Petroleum Production under the two degree scenario (2DS)

MILJØVERNDEPARTEMENTET

Final report
August 13, 2013

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Background

Rystad Energy has been engaged by the Norwegian Ministry of the Environment during May and June 2013 to analyze the potential consequences of reduced CO_2 emissions under the "two degree scenario" (2DS) for global petroleum production. The 2DS is defined by IEA in their «Energy Technology Perspectives 2012» and is broadly consistent with the "450 Scenario" from IEA's World Energy Outlook. The 2DS *«describes an energy system consistent with an emissions trajectory that recent climate science research indicates would give an 80% chance of limiting average global temperature increase to 2°C. It sets the target of cutting energy-related CO2 emissions by more than half in 2050 (compared with 2009) and ensuring that they continue to fall thereafter."*

The analysis done by Rystad Energy discusses neither the underlying assumptions of the 2DS nor the realism of the scenario. It is a pure fact-based «what-if» analysis based on the IEA-forecasted energy demand and energy mix under 2DS. Dynamic effects of energy policies or potential technology or fiscal policy changes are not accounted for.

Rystad Energy is a Norwegian oil and gas focused consulting and data/research firm with proprietary databases on global upstream activities.

This has been a low budget project, and Rystad Energy has also invested in the project to develop it to the standard we prefer.

This report draws on the following principal sources of information/data:

a. Rystad Energy global upstream database, UCube with 68,000 oil and gas fields
b. Information obtained through industry interviews and industry reports
c. Research and analysis done by the Rystad Energy consulting team

The report aims to

1) Clarify the oil and gas CO_2 emission budget under 2DS under various coal scenarios and compare this budget with known resources.
2) Quantify how much of forecasted unrestricted oil and gas production in the period 2013-2050 will potentially not be produced under 2DS. Characterization of these stranded resources is also included.

Executive summary

The first part of the study compares the 2DS CO_2 emission budget ("carbon budget") with potential emissions during combustion of all known fossil resources produced from now till infinity. The carbon budget used is based on IEA and Carbon Tracker (80% probability of 2DS or below) and is 1,075 Gt including CCS. When comparing this carbon budget with potential emissions from all known fossil resources, it becomes apparent that 2/3 of known fossil resources must be left in the ground under 2DS.

However, coal is the dominating resource both in terms of potential CO_2 emissions and known resources. While 78% of the known coal resources must be left in the ground under 2DS, 35% and 38%, respectively, of known oil and gas resources are stranded under 2DS. It is worth noting that most of the lost production is after 2050 versus the unrestricted case.

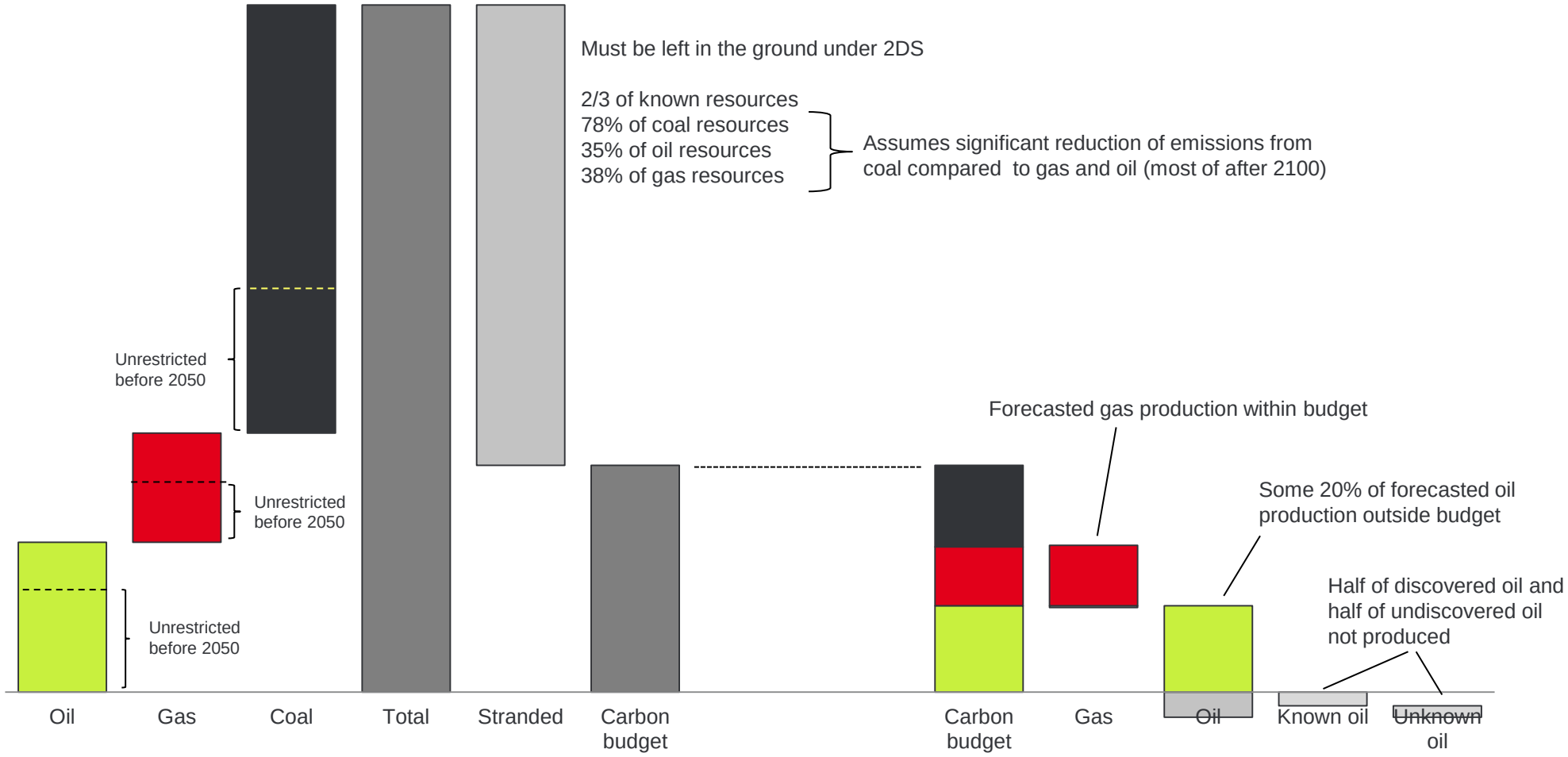
It is shown that coal consumption relative to oil and gas is the main determinant of the oil and gas carbon budget under 2DS. The oil and gas emission budget under 2DS for low, medium and high coal consumption is 690 Gt, 603 Gt and 520 Gt, respectively, for the period 2013-2050.

The second part of the study compares the 2DS carbon budget of oil and gas with potential emissions during combustion of the forecasted unrestricted production from 2013-2050. It is estimated that 15% of the likely unrestricted hydrocarbon production towards 2050 must be removed under 2DS. This corresponds to 22% of the oil and 3% of the gas. The relatively low share of stranded production in the period 2013-2050 is due to significant forecasted production also after 2050, and only 16% of the resources after 2050 could be produced if one should stay within the carbon budget.

All oil fields currently in production or under development could be produced under the 2DS scenario, emitting in total 259 Gt. For fields not yet sanctioned for development, 59% of the resources must remain in the ground over the period 2013-2050. For undiscovered resources, 45% of the likely finds must remain in the ground to keep the emissions within the 2DS scenario. These results are achieved based on a methodology, where fields and exploration areas are sorted by break-even prices from the lowest to the highest. Then the CO_2 emissions are aggregated until the carbon budget of 99 Gt is reached. This happens at a break-even price of 72 USD/boe. Oil companies typically add another 10-15 USD/boe as a safety margin before sanctioning a project, meaning that the carbon budget will be reached “automatically” with an oil price of 85-90 USD/ boe.
Fields with a break-even above USD 72 will then be the “stranded fields” under 2DS. These are characterized as follows:

1. Discovered fields with extremely deep reservoirs, demanding surface conditions, very low permeability, sour or very heavy oil or oil sands. The largest base of non-commercial resources is located in Russia, Canada and the Middle East.
2. Undiscovered fields in areas with high exploration, development and operating cost. Largest stranded areas are offshore North- and South America, West Africa and in the Arctic.
3. Stranded fields in Norway towards 2050 have similar characteristics. A group of oil fields with break-even above 72 USD/boe are listed. All gas fields could be produced within the 2DS, but this is not likely to happen under a low price regime due to commercial reasons.
4. Some exploration for oil in Norway could happen within the 2DS scenario, because many new finds are expected to be more robust economically than existing undeveloped fields. Most economically robust areas are expected to be mature areas close to infrastructure and frontier areas without arctic conditions or close to shore, like Lofoten and the Barents Sea South.

CO_2 emission balances under the two degree scenario (2DS)



The time horizon is potentially several hundred years into the future. While a large part of known oil and gas resources will be produced before 2050 in an unrestricted case, only around one third of coal resources are likely to be produced in the same period .

The time horizon is 2013-2050. Forecasted production not restricted by low demand and low oil price is compared to the 2DS carbon budget, assuming the emission mix between coal, oil and gas as proposed by IEA Energy Technology Perspectives

Source: IEA ETP; Rystad Energy UCube

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Mandate for our study

This is:

- Assessment of oil and gas resources that could be produced within 2DS carbon budget (as used by IEA) in a “static case” based on pure economical decisions
  - Globally
  - In Norway
  - Under various coal shares
  - With static cost base and frame conditions

This is NOT:

- Assessment of relevance of carbon budget for 2DS
- Assessment of dynamic effects of carbon policies
- Assessment of effects of new technologies, cost changes or changes in fiscal regimes

PRESS RELEASE (Norwegian version)

Rystad Energy har på oppdrag for Miljøverndepartmentet vurdert den globale og nasjonale olje- og gassproduksjon som er mulig under et lavutslippsscenario; det såkalte tograders-scenariet (2DS). Rystad Energy har tatt utgangspunkt i et karbonbudsjett og etterspørselkurver for dette scenariet slik det er definert av Det internasjonale energibyrået (IEA) som sier at samlede CO2 utslipp fra olje, gass og kull ikke må overstige 1000 Gt i perioden 2013 til 2050. Rystad Energy har ikke vurdert om dette budsjettet er relevant i forhold til å oppnå ønsket CO2 mengde i luften eller ønsket virkning på den globale temperaturen. Studien er basert på en analyse av CO2 utslipp ved forbrenning av produserte hydrokarboner fra hvert enkelt olje eller gassfelt ved bruk av Rystad Energy sin database av over 68 000 felt globalt.

Hovedfunnene i studien er at 78 prosent av oljen og 97 prosent av gassen kan produseres frem til 2050 i forhold til det som maksimalt kan produseres. I praksis betyr dette at olje og gass som er i felt som er besluttet bygget ut eller i produksjon kan produseres. «Det vil ikke være lønnsomt hverken samfunnsøkonomisk eller for klima å begrense produksjonen i felt som allerede er i gang», sier Jarand Rystad i en kommentar. «Derimot må man i et slikt scenario begrense produksjonen fra felt som er funnet, men ennå ikke besluttet bygget ut. Kriteriet for dette vil være lønnsomhet som igjen avhenger av oljepris og kostnad. Med det høye kostnadsnivået vi har nå vil faktisk hele begrensningen komme av seg selv dersom oljeprisen går ned til et nivå der felt med 72 dollar i «breakeven» ikke blir besluttet. Dette vil kanskje skje på 85–90 dollar per fat. I et slikt scenario vil 60 prosent av dagens ressurser som ikke ennå er besluttet utbygget ikke bli bygget ut, og det samsvarer med kravet til utslippsreduksjon», sier Rystad. «Spesielt er det olje og kondensat i vanskelige reservoarer samt ukonvensjonelle ressurser som blir liggende.»

Når det gjelder leting vil den kunne fortsette fordi man vil finne ny olje som har bedre økonomi enn oljefelt som er funnet og ikke bygget ut. Kravet for å tilfredstille 2DS karbonbudsjettet er at 45 prosent av nye funn blir liggende igjen, mens 55 prosent kan bygges ut. Igjen er det de mest lønnsomme ressursene som bør bygges ut, og dette er uoppdagede ressurser enten i modne områder, eller i nye områder med forventet god økonomi. «For Norges del vil leting nær eksisterende infrastruktur eller i nye områder med forventet god økonomi som Lofoten og det sørlige Barentshavet være sannsynlig også under 2DS, mens krevende ressurser lenger nord og øst vil kunne bli økonomisk lite interessant», sier Rystad.

I og med at kull har langt større utslipp av CO2 enn olje og gass per energienhet, vil kullproduksjonen avgjøre hvor mye olje og gass som kan produseres. I hovedscenariet antas det i likhet med IEA at andelen utslipp fra kull går ned fra 45 til 36 prosent fram mot 2050. Dersom kullandelen går ytterligere ned til 27 prosent vil nesten all olje og gass kunne produseres, mens en kullandel på dagens nivå vil gi vesentlig større reduksjon av olje- og gass produksjon dersom 2 gradersmålet likevel skal nås. «Den store utfordringen er altså å redusere utslippene fra kull», sier Rystad.

Det går også frem av studien at IEA i sine etterspørselkurver sannsynligvis har undervurdert de potensielle utslippene fra olje og gass etter 2050. Den gjenværende delen av karbonbudsjettet etter 2050 er på kun 75 Gt, noe som ikke samsvarer med etterspørselkurven fram til 2050, selv med en massiv CCS. Det er etter 2050 at man ser et stort gap mellom karbonbudsjettet og sannsynlige utslipp, og det er i denne perioden at mestparten av de store deler av kjente kullreserver må holdes tilbake.

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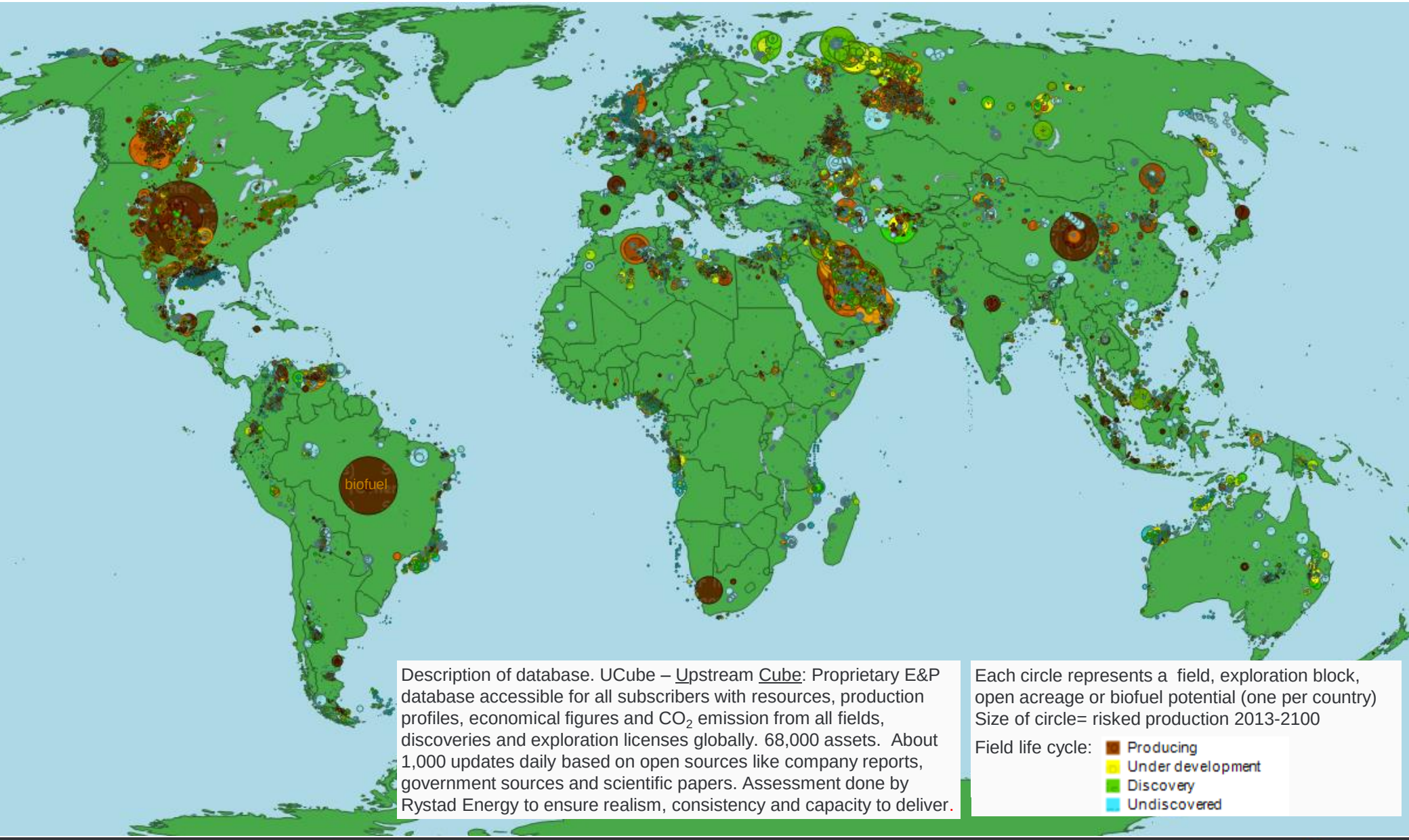
Data source used: Rystad Energy UCube with fields and blocks as exposed here



Description of database. UCube – Upstream Cube: Proprietary E&P database accessible for all subscribers with resources, production profiles, economical figures and CO_2 emission from all fields, discoveries and exploration licenses globally. 68,000 assets. About 1,000 updates daily based on open sources like company reports, government sources and scientific papers. Assessment done by Rystad Energy to ensure realism, consistency and capacity to deliver.

Each circle represents a field, exploration block, open acreage or biofuel potential (one per country)
Size of circle= risked production 2013-2100

Field life cycle:
- Producing
- Under development
- Discovery
- Undiscovered

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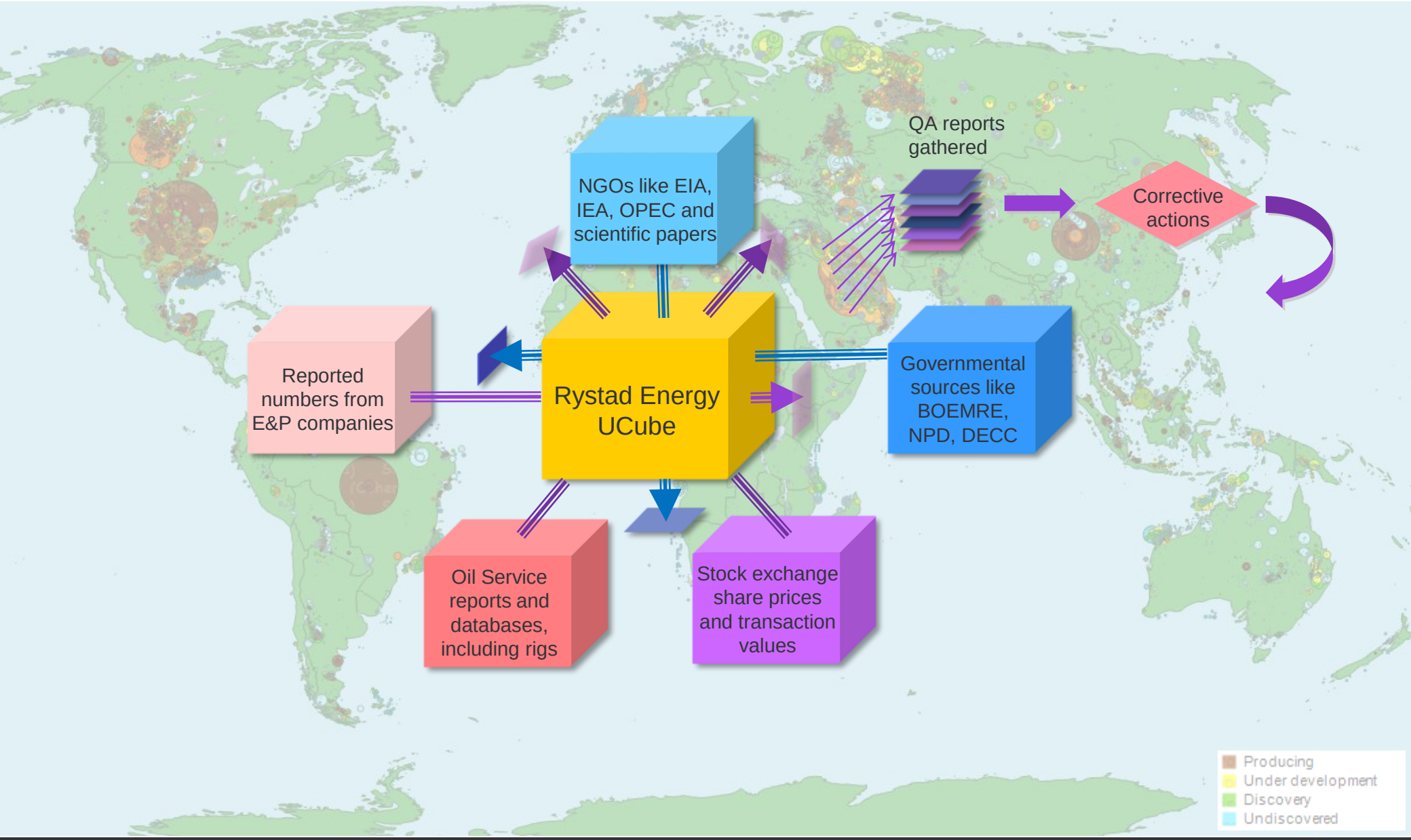
UCube is constantly calibrated and quality checked against 1000's of primary sources



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UCube – a revolution within E&P business intelligence!

- UCube is an online, field-by-field database for the international upstream oil & gas industry
- UCube consists of one, integrated, complete database along all dimensions including geography, on-/offshore, hydrocarbon types including unconventionals, and field life cycle
- UCube contains reserves, production profiles, owner shares, financial figures and a range of additional key parameters for all fields, discoveries and exploration licenses globally
- UCube includes near 68,000 assets and 3,200 companies, and historical data from 1900 and forward looking data to 2100
- UCube is a multi-use tool for a variety of purposes within analysis, strategy, benchmarking, deal screening, valuation and climate studies

IEA Energy Technology Perspectives (ETP*) Scenarios

The table shows IEA's assumptions behind its different scenarios 6DS, 4DS and 2DS.

The 6DS is the future scenario, which projects a long-term temperature increase of 6°C, 4DS correspond with an increase of 4°C, and 2DS with an increase of 2°C.

Stated oil/gas prices are calculated as the average oil/gas prices per year forecasted by IEA and is part of the underlying assumptions of this study.

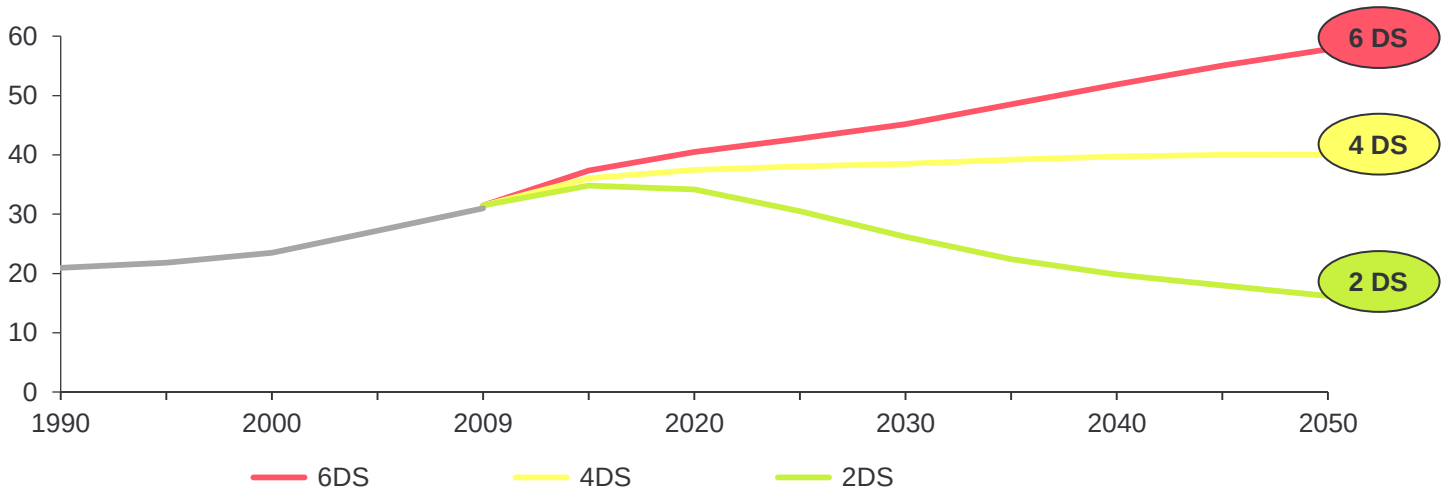
The lower right graph shows ETP* 2012's three possible energy futures, the boundaries of which are set by the total energy-related CO_2 emissions.

According to this, to limit the global temperature increase to 2°C, global energy-related CO_2 emissions in 2050 must be half of the current level.

Rystad Energy has not assessed the relevance or correctness of these scenarios.

Scenario	Description	IEA 2050 demand for oil and gas* Million boe	IEA average oil price USD/bbl	IEA average gas price USD/kcf
6 DS	Projecting a long-term temperature increase of 6°C Broadly consistent with the World Energy Outlook (WEO) **Current Policy** Scenario through 2035	78,480	129	9
4 DS	Projecting a long-term temperature increase of 4°C Broadly consistent with the WEO **New Policies** Scenario through 2035	70,612	112	12
2 DS	80% chance of limiting average global temperature increase to 2°C. Broadly consistent with the WEO **450** Scenario through 2035	42,090	**92****	**13****

Global CO_2 emissions per year*



* ETP: *Energy Technology Perspectives* is the International Energy Agency's most ambitious publication on energy technology. It demonstrates how technologies can make a decisive difference in limiting climate change and enhancing energy security.
** Based on average price given by IEA ETP (2012), Table A.3
Source: International Energy Agency (2012), Energy Technology Perspectives 2012, OECD/IEA, Paris

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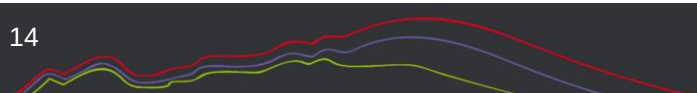


Carbon emission budget 2013-2050 for 2DS within 80% probability: 942 Gt

The chart compares the carbon budget from various sources. The carbon budget is the maximum cumulative CO_2 emissions that limits an average global temperature increase to 2°C.

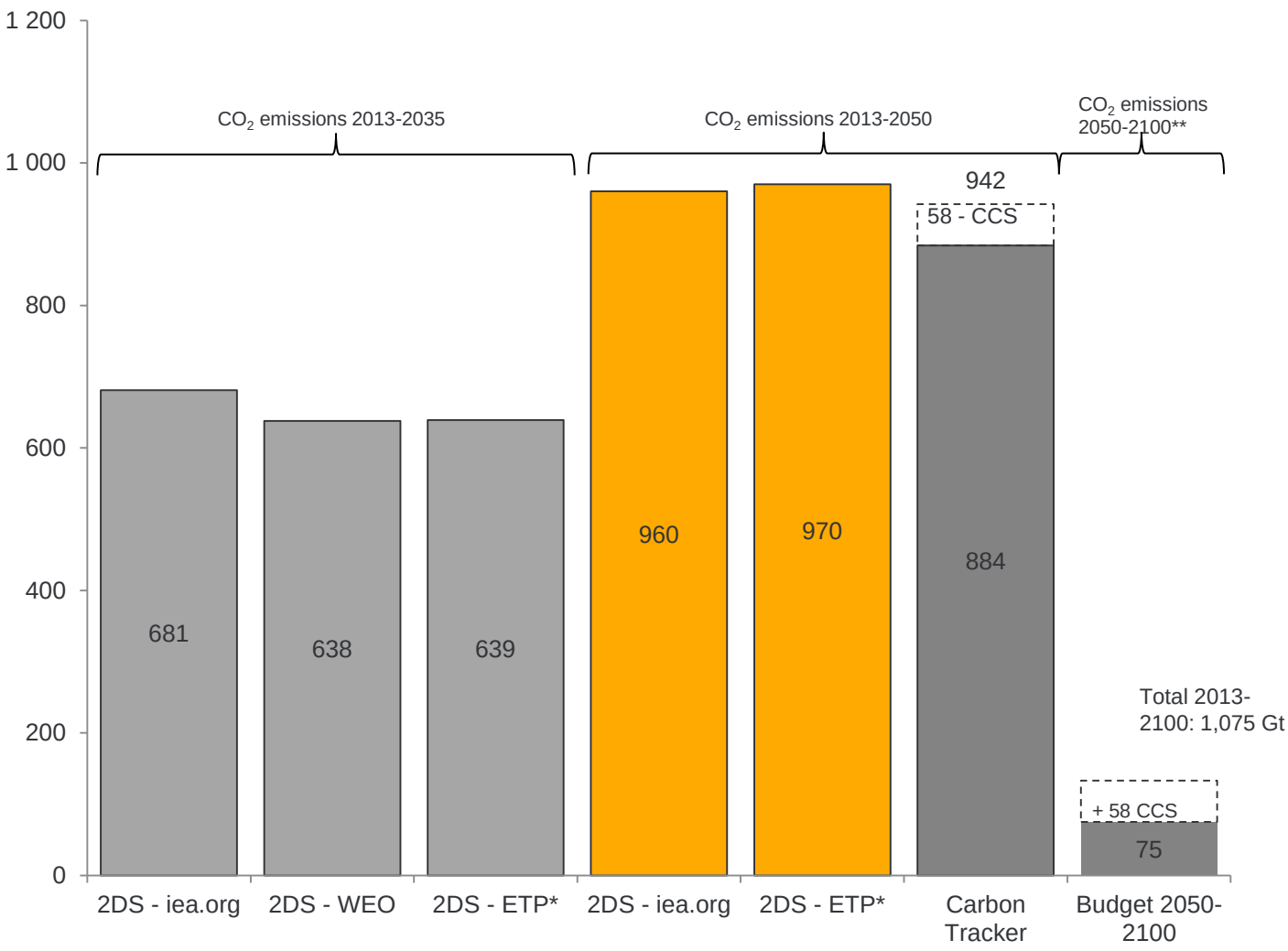
The IEA's carbon budget is higher than Carbon Tracker's 80% probability 2DS case. IEA assumes 58 Gt effect of CCS***, while Carbon Tracker does not account for increased emission potential due to carbon capture and storage (CCS). Carbon Tracker does however estimate that given a full investment in CCS, the carbon budget will increase by 12-14%.

Rystad Energy has chosen to use Carbon Trackers budget of 884 plus the 58 Gt from CCS from IEA, leaving us with a total carbon budget 2013-2050 that allows for 942 Gt of CO_2 emission from fossil resources.

After 2050 we have used the Carbon Tracker carbon budget of 75 Gt plus. CCS after 2050 is speculative and depends on demand for oil and gas. Still, it is likely that CSS will continue, and we keep the conservative estimate of 58 Gt as before 2050, leading to a total budget of 133 Gt.

The total carbon budget 2013-2050 for combustion from fossil resources given the 2DS scenario

CO_2 Gt



*) CO_2 emissions are calculated based on ETP's hydrocarbon demand estimates for each year
**) Carbon budget after 2050 : Source Carbon Tracker, "Unburnable carbon 2013"
***) The IEA CCS Roadmap 2009 *"Contributing to Global Climate Goals"*
Source: Rystad Energy research and analysis; International Energy Agency (2012), Energy Technology Perspectives 2012, OECD/IEA, Paris; IEA Energy Technology Perspective (2012)

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61% of all fossil resources to be left in ground under the chosen 2DS carbon budget

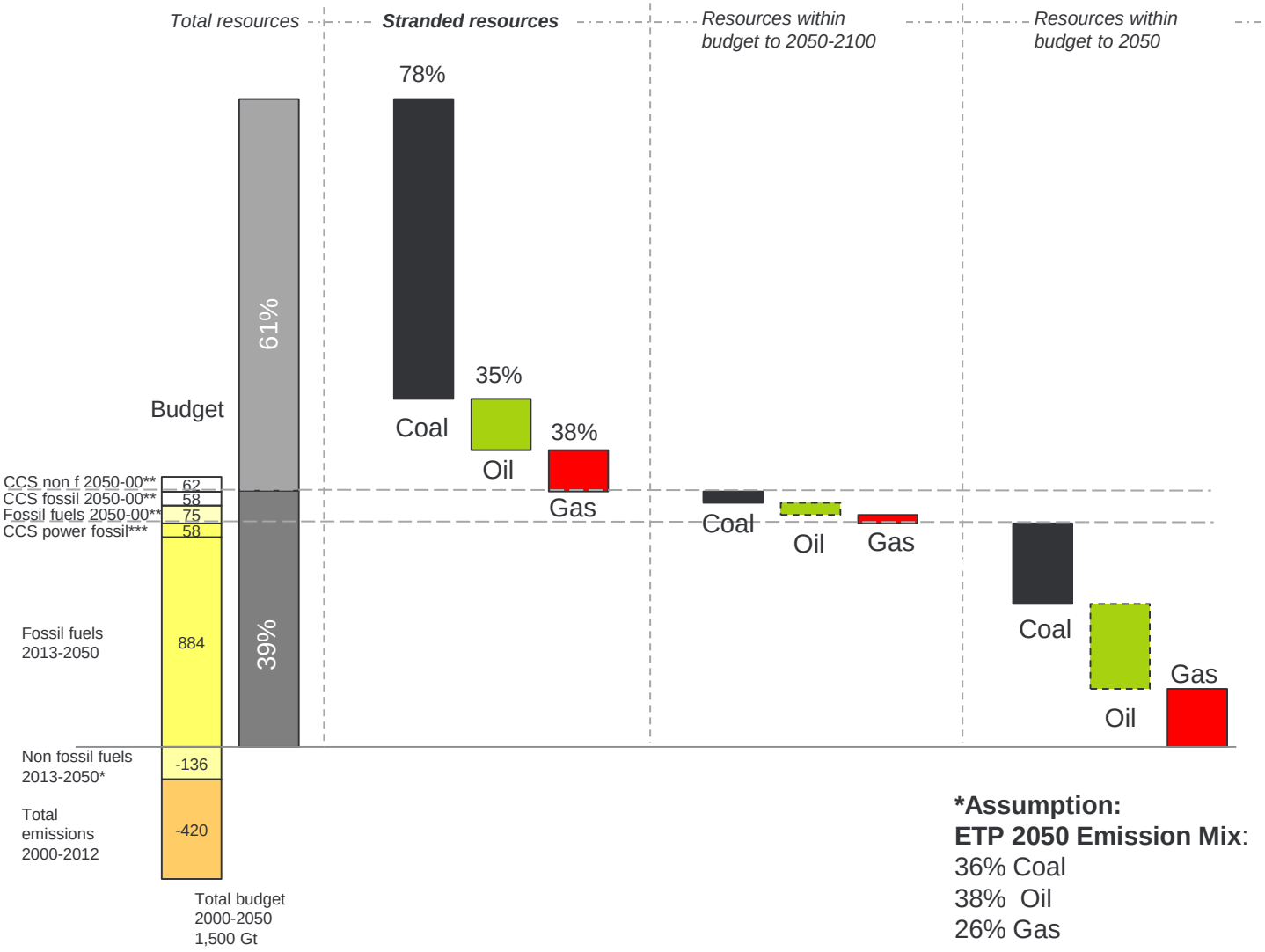
Under the 2DS, maximum cumulative CO_2 emissions during the first half of the 21st century is 1,500 Gt CO_2*. Maximum emissions from fossil resources during 2013-2050 is as shown 942 Gt, including 58 Gt removed from the atmosphere with CCS.

Measured in potential CO_2 emissions during combustion, 61% of known fossil resources must be left in the ground under 2DS. 78% of known coal resources must be left in the ground.

Assuming ETP 2050 emission mix, 35% of known oil resources and 38% of known gas resources must be left in the ground under 2DS. The large share of this "lost production" will happen after 2050.

Again, if the 2DS with 50% probability from Carbon Tracker was applied, the budget would increase by 400 Gt. Using ETP emission mix, 10% of oil and 23% of gas must be left in the ground.

Known resources versus 2DS carbon budget 2012-2050
Gt CO_2 emissions during combustion



***Assumption:**
ETP 2050 Emission Mix:
36% Coal
38% Oil
26% Gas

*Source IEA World Energy Outlook 2012
**Source Carbon Tracker, Unburnable Carbon 2013
***Budget increase due to increased Carbon Capture and Storage(CCS). Source IEA
****Source: Rystad Energy UCube, Expected value (P-Mean)

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Emission budget for oil and gas depends heavily on coal budget

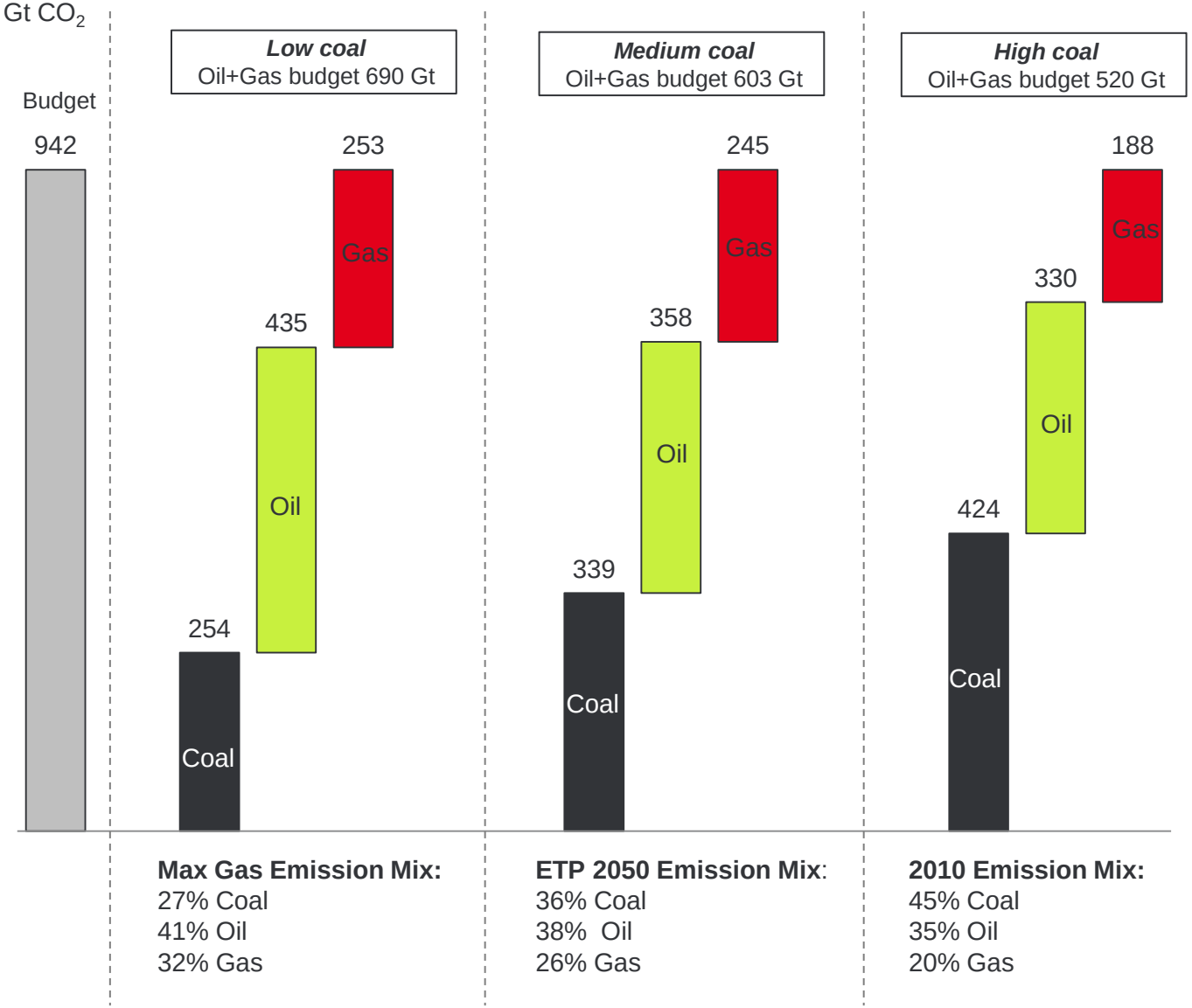
The chart on the right compares the carbon budget per fuel type for three scenarios for the CO_2 emission mix.

The "Medium coal" scenario corresponds to the average emission mix under 2DS and is the case discussed in this study.

The "High coal" scenario corresponds to the current emission mix, while the "Low coal" scenario corresponds to producing all available gas combined with a reduction of coal's emission fraction to 27%.

The carbon budget of hydrocarbons is 30% higher in the "Low coal" case than the "High coal" case, showing that coal's share of emission mix will heavily impact emission budget of hydrocarbons towards 2050.

Carbon budget per fuel type for three coal-fraction scenarios



Source: Rystad Energy research and analysis

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Most stranded oil and gas resources under 2DS are to be produced after 2050

Right chart compares forecasted CO_2 emissions in an unrestricted oil price scenario with the 2DS carbon budget before and after 2050.

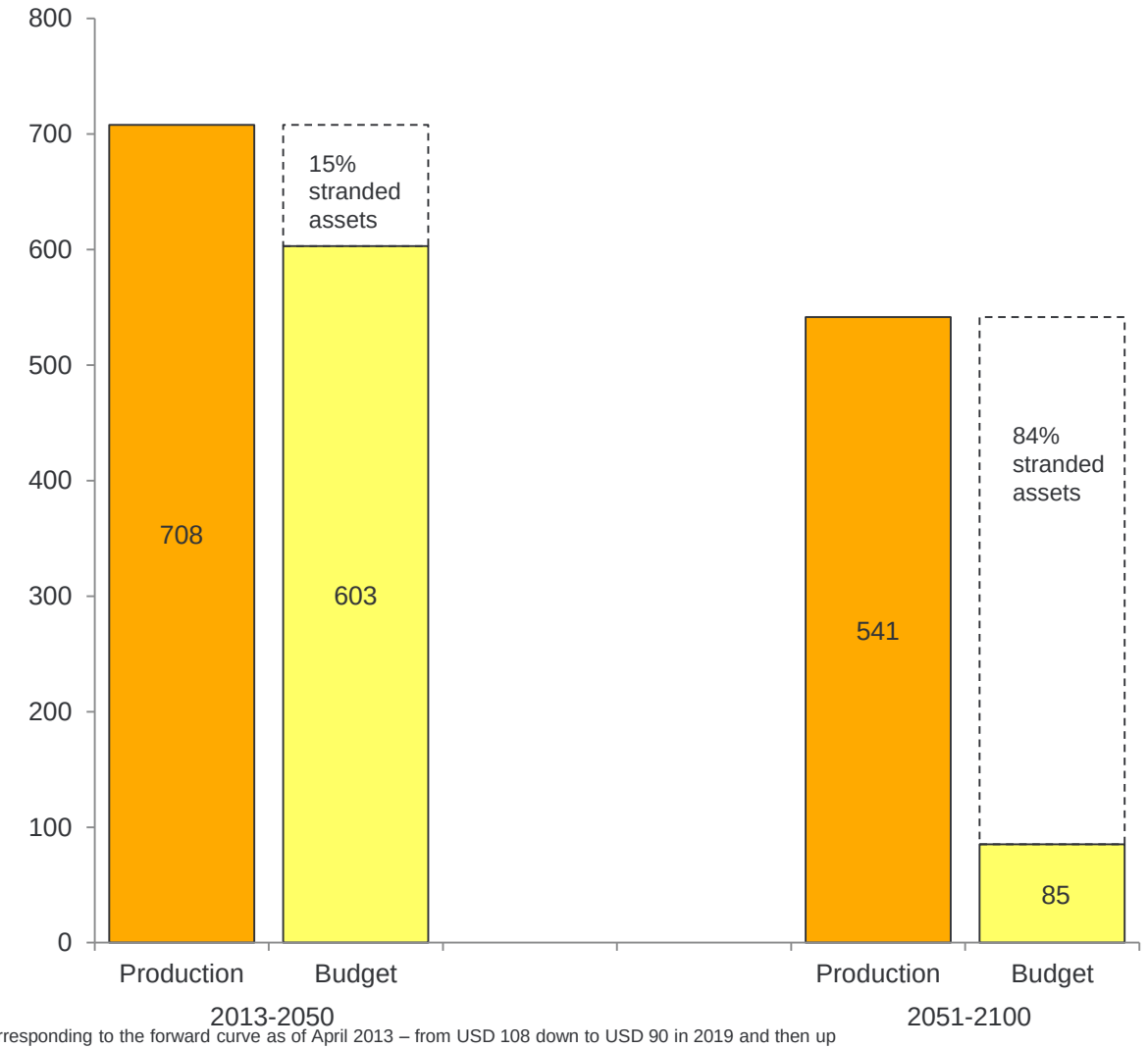
CO_2 emissions are aggregated emissions from combustion of each field's production, taking different emission factors of different hydrocarbons into account. Forecasted production from not yet discovered fields is also included in this forecast.

15% of forecasted emissions in the unrestricted base case* are above the carbon budget before 2050.

However, the 2DS scenario requires a drop to very low CO_2 emission levels post 2050 (85 Gt**), while forecasted emissions in the unrestricted case are 541 Gt. Thus, 84% of the assets are stranded under the 2DS using the 80% probability case from Carbon Tracker. However, the 50% probability case has a carbon budget of 475 Gt + CCS, which is more achievable.

Forecasted unrestricted hydrocarbon production compared to 2DS carbon budget

Gt CO_2



*Using the unrestricted forecasted production under the Brent oil price corresponding to the forward curve as of April 2013 – from USD 108 down to USD 90 in 2019 and then up

** 75Gt + 58 Gt in CCS = 133 Gt. Coal then accounts for 48 Gt of this, and 85 Gt left for oil and gas. – coal share

Source: Rystad Energy UCube

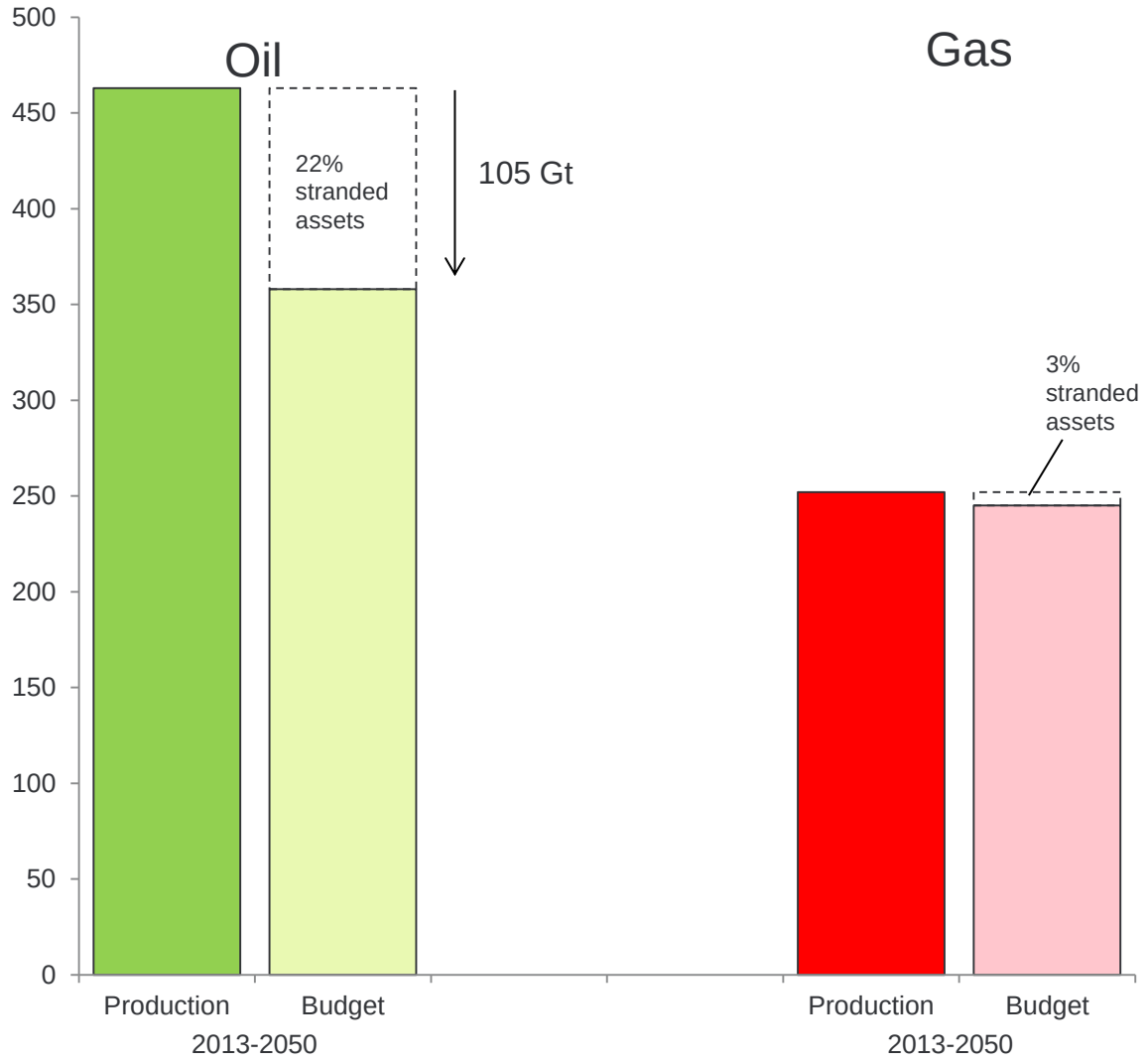
2013-2050: Gas production within carbon budget, while 22% of the oil is stranded

The chart on the right compares forecasted CO_2 emissions in an unrestricted oil price scenario with the 2DS carbon budget before 2050 for oil and gas separately, assuming the "Medium coal" energy mix scenario.

CO_2 emissions are aggregated emissions from combustion of each field's production, taking different emission factors of different hydrocarbons into account.

Only 3% of forecasted emissions from produced gas in the unrestricted case are above the carbon budget, while 105 Gt or 22% of emissions from produced oil in the unrestricted case are above the carbon budget.

Forecasted unrestricted oil and gas production compared to 2DS carbon budget before 2050
Gt CO_2



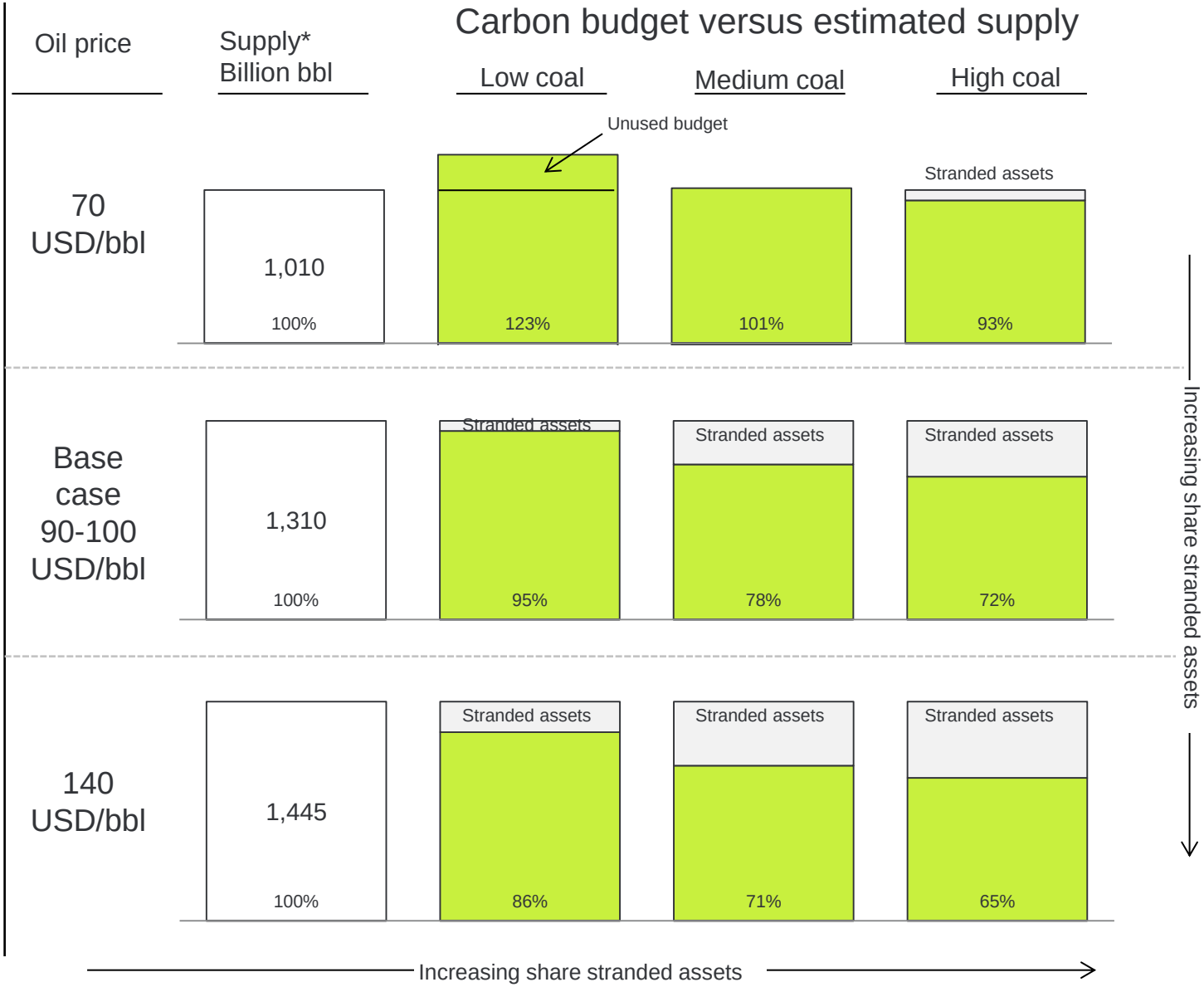
*Measured as emissions of CO_2 from combustion of produced hydrocarbons

Stranded oil varies from 0-35% of max. supply, depending on oil price level and energy mix

The table on the right compares forecasted global unrestricted oil production in 2013-2050, including resources not yet found, with oil carbon budget under the three coal fraction scenarios at three different oil price scenarios. The middle scenario reflects the base case, which is the Brent forward curve as of April 2013.

The share of production potential that is stranded increases both with augmenting coal fraction in the energy mix and with increasing oil price level.

In a low coal and low oil price scenario, forecasted supply of oil is likely to match the carbon budget.



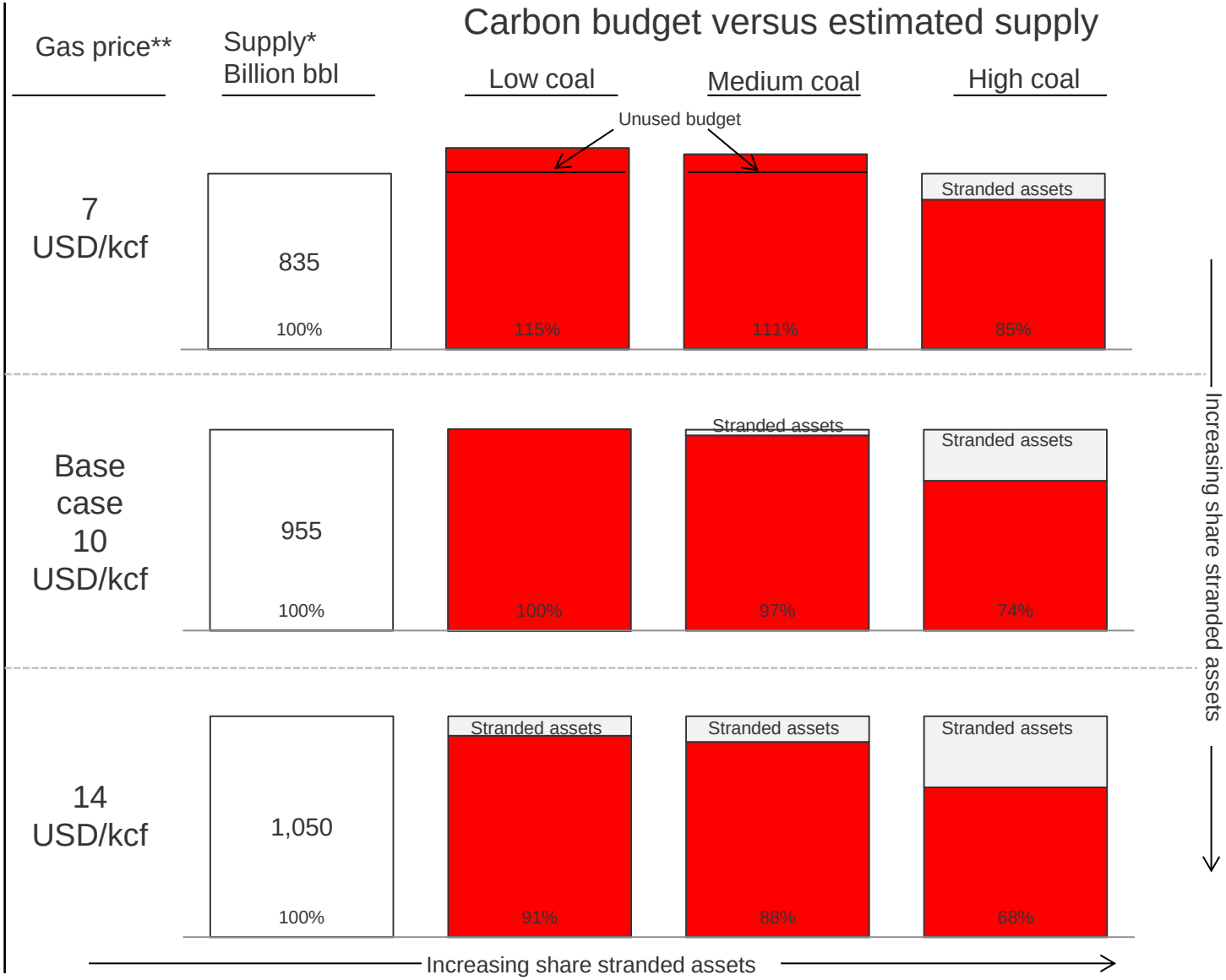
*Source: Rystad Energy UCube

Stranded gas varies from 0-32% of max. supply, depending on oil price level and energy mix

The table on the right compares forecasted global unrestricted gas production in 2013-2050, including resources not yet found, with gas carbon budget under the three coal fraction scenarios at three different oil price scenarios.

The share of production potential that is stranded increases both with increasing coal fraction in the energy mix and with increasing oil price level.

Significant levels of stranded gas exist most likely only in the high coal or high oil price scenarios.



*Source: Rystad Energy UCube
**Adapted to local gas markets globally. Europe continental price estimated to be oil price/10. Separate and lower prices used for North America.

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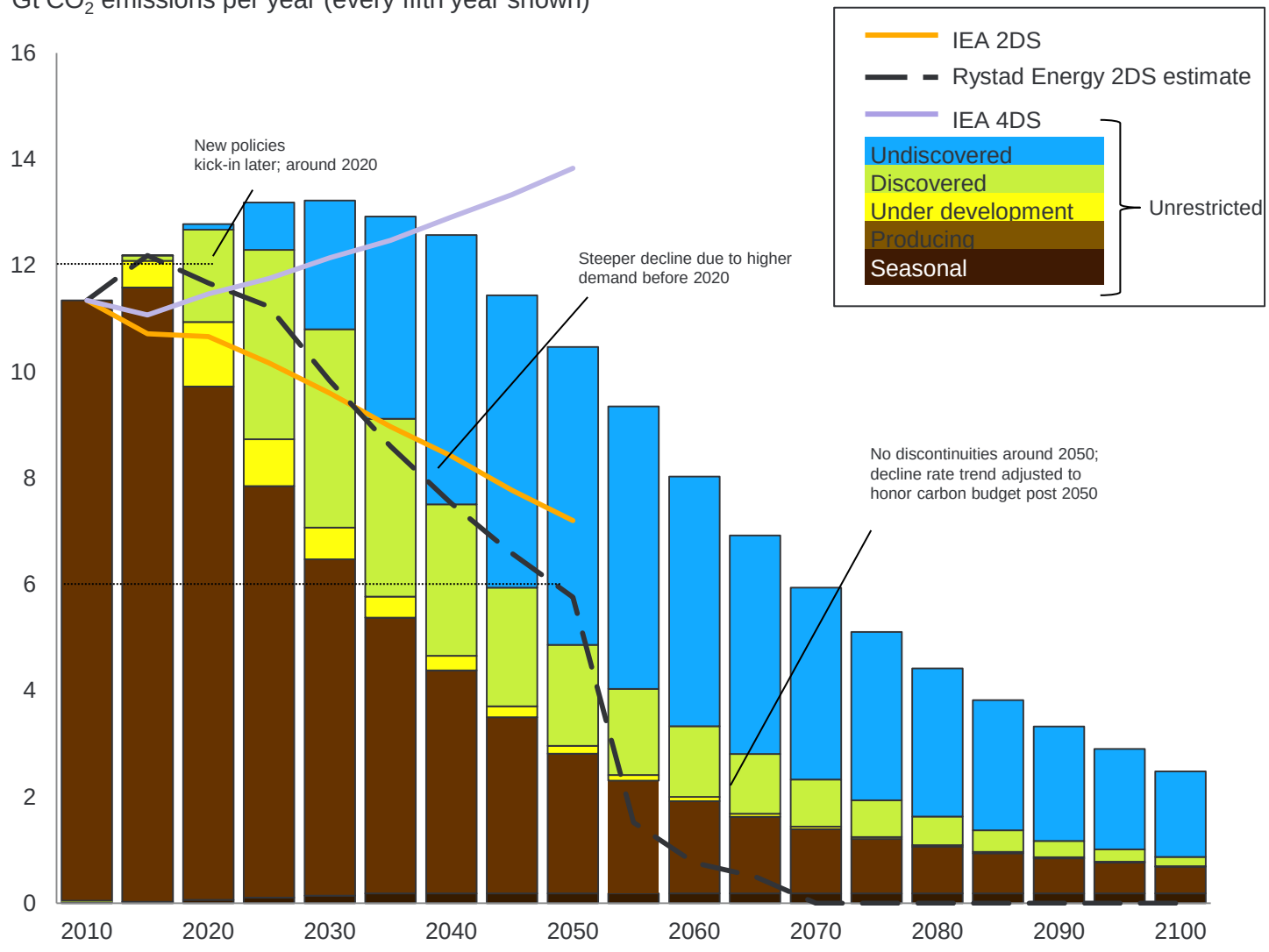
Global oil production to be reduced with 50% between 2020 and 2050 under 2DS

The chart on the right outlines CO_2 emissions from the global oil production towards 2050 spilt by current life cycle (fields in production, under development, discoveries not yet approved for development and undiscovered).

The yearly CO_2 emissions are based on 68,000 fields assessed bottom-up by Rystad Energy. The emission factors used are estimated individually for each oil and gas category, and they are calibrated to best match the factors used by the IEA.

Taking into account a likely delay of the effect of new policies until 2020, Rystad Energy suggests a steeper decline curve than IEA. This curve suggests a necessary reduction of global oil production of 50% from 2020 to 2050 under 2DS versus the unrestricted base case.

Supply of oil 2010-2100 under 2DS versus unrestricted production potential
Gt CO_2 emissions per year (every fifth year shown)



Source: Rystad Energy UCube, Rystad Energy research and analysis, IEA Energy Technology Perspectives 2012

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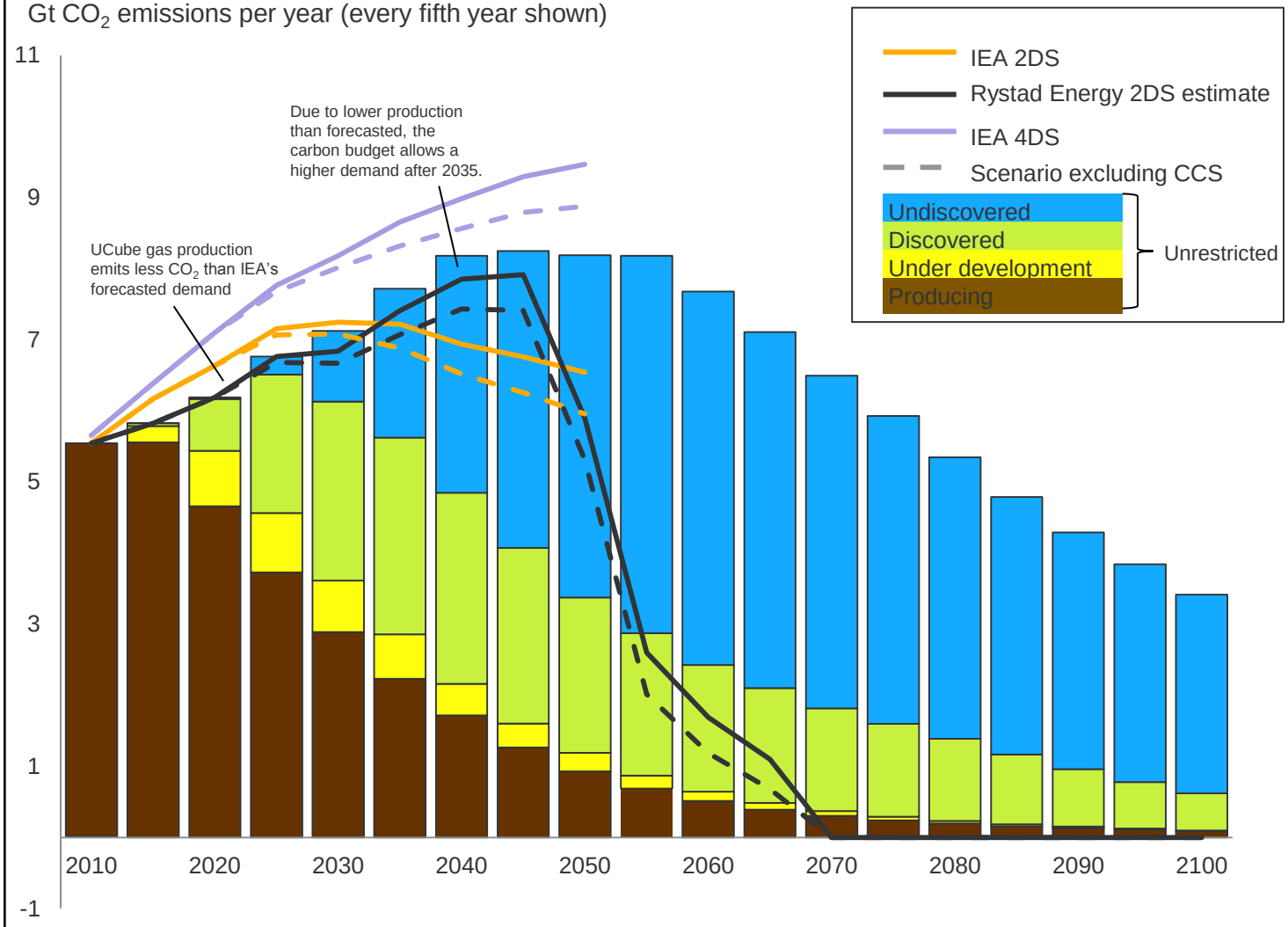
The transition from coal to gas may result in tight supply-demand balance for gas before 2035

The chart on the right outlines CO_2 emissions from the global gas production towards 2050 spilt by current life cycle (fields in production, under development, discoveries not yet approved for development and undiscovered).

The yearly CO_2 emissions are based on 68,000 fields assessed bottom-up by Rystad Energy. The emissions factors used are estimated individually for each oil and gas category, and they are calibrated to best match the factors used by the IEA.

The IEA demand curve illustrates gas demand during transition from the high to medium coal scenario, implying a tight supply/demand balance for gas before 2035

Supply of gas 2010-2100 under 2DS versus unrestricted production potential
Gt CO_2 emissions per year (every fifth year shown)



Source: Rystad Energy UCube, Rystad Energy research and analysis, IEA Energy Technology Perspectives 2012

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Stranded assets under 2DS likely to be fields not yet approved for development

The chart on the right shows estimated global CO_2 emissions from combustion of produced oil per current life cycle of oil field.

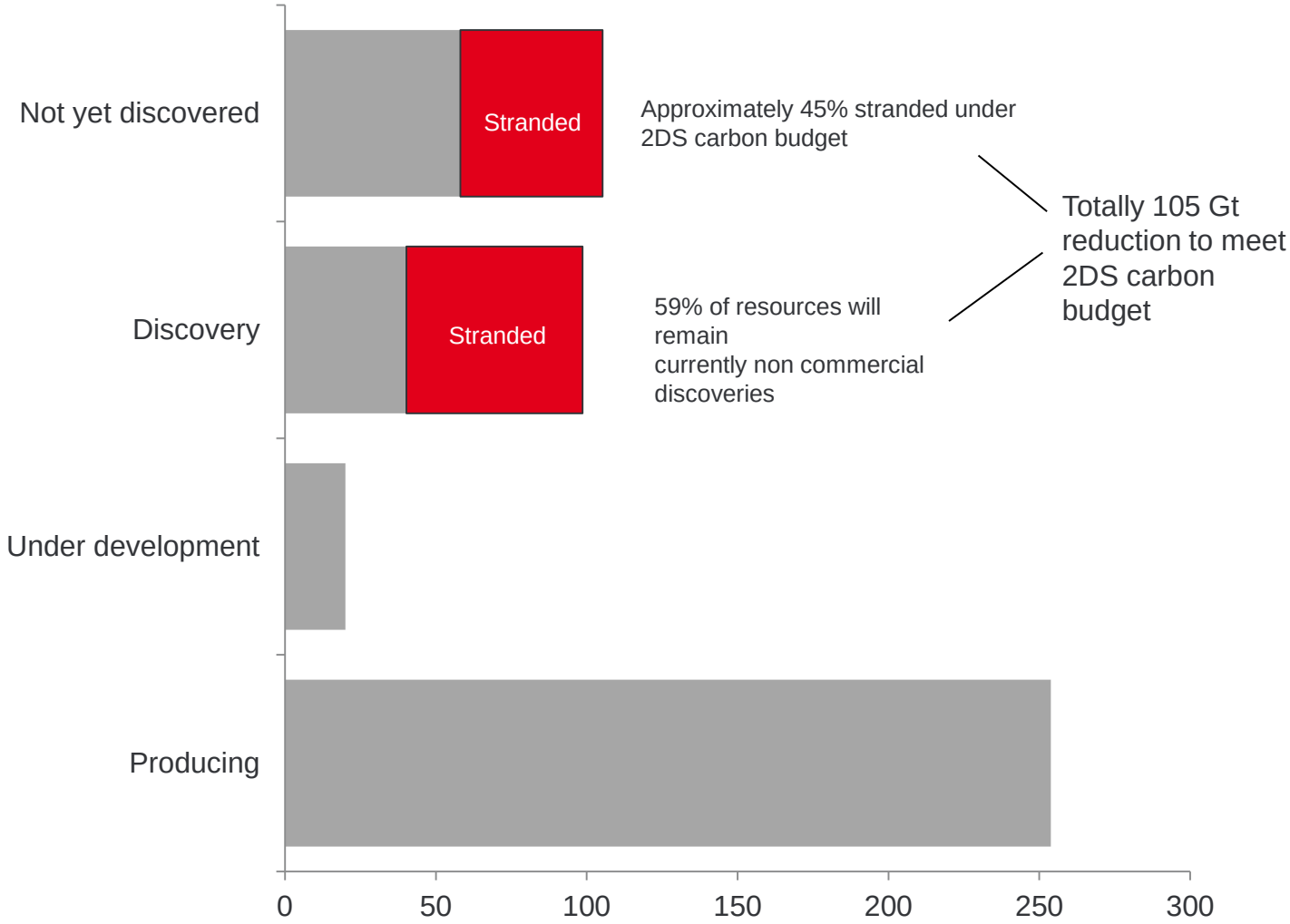
To meet oil carbon budget of 603, emissions must be reduced by 105 Gt. Since decisions are taken and capital is sunk for producing fields and fields under development, we have made the simplified assumption in this study* that these fields will continue to produce under 2DS.

All cuts are taken for fields not yet sanctioned for development. The prioritization is based on break-even prices and shown on a separate page.

The result is that 59% of unsanctioned resources and 45% of not-yet-discovered resources will have to remain in the ground.

Potential production from these two groups of assets will then be respectively 41 Gt and 58 Gt = 99 Gt, while 105 Gt will be "stranded" and unproduced, meeting the energy demand by 2050.

Global CO_2 emissions from combustion of produced oil 2013-2050 per lifecycle category
Gt CO_2



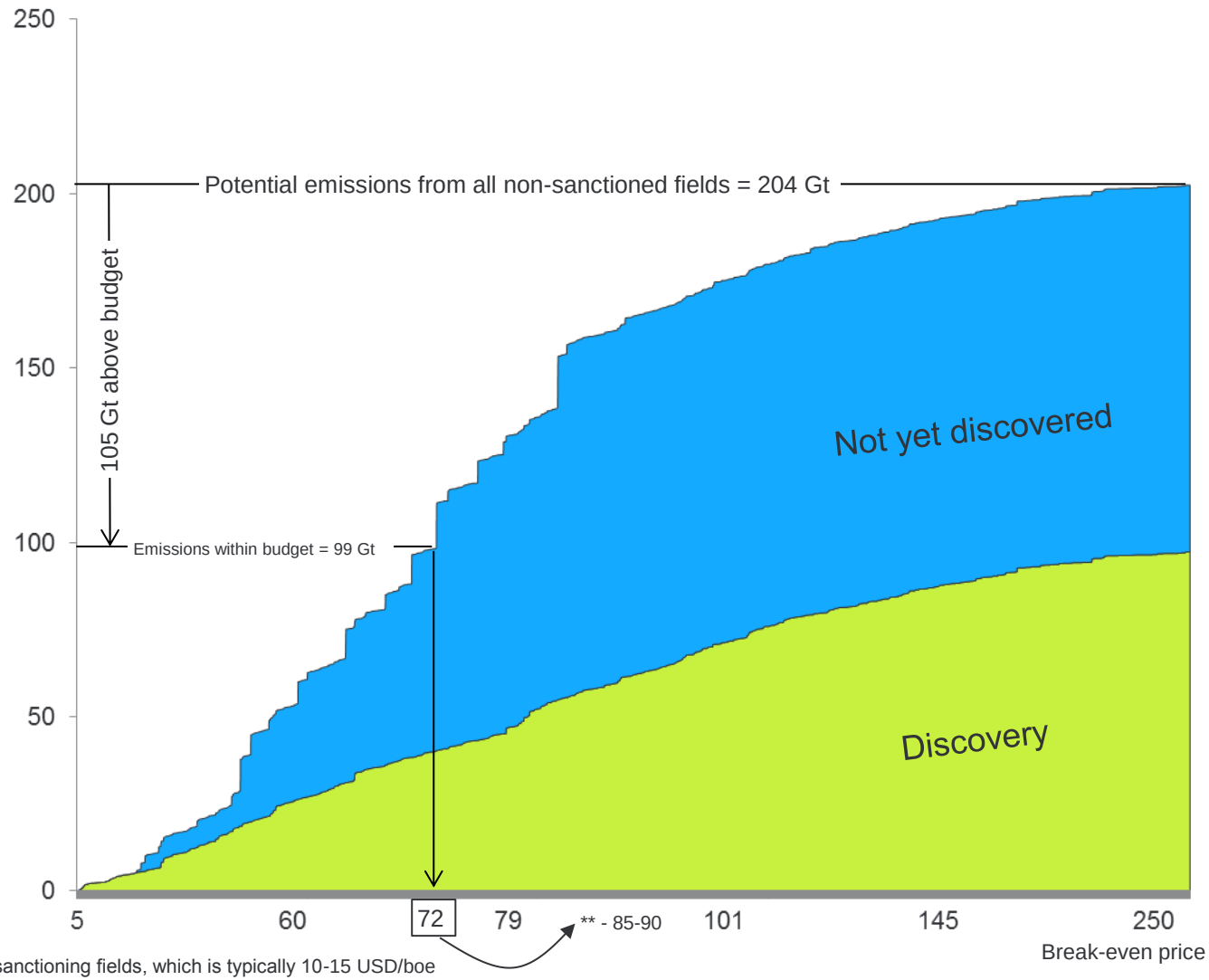
* Some producing fields might in any case be shut in under moderate and low oil prices, providing additional budget for unsanctioned fields. But this complication is not accounted for in this study.
Source: Rystad Energy UCube, Rystad Energy research and analysis

Our methodology shows that 2DS carbon budget is reached at break-even price of 72 USD/boe; Resulting oil price probably 85-90 USD per barrel

The chart shows potential cumulative CO_2 emissions during combustion of production from all currently non-producing fields between 2013 and 2050 split by discovered and not yet discovered fields.

The total 204 Gt potential emissions must be reduced with 105 Gt down to 99 Gt under 2DS, which implies that fields with break-even cost above 72 USD/bbl will not be developed.
Adding an assumed 15 USD/bbl in contingency**, an estimate of the oil price level needed to result in 2DS is 85-90 USD/bbl.

Cumulative CO_2 emissions (2013 non producing fields) 2013-2050 versus break-even price



**Probable oil price given companies' "security margins" when sanctioning fields, which is typically 10-15 USD/boe
Source: Rystad Energy UCube and special CO_2 emission database and methodology

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Most non-commercial discovered resources are located in Russia, the Middle East and Canada

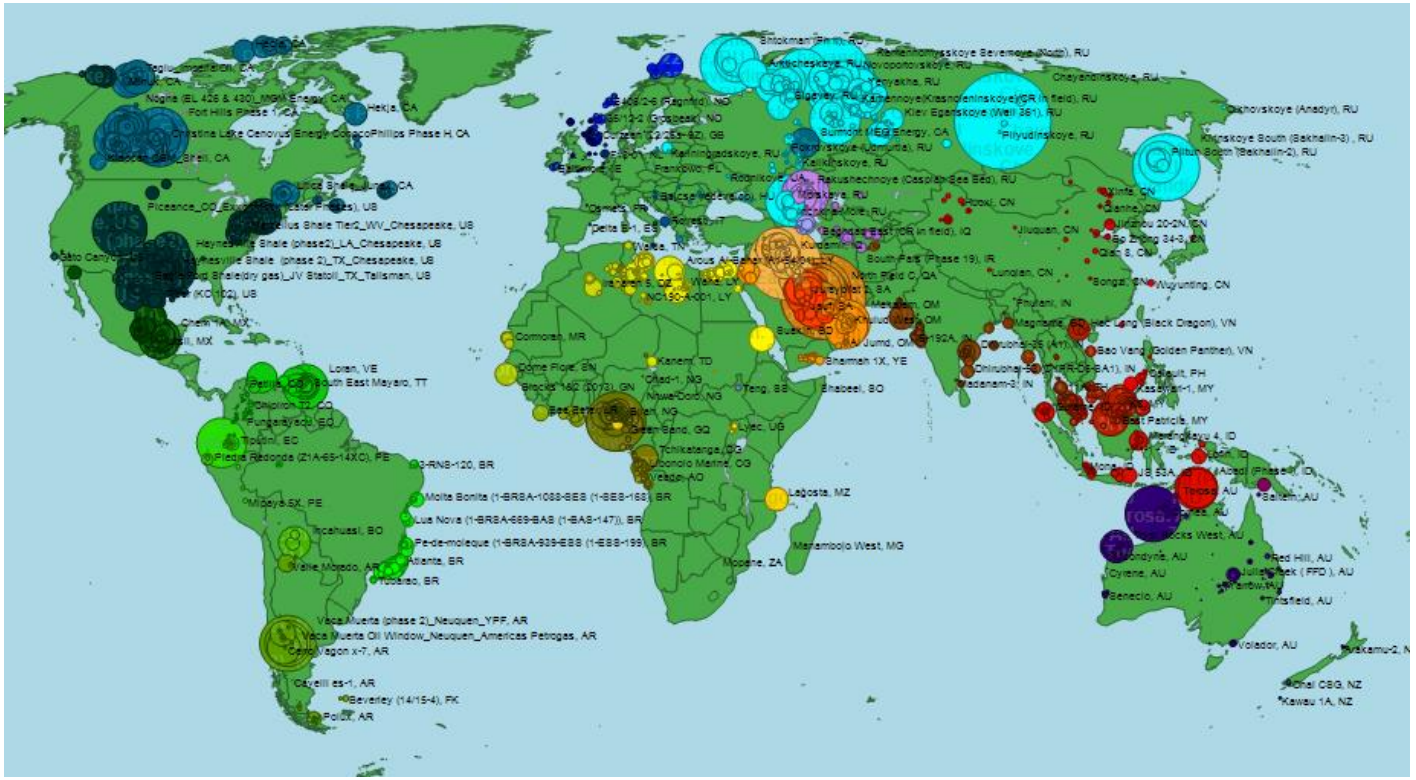
The map shows fields that are likely to be stranded under a 2DS scenario.

Most of the resources are located in Russia, the Middle East, Canada, the USA and West Africa. Difficult and deep reservoirs, unconventional recovery techniques, difficult surface conditions and sour/heavy oil might be drivers for making a field uneconomical under a 2DS oil price scenario.

The name list displayed on the map is not complete, but illustrates some of the stranded fields under 2DS.

Field economics might change as new appraisal wells are drilled, new technologies are emerging or through fiscal changes. This is not accounted for in this study.

Lost production 2013-2050 from fields that are "stranded" under a 2DS scenario



Source: Rystad Energy UCube; team analysis

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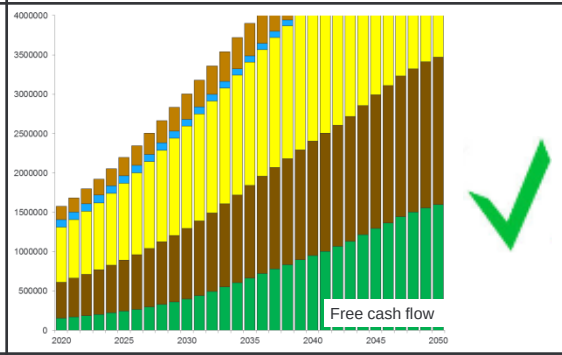
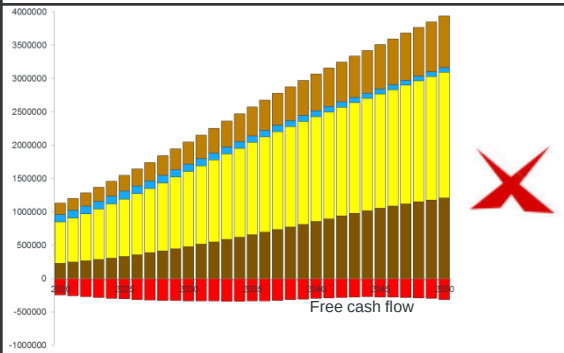
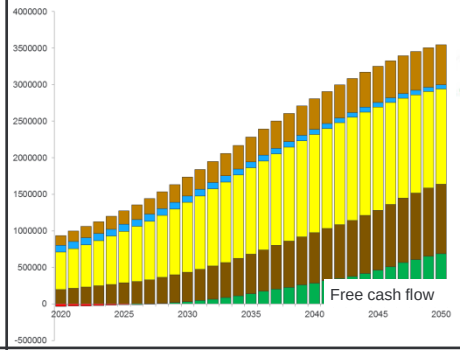
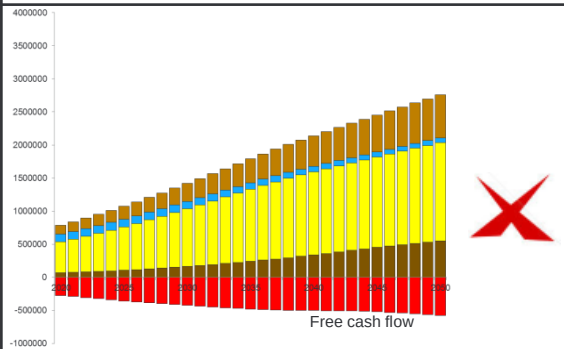
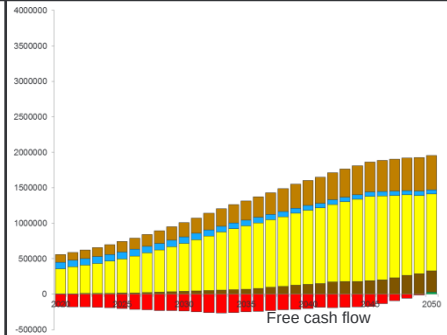
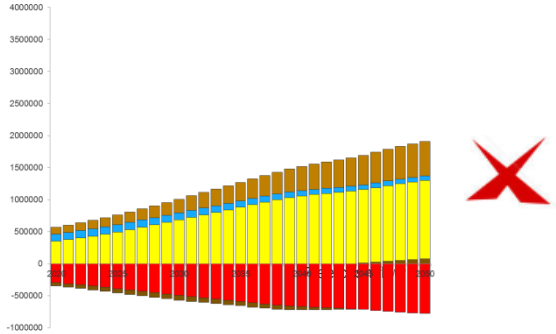
Methodology for examining undiscovered resources. Arctic example.

These graphs show the present value (PV) of aggregated regional economics from projected discoveries in currently unawarded areas in the Arctic in each of the years 2025-2050. The analysis of this area serves as methodology example.

The green bars represent the PV of free cash flow, assuming a discount rate of 7%. Each combination of price scenario and hydrocarbon type is examined to determine whether the resources will be stranded (cross) or developed (checked).

Negative PV of free cash flow over a long period indicates stranded resources while positive PVs of free cash flow indicate that resources in the region will be developed.

The regional break-even price can be determined as the lowest price that generates regional positive PV of free cash flow.

Oil/gas price USD per bbl/kcf	Oil	Gas
135 / 14	 ✓	 ✗
95 / 10	 ✓ ≥2028 ✗ <2028	 ✗
65 / 7	 ✗	 ✗

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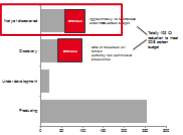


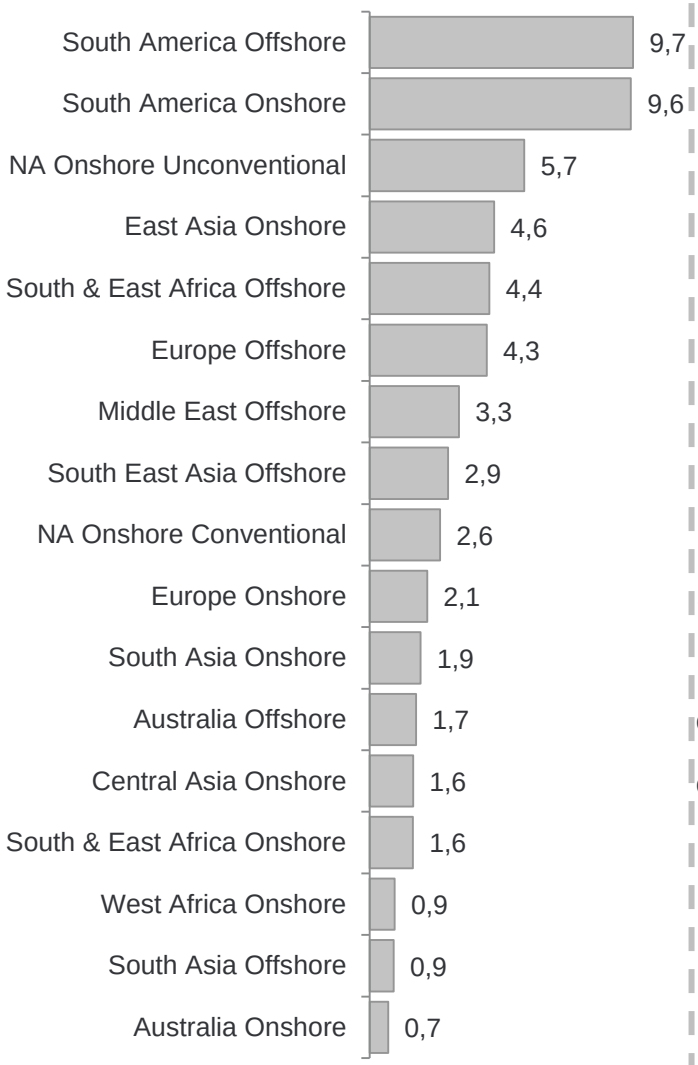
47 Gt CO_2 emissions are stranded from assets that are not yet discovered

The chart shows, which yet to be found areas that are likely to be and not be developed given the 2DS scenario.

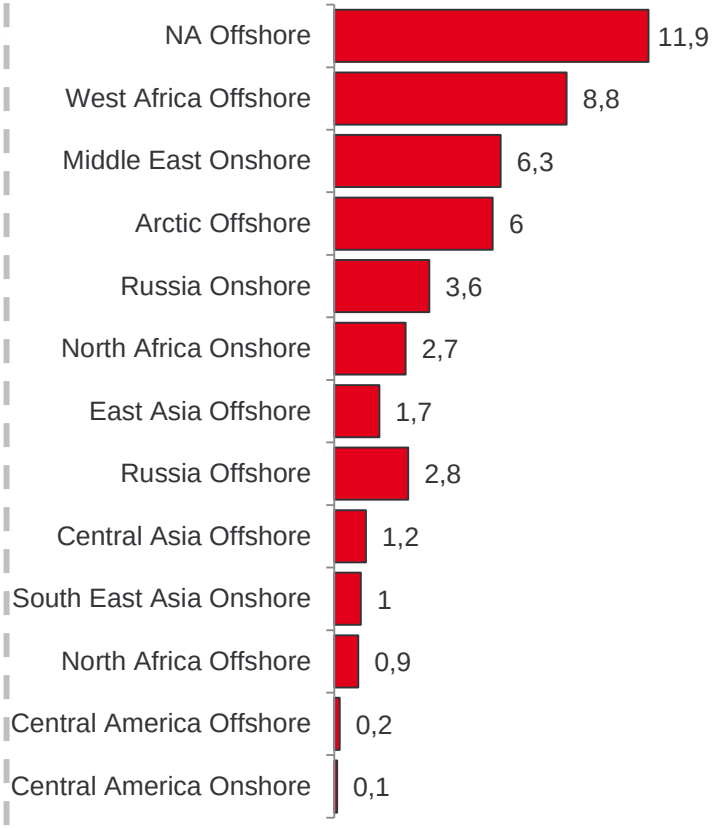
In order to be developed, these areas will likely have a break-even price below 70-80 UDS/bbl. Taking an assumed 15 USD/bbl in contingency into account, the areas in the right chart will probably be stranded in a 85-90 UDS/bbl oil price regime.

Each area will have both some developed and some stranded fields. The graphs outline areas, where most of the fields are likely to be developed (left) or stranded (right) under 2DS.

Developed areas from not yet discovered fields
Gt CO_2 emissions



Stranded areas from not yet discovered fields
Gt CO_2 emissions



Note: NA = North America
Source: Rystad Energy research and analysis

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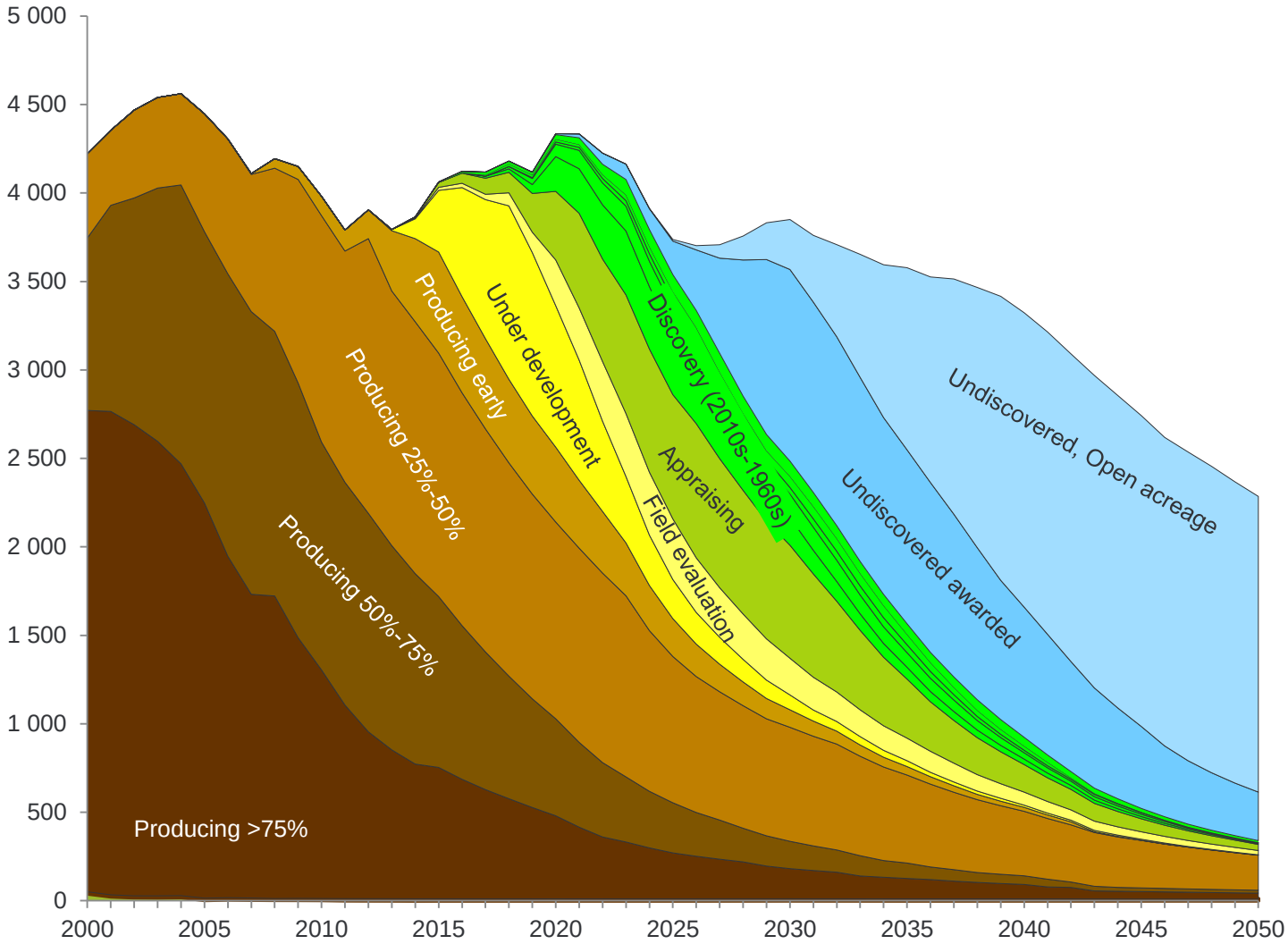
Production from Norway in an unrestricted case with high oil price

This graph shows the production potential from Norway in an unrestricted case, meaning that all fields will be produced, including fields that are currently marginally commercial.

Oil and gas production from Norway – by life cycle
Thousand boe per day



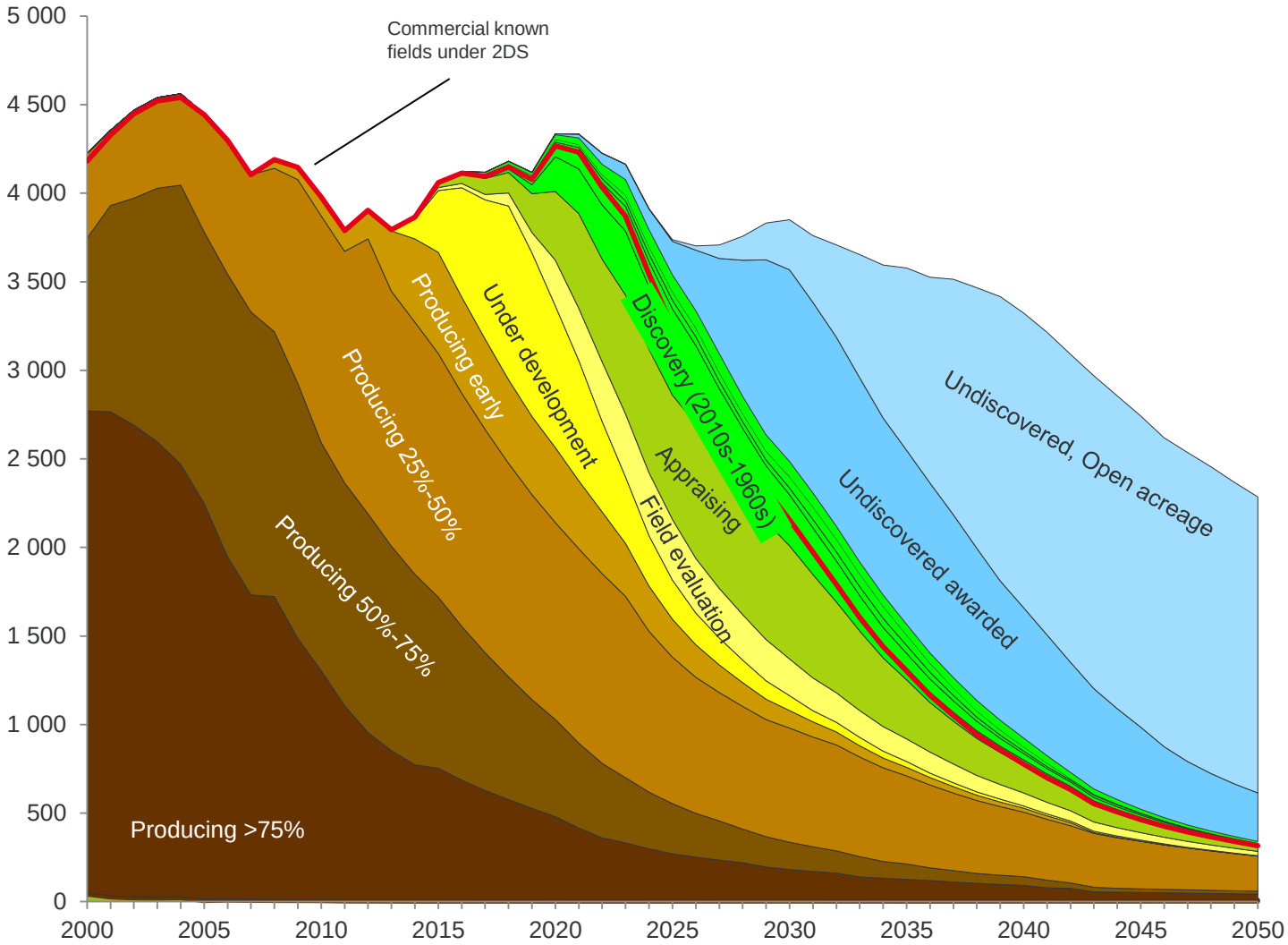
Source: Rystad Energy UCube

Restricted oil price assumptions results in more non-commercial fields

This graph shows the production potential from Norway in an unrestricted case, meaning that all fields will be produced, including fields that are currently marginally commercial.

The red line shows the production profile for fields that will be commercial under a restricted oil price assumption under the 2DS.

Oil and gas production from Norway – by life cycle
Thousand boe per day



Source: Rystad Energy UCube

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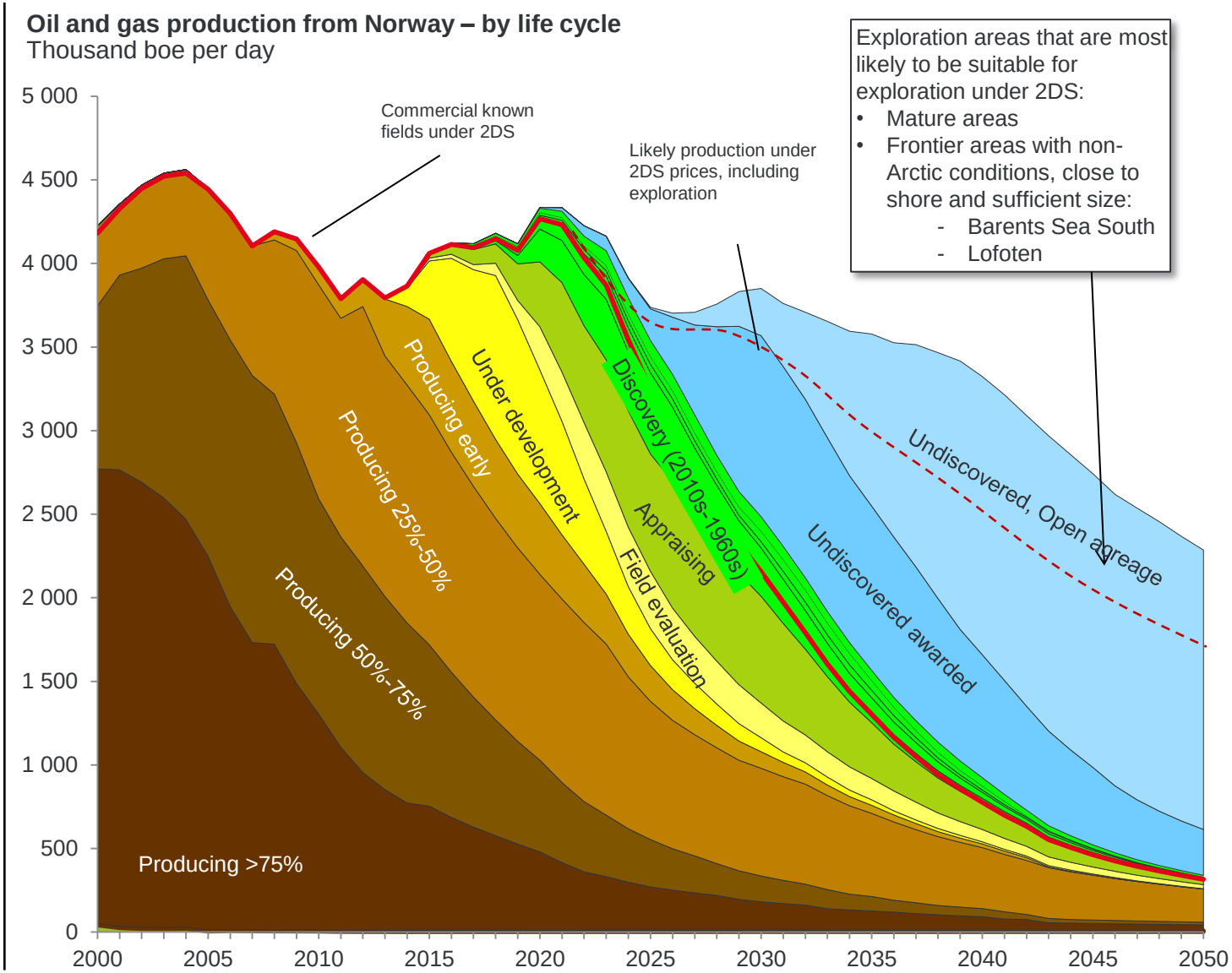
Globally, 55% of undiscovered volumes could be found and produced by 2050 – Example from Norway

This graph shows the production potential from Norway in an unrestricted case, meaning that all fields will be produced, including fields that are currently marginally commercial.

The red line shows the production profile for fields that will be commercial under a restricted oil price assumption under the 2DS.

The *dotted* red line includes also production from undiscovered fields that are viable within the 2DS scenario. Many of these fields will have better economic performance than existing unsanctioned discoveries.



Source: Rystad Energy UCube

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Potential lost production from Norway from fields that are not robust for 2DS oil prices

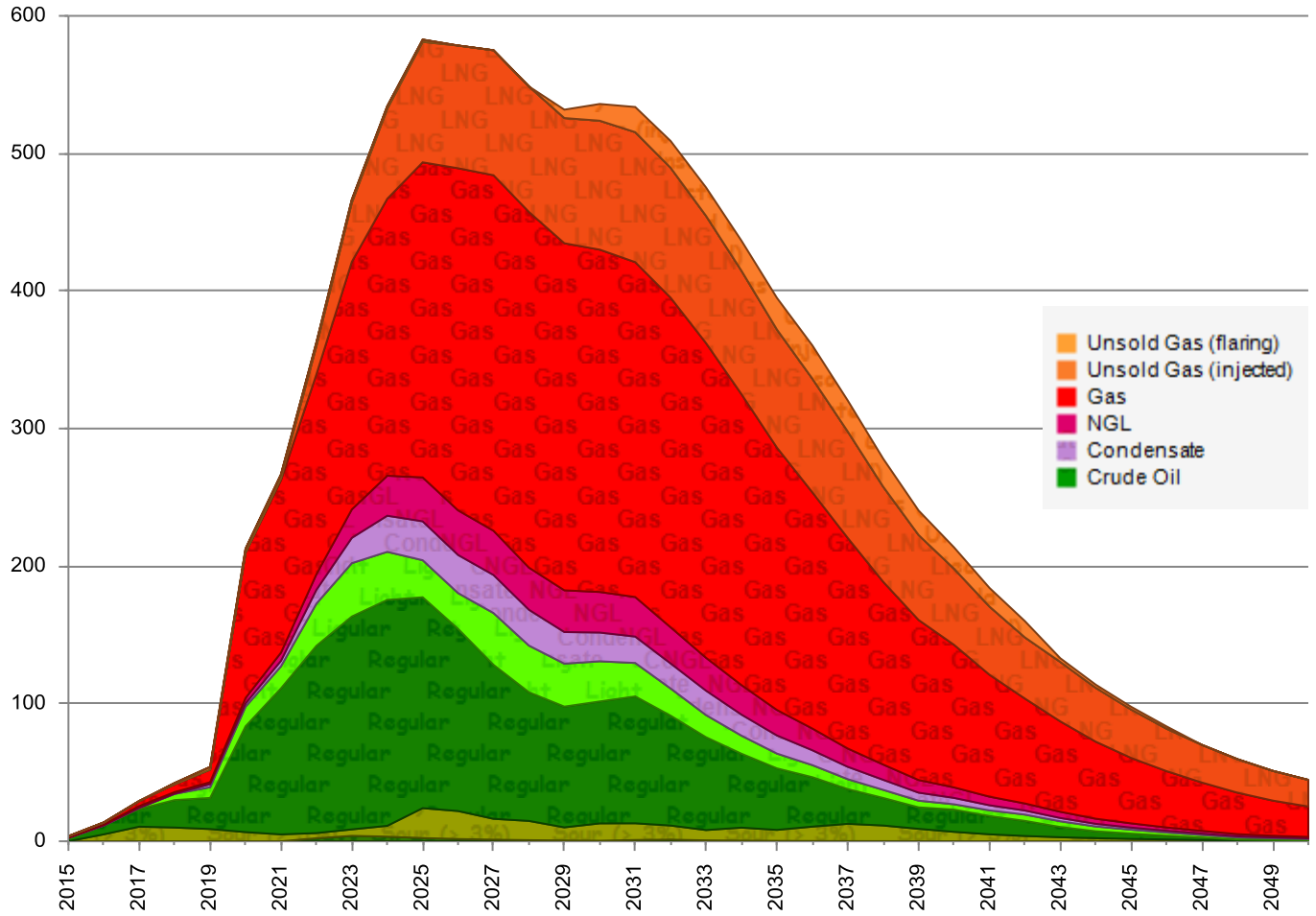
This graph shows production from fields not commercial under a regime with weak oil and gas prices in Norway, i.e. a scenario compliant to the current climate ambitions.

However, most of the omitted production is gas, which under the 2DS carbon budget still could be produced. Economic reasons hold back production even under 2DS.

As we see, peak production from these fields is above 500 thousand barrels per day in the 2020s.

Total omitted CO_2 emissions are about 1.4 Gt. However, only 25% comes from oil fields, and thus sort under a carbon budget.

Potential lost oil and gas production under 2DS prices in Norway – by HC type
Thousand boe per day



Source: Rystad Energy UCube

RYSTAD ENERGY

Potential production from Norway from fields that are not robust for 2DS oil prices

This graph shows production from fields not commercial under a regime with weak oil and gas prices in Norway, i.e. a scenario compliant to the current climate ambitions.

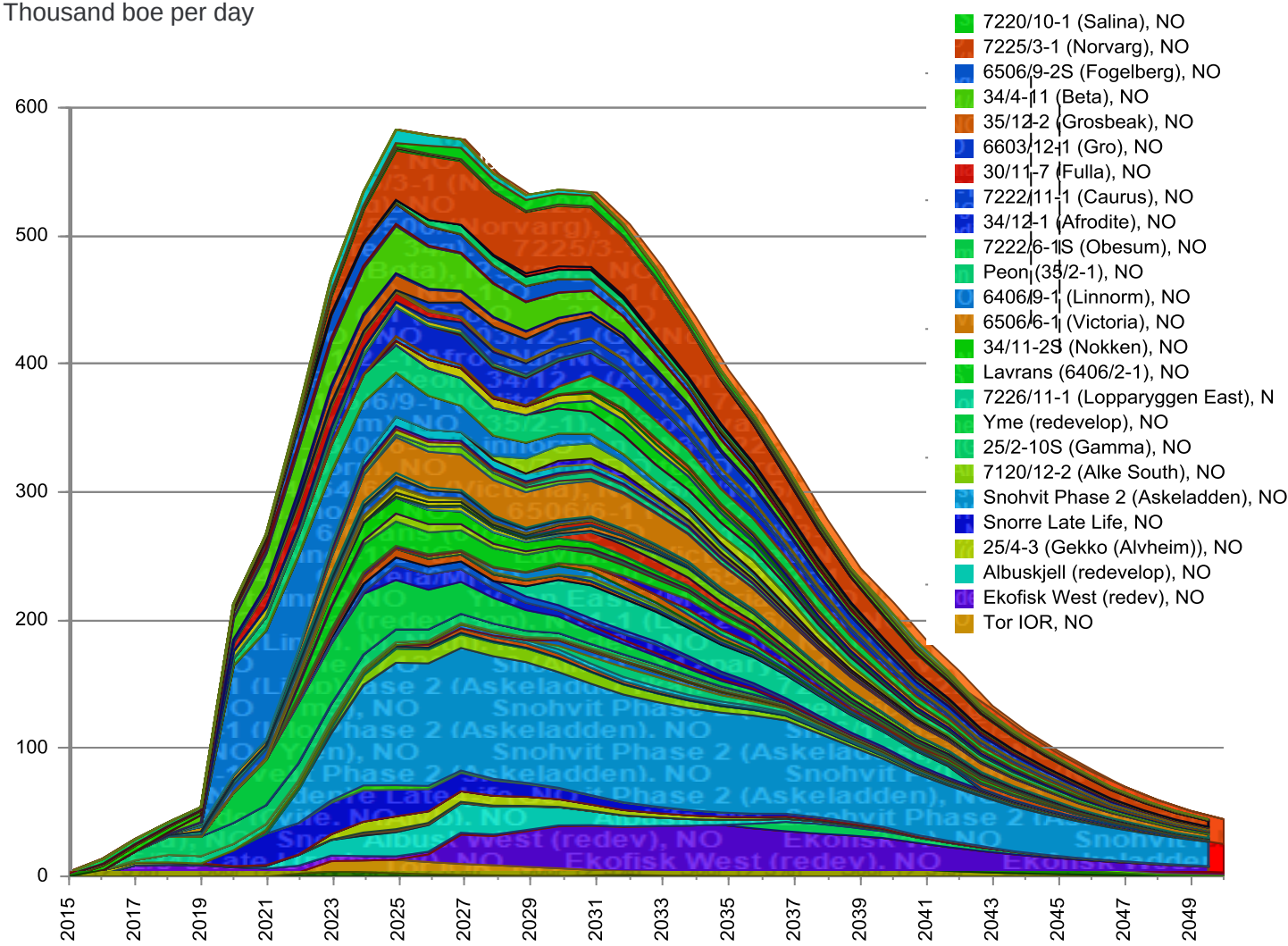
However, most of the omitted production is gas, which under 2DS still could be produced. Thus, lost gas production will sort under "unused carbon budget", since economic reasons hold back production that are viable even under 2DS.

As we see, peak production from these fields is above 500 thousand barrels per day in the 2020s.

Total omitted CO_2 emissions are about 1.4 Gt. However, only 25% ~~of~~ comes from oil fields, and thus sort under a carbon budget.

Here, the same production overview is shown with the top 25 fields shown explicitly.

Potential lost oil and gas production under 2DS prices in Norway – by HC type
Thousand boe per day



Source: Rystad Energy UCube

RYSTAD ENERGY

Unconventional oil represents around 78% of necessary emission reductions under 2DS

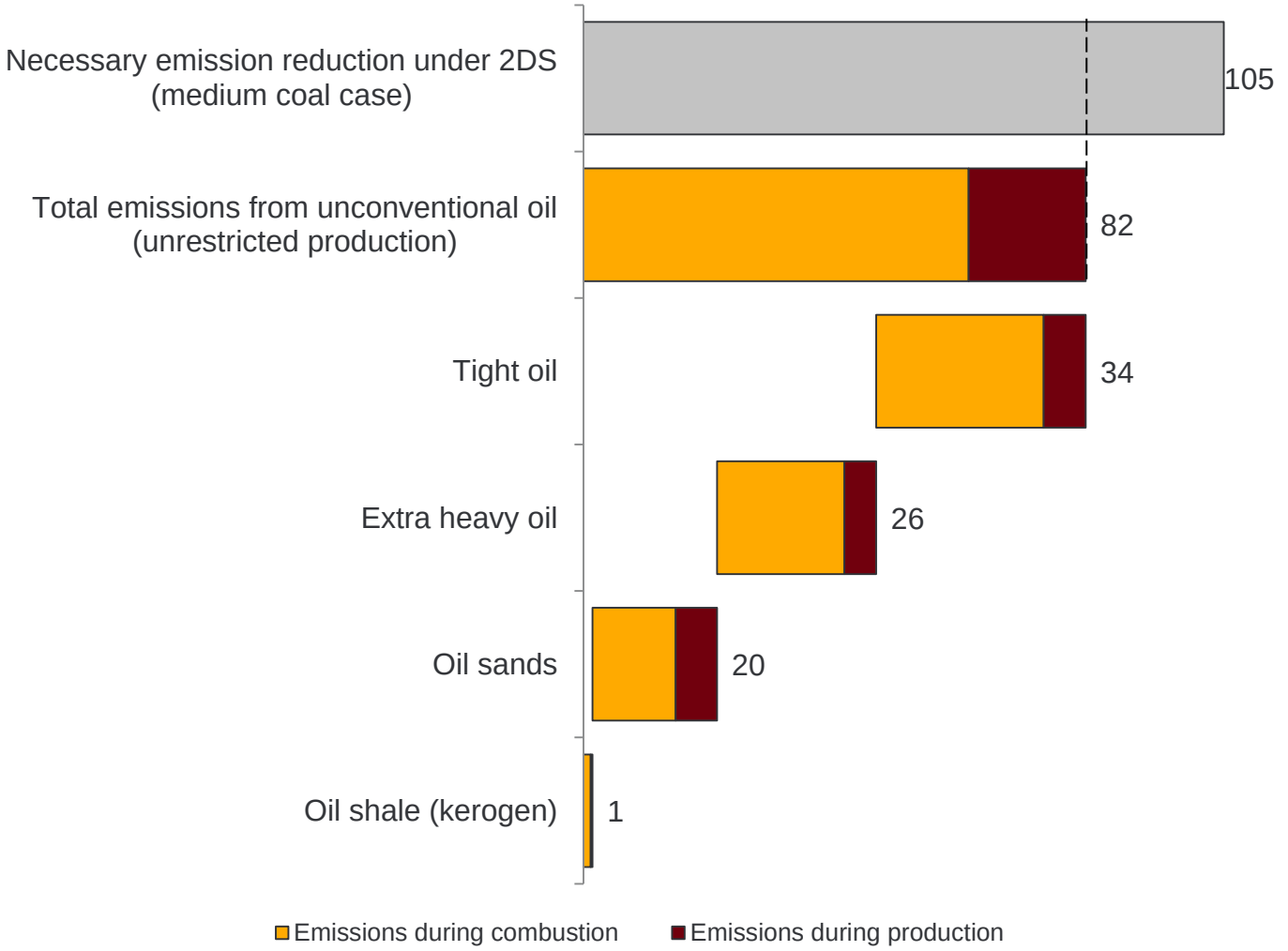
This report has discussed the adjustment of oil production to the carbon budget under 2DS, based on a pure economic approach.

An example of an alternative approach to adjusting oil production to the 2DS carbon budget is to reduce production from the fields with the highest total CO_2 emissions per volume of produced oil.

The chart on the right compares the total emissions resulting from production of oil from unconventional fields during 2013-2050 with the necessary emission reduction under 2DS discussed earlier in the report. The emissions are calculated per unconventional type as the sum of emissions during combustion and emissions during production*.

The total emissions from all unconventional oil (tight oil, extra heavy oil, oil sands and oil shale) are 82 Gt CO_2. This equals 78% of the necessary emission reduction in order to reach the 2DS scenario.

CO_2 emissions from 2013 to 2050
Gt CO_2 emissions



Source: Rystad Energy UCube, Rystad Energy research and analysis
*Emissions during production are assumed to be 25% of emissions during combustion for tight oil, extra heavy oil and oil shale, and 50% for oil sands.