data and cointegration testing. The estimate is provided as the oil consumption-weighted average in 2019 for the groupings of countries.

Source: Rystad Energy research and analysis, referenced literature

Table of included studies for long-term elasticity of oil demand (2/3)

Title	Author	Elasticity	Time Period	Geography	Comment
Are long-run income and price elasticities of oil demand time varying? New evidence from BRICS countries	Eleyan et al. (2021)	-0.16	1990-2018	BRICS	The study investigates and estimates long-term income and price elasticity, as well as the time variation of these elasticities, in the BRICS countries. The estimate for the group is the average elasticity of all five countries.
Review of key international demand elasticities for major industrializing economies	Huntington et al. (2019)	-0.15	1970-2019	BRIC + lower-income & industrializing economies	The study conducts a review of various estimates for energy demand, focusing on the long-run responses to changes in prices and income after capital stock turnover has been completed. The paper concludes that the PED for low income & industiralizing economies doesnt vary much from thier OECD counterparts.
World oil demand's shift toward faster growing and less price-responsive products and regions	Dargay & Gatley (2010)	-0.15	1989-2009	OECD	The study estimates the impact of price and income changes on world oil demand in 6 key regions from 1971 to 2008, with different elasticities calculated for 1971-1988 and 1989-2009 time periods, finding the long -un price elastcity of demand to have fallen over this period.
The Price of Oil – Will it Start Rising Again?	Fournier et al. (2013)	-0.17	1983-2011	Global	The paper examines the factors influencing the demand and supply of crude oil and their impact on oil prices. It constructs oil demand equations for OECD and non-OECD countries, combining these with supply behavior assumptions to analyze various macroeconomic and policy scenarios impact on the price of crude oil.
Crude oil conservation policy hypothesis in OECD (organisation for economic cooperation and development) countries: A multivariate panel Granger causality test	Behmiri & Manso (2012)	-0.05	1976-2009	27 OECD countries	The study investigates oil demand elasticity by examining the long-term relationship between oil demand and price in 27 OECD countries using panel data and cointegration testing.

Source: Rystad Energy research and analysis, referenced literature

Table of included studies for long-term elasticity of oil demand (3/3)

Title	Author	Elasticity	Time Period	Geography	Comment
Dynamic panel data approaches for estimating oil demand elasticity	Javan & Zahran (2015)	**-0.17**	1993-2012	25 Countries	The study examines the relationship between oil consumption, oil prices, and GDP using a dynamic regression model with quarterly panel data from 25 countries that account for 75% of global oil demand. Eight of the 25 countries have oil price elasticity estimates that are statistically significant at the 10% level, but the result for the entire group is significant.
Determinants of oil demand in OECD countries: An application of panel data model	Ozcan (2015)	**-0.16**	1980 - 2011	20 OECD Countries	The study investigates price and income elasticity of oil in 20 OECD countries using a panel dataset and examines the relationship between economic growth and oil consumption in these countries. Seven of the 20 countries have oil price elasticity estimates that are statistically significant at the 10% level, but the result for the entire group is significant.
Price and income elasticities of demand for crude oil. A study of thirteen OECD and non-OECD Countries	Tsirimokos & Maroulis (2016)	**-0.09**	1980-2015	13 Countries	The study examines price and income elasticity of oil in 13 countries, both within and outside the OECD, which account for 62% of global oil demand. The study employs a regression model that corrects for endogeneity.
Testing for oil saving technological changes in ARDL models of demand for oil in G7 and BRICs	Asali (2011)	**-0.15**	1990 - 2010	G7 and BRIC	The study examines both long-term and short-term income and price elasticity of oil using an ARDL model with quarterly data. Additionally, it investigates the demand effect of oil-saving technology. The study finds plausible long-term income and price elasticity estimates for all countries.

Source: Rystad Energy research and analysis, referenced literature

Several studies on demand elasticity are not relevant or representative and thus excluded (1/2)

Evaluation of literature on crude oil price elasticity

Study	Elasticity Estimate	Elasticity definition (Long-term crude oil)	Recognition (Peer reviewed or reputable organization)	Year of publication (from 2008)	Era investigated (from 1970)	Geographical focus (Global)	Included in Literature Review
IMF (2017)	0.08	✓	✓	✓	✓	✓	✅
IMF (2011)	0.07	✓	✓	✓	✓	✓	✅
Ozcan (2015)	0.16	✓	✓	✓	✓	✓	✅
Asali (2011)	0.15	✓	✓	✓	✓	✓	✅
Askari & Krichene (2010)	0.03	✓	✓	✓	✓	✓	✅
Schryder & Peersman (2013)	0.14	✓	✓	✓	✓	✓	✅
Fawcett & Price (2012)	0.07	✓	✓	✓	✓	✓	✅
Behmiri & Manso (2012)	0.05	✓	✓	✓	✓	✓	✅
Javan & Zahran (2015)	0.17	✓	✓	✓	✓	✓	✅
Tsirimokos & Maroulis (2016)	0.09	✓	✓	✓	✓	✓	✅
Eleyan et al. (2021)	0.16	✓	✓	✓	✓	✓	✅
Fournier et al (2013)	0.17	✓	✓	✓	✓	✓	✅
Huntington et al. (2019)	0.15	✓	✓	✓	✓	✓	✅
Dargay & Gatley (2010)	0.15	✓	✓	✓	✓	✓	✅
Sharma et al. (2021)	-	-	✓	✓	✓	✗	❌
Hughes et al- (2008)	-	✗	✓	✓	-	-	❌
Sillah & Al-Sheikh (2012)	-	✗	✓	✓	-	✗	❌
Narayan & Smyth (2007)	-	✓	✓	✗	-	✗	❌
WEO (2011)	-	-	✓	✓	-	✗	❌
Golombek et al. (2018)	0.35	✓	✓	✓	✓	-	❌
Balke and Brown (2018)	0.35	✓	✓	✓	✓	✗	❌
Xiong & Wu (2008)	0.37	✓	✓	✓	-	✗	❌
Dash et al. (2018)	0.43	✓	✓	✓	✓	✗	❌
Ghosh (2009)	0.63	✓	✓	✓	✓	✗	❌
Altinay (2007)	0.18	✓	✓	✗	✓	✗	❌
Cooper (2003)	0.21	✓	✓	✗	✓	✓	❌
Krichene (2005)	0.26	✓	✗	✗	✓	✓	❌

Source: Rystad Energy research and analysis, referenced literature

Several studies on demand elasticity are not relevant or representative and thus excluded (2/2)

Evaluation of literature on crude oil price elasticity

Study	Elasticity Estimate	Elasticity definition (Long-term crude oil)	Recognition (Peer reviewed or reputable organization)	Year of publication (from 2008)	Era investigated (from 1970)	Geographical focus (Global)	Included in Literature Review
Gatley & Huntington (2002)	0.37	✓	✓	✗	✓	-	⊗
Baumeister & Hamilton (2019)	0.35	✗	✗	✓	-	-	⊗
Genc (2017)	0.6	✗	✓	✓	-	✓	⊗
Kilian & Murphy (2014)	0.26	✗	✓	✓	✓	✗	⊗
Caldara et al. (2019)	0.14	✗	✓	✓	-	-	⊗
Bodenstein and Guerrieri (2011)	0.42	✗	✗	✓	✓	✗	⊗
Brons et al. (2008)	0.42	✗	✓	✓	-	-	⊗
Bown et al. (2014)	0.45	✗	✗	✓	-	-	⊗
Coliganese et al. (2017)	0.19	✗	✓	✓	-	-	⊗
Dahl and Sterner (1990)	0.86	✗	✓	✗	-	✓	⊗
Dahl (2012)	0.32	✗	✓	✓	-	✓	⊗
Dahl (2014)	0.38	✗	✗	✓	✓	✗	⊗
Goodwin et al. (2004)	0.32	✗	✓	✗	-	-	⊗
Graham & Glaister (2002)	0.78	✗	✓	✗	-	✓	⊗
Hausman and Newey (1995)	0.8	✗	✓	✗	✓	✗	⊗
Knittel and Tanaka (2019)	0.19	✗	✗	✓	-	✗	⊗
Krupnick et al. (2017)	0.53	✗	✗	✓	✓	✓	⊗
Levin et al. (2017)	0.16	✗	✓	✓	-	✗	⊗
Lin and Zeng (2013)	0.17	✗	✓	✓	-	-	⊗
Serletis et al. (2010)	0.12	-	✓	✓	✗	-	⊗
Yatchew and No (2001)	0.9	✗	✓	✗	✓	✗	⊗
Erikson et al. (2018)	0.2	✗	✓	✓	-	✓	⊗
Brown (1998)	0.72	✓	✗	✗	-	✓	⊗
Uria-Martinez et al. (2018)	0.26	✓	✗	✓	✗	✓	⊗
Hamilton (2009)	0.2	✗	✓	✓	✓	✓	⊗

Source: Rystad Energy research and analysis, referenced literature

Table of included studies for long-term elasticity of natural gas demand (1/2)

Title	Author	Estimate	Era investigated	Gegrapahy studied	Sector investigated	Comment
Price responsiveness of commercial demand for natural gas in the US	Li et al. (2022a)	-0.37	1991 - 2020	USA	Residential	A study on gas elasticity in the U.S. residential sector. Uses a panel dataset with monthly data from 1991 to 2020. Explores five different parametric specifications and finds a relatively inelastic long-term demand.
How price responsive is industrial demand for natural gas in the United States?	Li et al. (2022b)	-0.12	2001 - 2019	USA	Industrial	A study on gas elasticity in the U.S.industrial sector. Uses a panel dataset with monthly data from 1991 to 2020. Explores five different parametric specifications and finds a relatively inelastic long-term demand.
Price elasticity for energy use in buildings in the United States	IEA (2021)	-0.26	-	USA	Residential	A report from the IEA that supports the choice of elasticities for energy products in the IEA's annual report Annual Energy Outlook for 2020. Elasticities are estimated through a simulation. The report differs from other sources in the sense that it determines elasticities relevant for future forecasts rather than historical data.
Review of key international demand elasticities for major industrializing economies	Huntington et al. (2019)	-1.36	1984 - 2019	Lower-income & industrializing economies	General	A meta-study of 54 articles on the elasticity of energy products, focusing on industrializing countries with relatively low GDP. Complements other literature in the field, which primarily focuses on OECD countries. Finds higher elasticities than other studies, attributing this to the lack of similarly developed gas infrastructure
A meta-analysis on the price elasticity of energy demand	Labandeira et al. (2017)	-0.73	1990 - 2016	Global	General	A meta-study of 428 research articles on the elasticity of energy products. Gas is found to be the most price-elastic energy product. The study finds that long-term elasticities have decreased since the oil crisis of 1973, which may suggest that current elasticities are lower than previously estimated.
The price and income elasticities of natural gas demand: International evidence	Burke & Yang (2016)	-1.25	1978 - 2011	Global (44 countries)	General	Examines global price and income elasticity for gas in both the short and long term using a particularly broad dataset covering 72% of global gas demand (as of 2011). Finds high long-term elasticity and notes that aggregated elasticities are somewhat higher than sector-specific ones

Source: Rystad Energy, referenced reasearch articles

Table of included studies for long-term elasticity of natural gas demand (1/2)

Title	Author	Estimate	Era investigated	Gegrapahy studied	Sector investigated	Comment
What drives natural gas consumption in Europe? Analysis and projections	Dilaver et al. (2014)	-0.16	1978 - 2011	Europe (23 countries)	General	A frequently referenced study that examines the long-term elasticity of gas in European OECD countries. It accounts for suppliers' market power through an underlying energy demand trend. The model is also applied into the future to provide a forecast for gas demand.
Long run elasticities of demand for natural gas: OECD panel data evidence	Bilgili (2014)	-0.82	1979 - 2006	Global (8 countries)	General	Investigates the global price and income elasticity of gas in the long term. Utilizes modified estimators in the regression analysis to account for endogeneity issues and autocorrelation to a greater extent than previous studies. Finds a relatively high elasticity.
How is demand for natural gas determined across European industrial sectors?	Andersen et al. (2011)	-0.44	1978 - 2003	Europe (13 countries)	Industrial	Examines price and income elasticities for gas in European industry in both the short and long term. Uses the same methodology as in Asche et al. (2008). Elasticities are estimated for all 13 countries and 11 sub-industries individually. The estimated elasticities vary significantly depending on the choice of region, sub-industry, and statistical estimation method.
Natural gas demand in the European household sector	Asche et al. (2008)	-0.75	1978 - 2002	Europe (12 countries)	Residential	Examines price and income elasticities for gas in the European residential sector in both the short and long term. These are estimated through experiments with a range of different statistical estimators, as well as separately for each of the 12 countries. The estimated elasticities are highly sensitive to the choice of region and statistical estimation method.
A meta-analysis on the price elasticity of energy demand	Labandeira et al. (2017)	-0.73	1990 - 2016	Global	General	A meta-analysis of 428 research articles on the elasticity of energy products. Gas is found to be the most price elastic energy product. It finds that long-term elasticities have decreased since the oil crisis in 1973, which may mean that today's elasticities are lower than estimated.

Source: Rystad Energy research and analysis, referenced reasearch articles

Several studies on demand elasticity are not relevant or representative and thus excluded

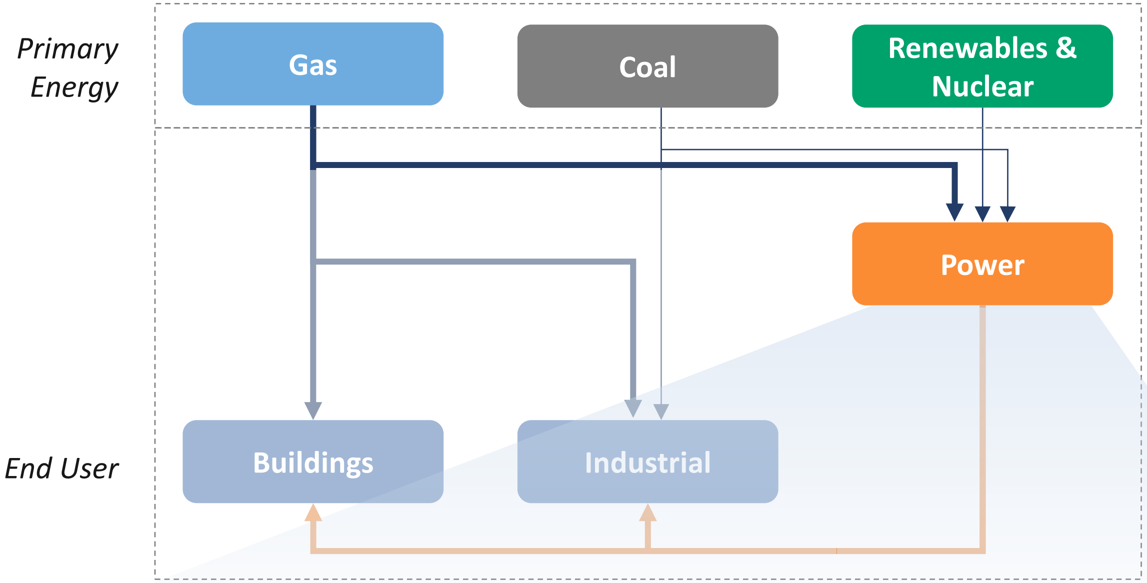
Study	Elasticity Estimate	Elasticity Definition (Long Run Natural Gas)	Recognition (Peer reviewed or reputable organization)	Study Year (from 2008)	Geography (global or significant region)	Included in Literature Review
Asche et al (2008)	0.8	✓	✓	✓	✓	✅
Andersen et al (2011)	0.4	✓	✓	✓	✓	✅
Dilaver et al (2014)	0.2	✓	✓	✓	✓	✅
Bilgili (2014)	0.8	✓	✓	✓	✓	✅
Burke and Yang (2016)	1.3	✓	✓	✓	✓	✅
Labandeira et al (2017)	0.7	✓	✓	✓	✓	✅
Huntington et al (2019)	1.4	✓	✓	✓	✓	✅
IEA (2021)	0.3	✓	✓	✓	✓	✅
Li et al (2022)	0.4	✓	✓	✓	✓	✅
Li et al (2022)	0.1	✓	✓	✓	✓	✅
Bernstein and Madlener (2011)	0.5	✓	✓	✓	✓	❌
Maddala et al (1997)	0.8	✓	✗	✓	✓	❌
Liu (2004)	-	✓	✓	✓	✓	❌
Holz et al (2006)	-	-	✓	-	✓	❌
Egging et al (2007)	0.23	✗	✓	-	✓	❌
Dagher (2011)	-	✓	✓	✓	✗	❌
Sønstebø (2012)	-	✗	✗	-	✗	❌
Burns (2021)	0.09	✗	✓	✓	✓	❌

Source: Rystad Energy research and analysis

Content

In the power sector, an increased supply of gas is likely to reduce the demand for coal

Simplified energy system relevant to gas



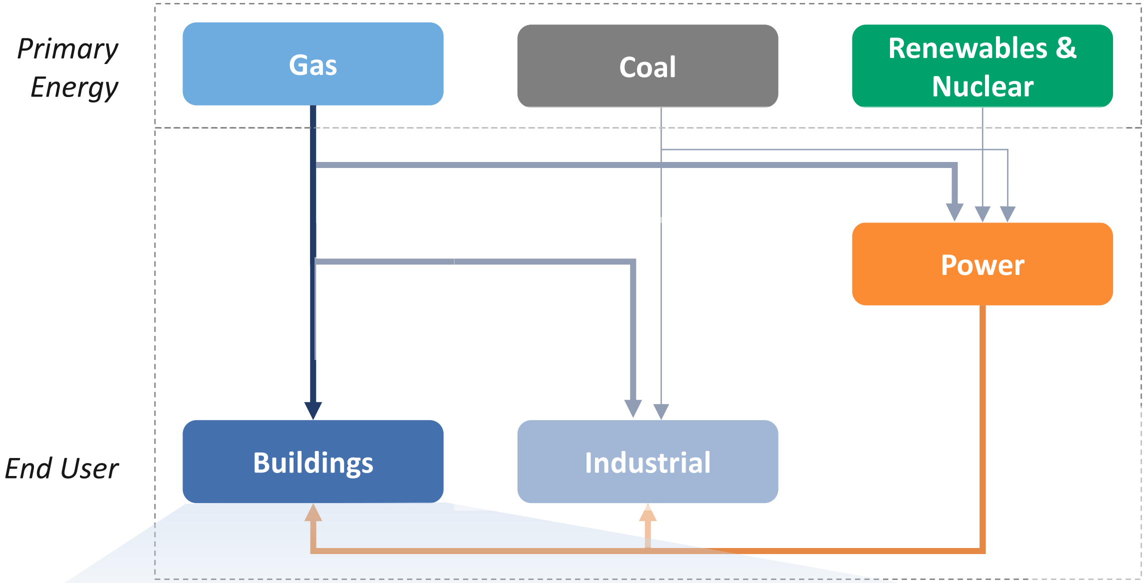
Electricity production mainly has three sources of primary energy as shown with the arrows entering the electricity sector above. This means that increased gas supply and lower gas prices can lead to substitution away from either coal or non-fossil power (renewable energy or nuclear power). In practice, coal is expensive, which suggests that coal power will be substituted away.

Source: Rystad Energy research and analysis

- In the electricity sector, coal, as well as non-fossil energy sources such as renewable energy and nuclear power, constitute as alternatives to gas. If an increased supply of Breidablikk gas does not lead to a total increase in global energy demand, one of these sources must therefore give way to increased gas supply.
- Because coal constitutes a more expensive source of power than other energy sources, it is rational that coal power will be forced out.
- Coal will probably constitute a significant part of the global power mix in 2035. At the same time, global gas power capacity is capable of absorbing moderate amounts of new gas without making new investments. Taken together, this makes coal-to-gas substitution possible

In the building sector, lower gas and electricity prices resulting from an increased gas supply will lead to a limited substitution effect

Simplified energy system relevant to gas



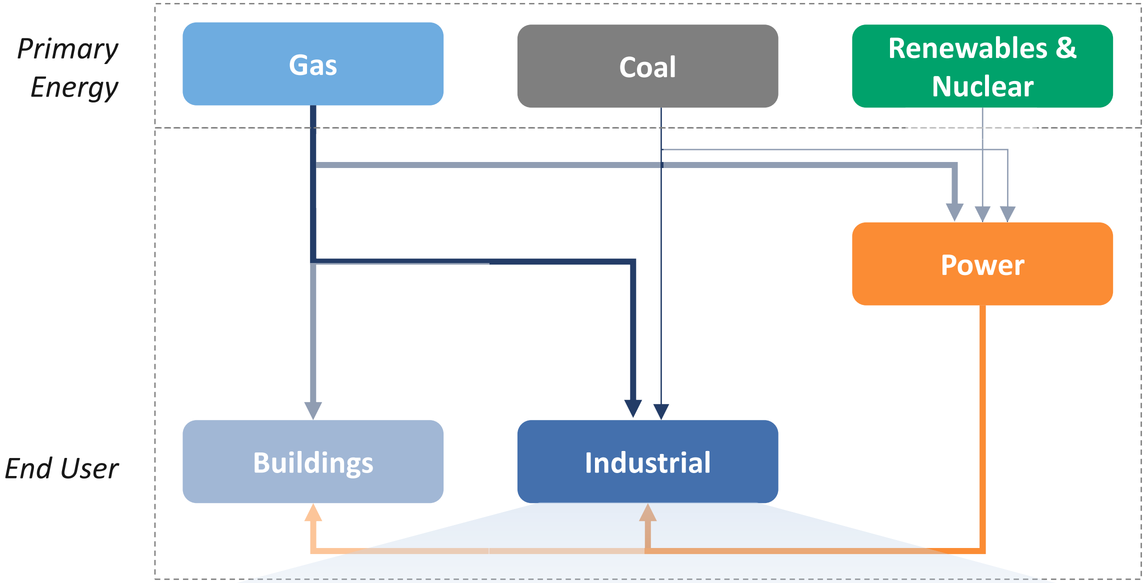
Buildings generally have a limited range of energy alternatives, primarily gas and electricity. With an increase in the gas supply, gas prices will decrease. However, since gas and coal typically serve as marginal electricity producers and thus influence pricing, lower gas prices will also lead to lower electricity prices. In this case, the relative prices of gas and electricity remain unchanged, and the building sector does not substitute one for the other.

- The building sector is more restricted than other sectors when it comes to energy sources. Generally, electricity is the only alternative to gas.
- With an increase in gas supply from Breidablikk, two effects will materialize in the energy system, all else equal. On one hand, gas prices will decrease marginally. On the other hand, this price decrease will also be reflected in electricity production, and because gas, along with coal, serves as a marginal electricity producer, this will impact electricity prices.
- While gas and electricity prices may decrease nominally, their relative price relationship remains stable. This implies that the building sector is unlikely to shift demand between them, keeping the distribution of demand largely unchanged.

Source: Rystad Energy research and analysis

Industrial use will switch from coal to gas if the gas supply increases

Simplified energy system relevant to gas



Most energy-intensive industries cannot be electrified in the short and medium term. In such cases, coal is the primary substitute for gas, and coal demand must decrease marginally with an increase in gas supply. For parts of the industry with electrification potential, the effect is analogous to that in the building sector—electricity prices are influenced by gas prices, and a reduction in one leads to a reduction in the other, thereby dampening the substitution effect.

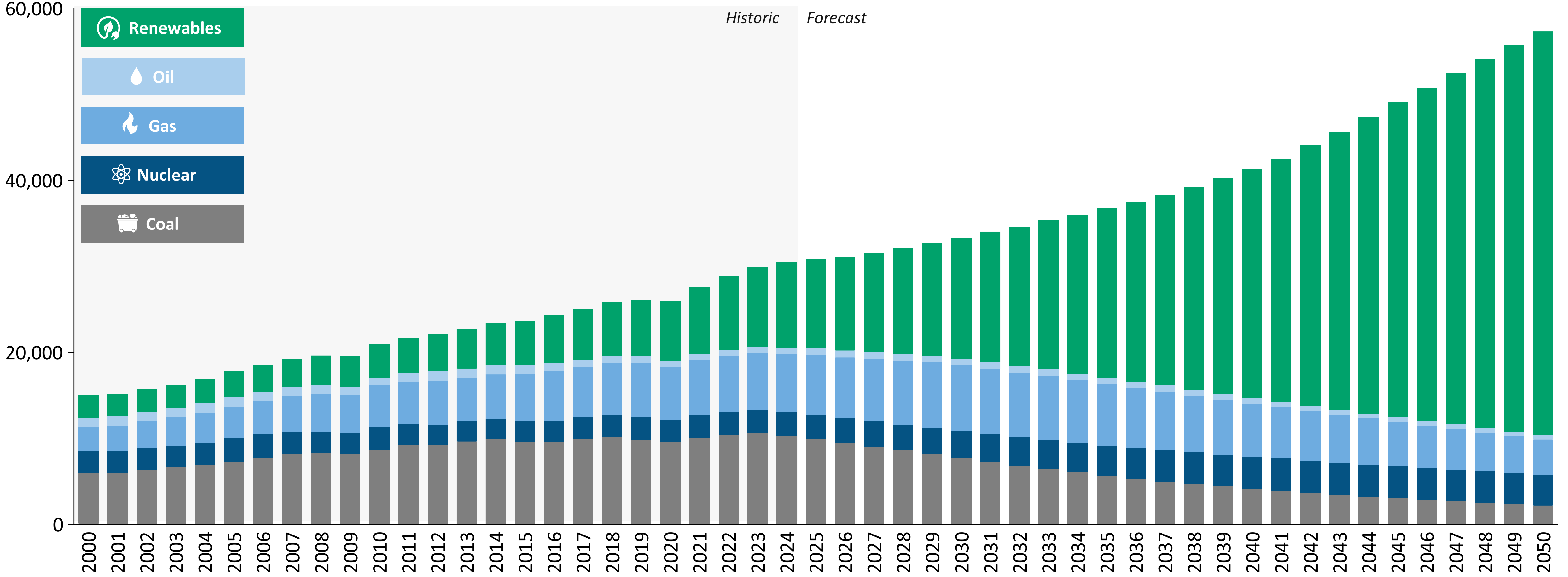
Source: Rystad Energy research and analysis

- In the short and medium term, most industries will not electrify but continue to demand fossil fuels. In many cases, the only alternative to gas is coal. Therefore, an increased gas supply from Breidablikk could displace some coal consumption.
- In the short term, switching from coal to gas is relatively straightforward from a technical and cost perspective, as many of the industry's coal-fired turbines can also run on gas.
- For industries that can be electrified, electricity is the relevant substitute. However, as in the building sector, the effect of increased gas supply is limited. Lower gas prices reduce electricity prices, diminishing the incentive to switch to electricity. While industrial electrification may still occur, it's unlikely to be driven by increased gas supply.

Global coal energy generation is projected to be displaced by other primary sources

Time Series of global energy generation by primary energy source[1]

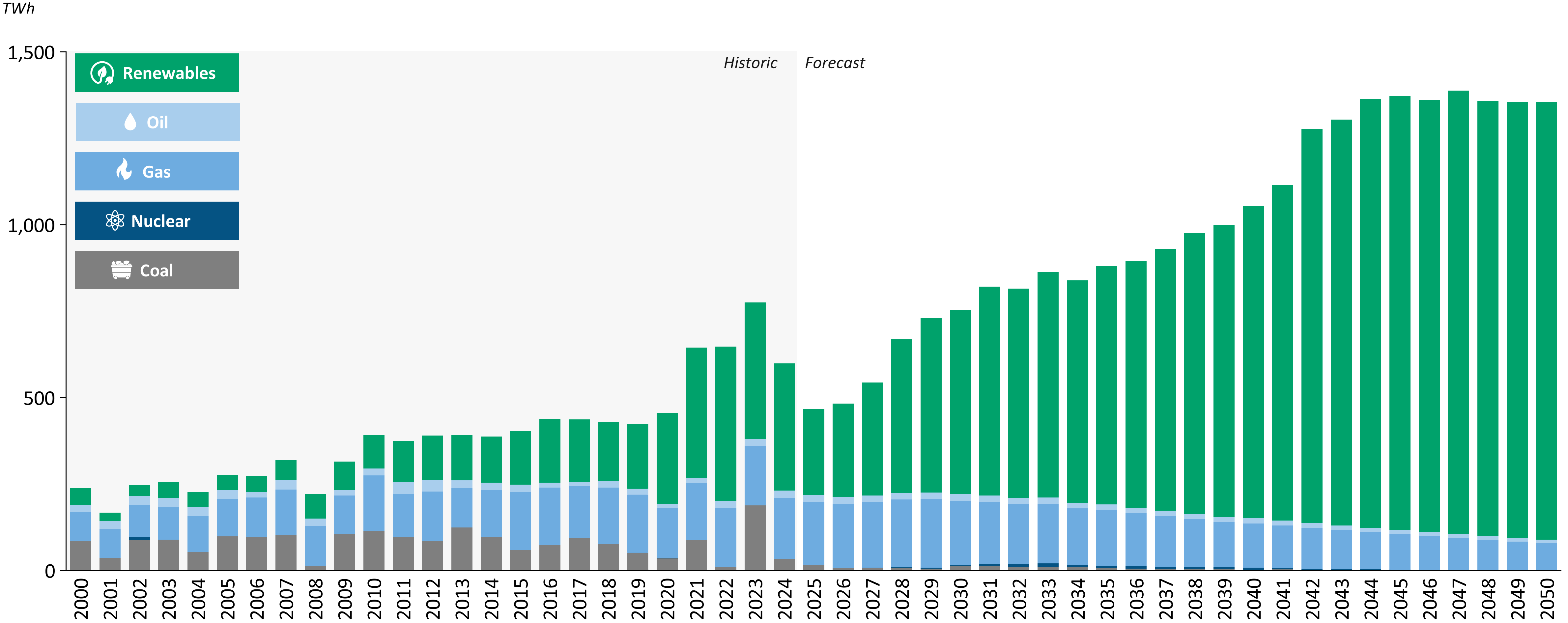
TWh



1) As per Rystad Energy 1.9 degrees scenario
Source: Rystad Energy research and analysis; Rystad Energy PowerCube

Coal is projected to have the least added energy generation out of all primary energy sources

Added generation capacity by primary energy source[1]

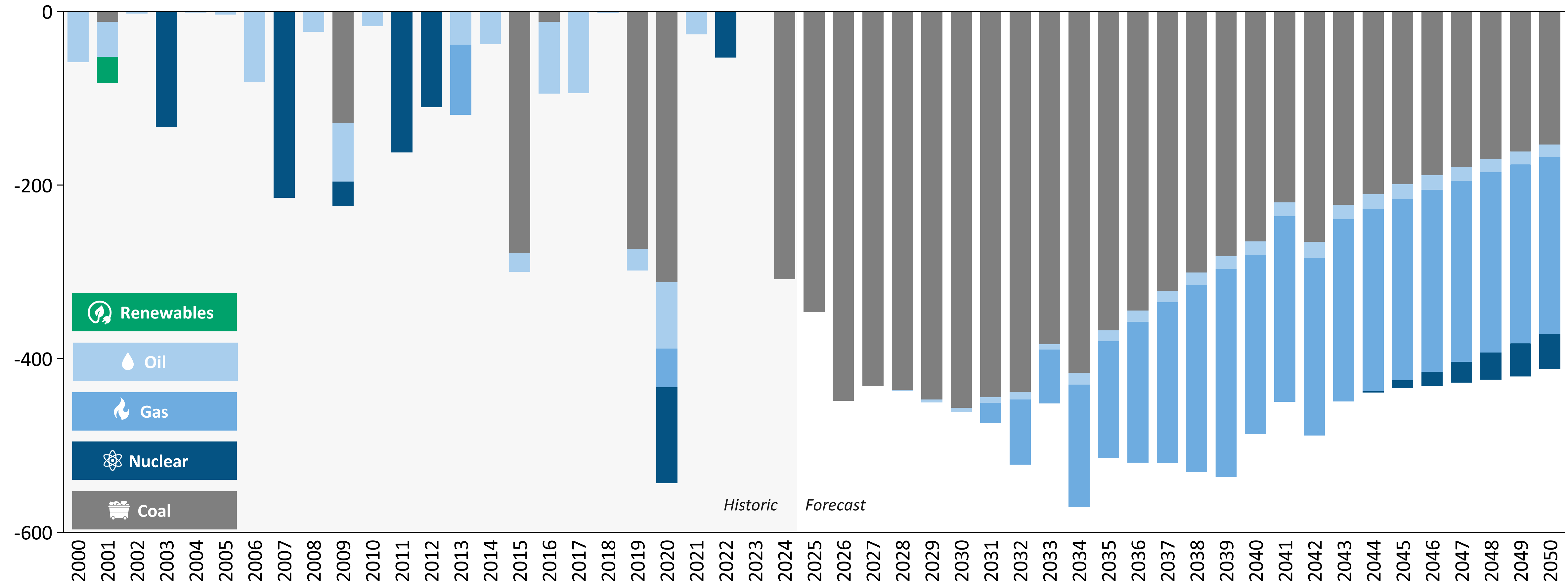


1) As per Rystad Energy 1.9 degrees scenario
Source: Rystad Energy research and analysis; Rystad Energy Global energy scenarios dashboard

The majority of projected global decreases in energy generation comes from coal

Annual decreases in energy generation by primary energy source[1]

TWh



1) As per Rystad Energy 1.9 degrees scenario
Source: Rystad Energy research and analysis; Rystad Energy Global energy scenarios dashboard

Content

The analysis includes the most conservative approach by disregarding the EU ETS

Norwegian oil & gas production is subject to the EU climate quota system, the EU ETS. Rystad Energy considers three ways this could impact the analysis:

1 Increased upstream emissions from Norwegian O&G production result in a one-to-one reduction in emissions from other sectors subject to the emissions trading system. This is known as the 'waterbed effect.' In such a scenario, increased Norwegian upstream emissions are offset by reduced emissions in other sectors. Thus, with this assumption, one could exclude emissions from the Norwegian continental shelf from calculations of global climate impact. However, since emissions on the Norwegian continental shelf are low, this does not significantly impact the calculated net climate effect.

2 The second possibility is a partial waterbed effect, where increased emissions from Norwegian O&G production result in reduced emissions from other sectors subject to the emissions trading system, but not one-to-one. In such a scenario, the future emissions cap is affected by changes in quota demand, so that increased emissions contribute to raising (or preventing a reduction in) the quota cap. In this case, one could argue that part of the emissions from the Norwegian continental shelf do not contribute to increasing global emissions, but to a lesser extent than in the point above.

3 The third possibility is to disregard the EU ETS. This scenario results in the highest emission contributions from production on the Norwegian continental shelf, which is the assumption used in this analysis.

In conclusion, neither the interpretation of the 'waterbed effect' nor the future development of the EU ETS is considered decisive for the outcome of the analysis

Source: Rystad Energy research and analysis

RystadEnergy

Navigating the future of energy

Rystad Energy is an independent energy consulting services and business intelligence data firm offering global databases, strategic advisory and research products for energy companies and suppliers, investors, investment banks, organizations, and governments.

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