2019 Report

The Production Gap

The discrepancy between countries' planned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C

APPENDICES

Contents

SEI, IISD, ODI, Climate Analytics, CICERO, and UNEP. (2019). The Production Gap: The discrepancy between countries' panned fossil fuel production and global production levels consistent with limiting warming to 1.5°C or 2°C.

Full report available at: http://productiongap.org/

Appendix A: Methodology for estimating the fossil fuel production gap

A.1 Estimating the fossil fuel production gap

To estimate the production gap, we used publicly available data to estimate the difference between national plans and projections for fossil fuel production and global production levels estimated to be consistent with 1.5°C or 2°C mitigation pathways.

To develop the global "plans and projections" pathway, we reviewed coal, oil, and gas production plans and projections from eight key producer countries, which currently account for around 60% of global production in energy terms: Australia, Canada, China, India, Indonesia, Norway, Russia, and the United States (IEA 2019b). Besides Norway, these countries constitute seven of the top ten fossil fuel producers globally (Saudi Arabia, Iran, and Iraq are not included due to limitations in data availability). The values are drawn from publicly available national plans, strategy documents, or projections by governments and affiliated institutions, as documented in Table A1.

These source documents presented the data in different units of production and did not cover all years between 2015 and 2040. We harmonized all data to units of exajoules per year (EJ/yr) and linearly interpolated between available years to derive a complete annual time series for 2015-2040. Conversion factors from physical to energy units were only provided with the original data sources for China and Australia. For other countries, factors were approximated using 2017 national production data from the International Energy Agency's 2018 World Energy Statistics and Balances (IEA 2019b). For China, coal production levels beyond 2020 were not available and are estimated from consumption projections, assuming that imports will continue to account for 7% of consumption based on the 2010-2018 average. The government projections of Russia and India included two scenarios of fossil fuel production, and we use the average of these values in our analysis. For Russia, where available projections do not extend to 2040, values are extrapolated from 2035 onward based on rates of growth in IEA NPS.

Table A1. Data sources and conversion factors used to compile the national plans and projections from eight key producer countries. Unit abbreviations are as follows: EJ = exajoules; MTCE = million tonnes of coal equivalent; MT = million tonnes; BCM = billion cubic meters; BCF = billion cubic feet; QBTU = quadrillion BTU; MTOE = million tonnes of oil equivalent; MBBL = million barrels; MBOE = million barrels of oil equivalent.

Country	Data sources	Units of original data	Conversion factor from physical to (net) energy units, where needed
Australia	Resources and Energy Quarterly 2019 from the Office of the Chief Economist; Australian Energy Projections to 2049-50 from the Bureau of Resources and Energy Economics (Office of the Chief Economist 2019; Syed 2014)	Energy (EJ)	
Canada	Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040 from the National Energy Board (National Energy Board 2018)	Physical (MBBL for oil and BCF for gas)	Oil: 1.659 EJ/MBD Gas: 0.035 EJ/BCM
China	China Energy Databook Version 9.0 (2016) from the China Energy Group and Lawrence Berkeley National Laboratory *(China Energy Group and Lawrence Berkeley National Laboratory 2016)*; China energy statistical yearbook 2018 from the National Bureau of Statistics *(Department of Energy Statistics, National Bureau of Statistics 2018)*; Energy Production and Energy Consumption Strategy (2016-2030)	Historical in energy (MTCE); Projection in physical (MT for coal and oil, BCM for gas)	Coal: 0.71 kgce/kg Oil: 1.425 kgce/kg Gas: 1.179 kgce/bcm

	from the National Development and Reform Commission (NDRC) and National Energy Administration (NEA) *(National Development and Reform Commission (NDRC) and National Energy Administration (NEA) 2016)*; 2050 World and China Energy Outlook (2018 Edition) from the Sinopec Economic Technology Research Institute *(Sinopec Economic Technology Research Institute 2018)*; 13th Five-Year Plan for Coal Industry Development (The People's Republic of China 2016)		
India	Draft National Energy Policy 2017 from the National Institution for Transforming India (NITI Aayog 2017)	Historical in physical (MT for coal and oil, BCM for gas); Future in energy (MTCE for coal, MTOE for oil) and in physical (BCM for gas)	Coal: 0.016 EJ/MT Oil: 1.975 EJ/MBD Gas: 0.035 EJ/BCM
Indonesia	Indonesia Energy Outlook 2018 from the Center of Assessment for Process and Energy Industry (PPIPE) and Agency for the Assessment and Application of Technology (BPPT) (PPIPE and BPPT 2018)	Physical (MT for coal, MBBL for oil, and BCF for gas)	Coal: 0.022 EJ/MT Oil: 1.922 EJ/MBD Gas: 0.037 EJ/BCM
Norway	Revised National Budget 2018-2019 from the Norwegian Ministry of Finance (Norwegian Ministry of Finance 2019)	Energy (MBOE)	
Russia	Draft Energy Strategy of the Russian Federation to 2035, Edition of 1 February 2017, from the Ministry of Energy of the Russian Federation (Ministry of Energy of the Russian Federation 2017)	Physical (MT for coal and oil, BCM for gas)	Coal: 0.024 EJ/MT Oil: 2.045 EJ/MBD Gas: 0.035 EJ/BCM
United States	Annual Energy Outlook 2019; Monthly Energy Review 2018 from the U.S. Energy Information Administration (U.S. EIA 2018; U.S. EIA 2019)	Gross energy (QBTU)	

For all other countries besides those in Table A1, we assume that planned production for each year occupies the same fraction of global coal, oil, or gas supply, respectively, as in each year of the International Energy Agency's New Policies Scenario (NPS) (IEA 2018). The NPS sees production from the countries in Table A1 continuing to account for approximately 60% of the fossil fuels (in energy terms) through 2040.

Report Table 3.1 includes four additional countries – Argentina, Brazil, Kazakhstan, and Mexico – for which plans and projections are publicly available. Because we did not conduct fuller reviews for these countries (see Chapter 4), we did not include them in deriving our global trajectory of planned and projected fossil fuel production. Had we included them, the production gap in 2030 would have been slightly larger because growth in oil and gas production in these projections are larger than those in the IEA NPS scenario. Data sources for these four countries are listed in Table A2.

Table A2. Data sources for additional national plans and projections listed in Table 3.1. Original data were all reported in physical units.

Country	**Data sources**
Argentina	National Energy Plan (Secretario de Gobierno de Energía 2018)
Brazil	Plano Decenal de Expansão de Energia 2027 (The Ten-Year Energy Expansion Plan 2027) (Ministério de Minas e Energia 2018)
Kazakhstan	Concept for the Development of the Fuel and Energy Sector until 2030 (Government of the Republic of Kazakhstan 2014)
Mexico	Oil and Oil Products, Natural Gas, and LP Gas Outlooks 2017-2031 (Secretaría de Energía SENER 2017c; Secretaría de Energía SENER 2017a; Secretaría de Energía SENER 2017b)

Least-cost mitigation pathways consistent with limiting warming to 1.5°C or 2°C above pre-industrial levels were drawn from the set of over a hundred scenarios compiled by the IPCC Special Report on 1.5 °C (IPCC 2018). Raw timeseries data from all models and scenarios, plus metadata, were downloaded from the IPCC 1.5°C scenario database (version 1.1, released Feb 2019)[1] maintained on the International Institute for Applied Systems Analysis website (Huppmann et al. 2018). Global fossil fuel production values are taken as the "Primary Energy|Coal", "Primary Energy|Oil", and "Primary Energy|Gas" variables.

These mitigation pathways relied on varying scales and types of carbon dioxide removal (CDR) deployment, with bioenergy with carbon capture and storage (BECCS) and afforestation being the most common CDR measures included. As the IPCC SR1.5 states, “CDR deployed at scale is unproven, and reliance on such technology is a major risk in the ability to limit warming to 1.5°C” owing to “multiple feasibility and sustainability concerns” (Rogelj et al. 2018, p. 96). In this analysis, we identify “1.5°C -consistent” and “2°C -consistent” mitigation pathways following the methodology outlined in the 2018 Climate Action Tracker (CAT) Warming Projections Global Update report (New Climate Institute et al. 2018), which considers the degree of overshoot for each temperature limit and imposes additional CDR constraints that are aligned with sustainability and economic considerations. Table A3 summarizes the classification and criteria of the 1.5°C- and 2°C-consistent pathways used in this report. Table A4 lists the number of scenarios analyzed by each model under each temperature limit. The full set of models, scenarios, and their characterizations and CDR constraints are shown in Table A5.

Table A3. Classification of pathways used in this analysis. The “pathway class” and “pathway selection criteria and description” definitions are drawn from Table 2.1 of SR1.5 Chapter 2. The same additional CDR constraints are applied to each pathway group.

Pathway group	Pathway class	Pathway selection criteria and description	Additional CDR constraints	Number of scenarios
1.5°C-compatible	Below-1.5°C	Pathways limiting peak warming to below 1.5°C during the entire 21st century with 50-66% likelihood	Pathways in which the average 2040-2060 BECCS values are lower than 5.0 $GtCO_2$/yr and average 2040-2060 afforestation values are lower than 3.6$GtCO_2$/yr	4
	1.5°C-low overshoot	Pathways limiting median warming to below 1.5°C in 2100 and with a 50-67% probability of temporarily overshooting that level earlier, generally implying less than 0.1°C higher peak warming than Below-1.5°C pathways		15
2°C-compatible	1.5°C-high overshoot	Pathways limiting median warming to below 1.5°C in 2100 and with a greater than 67% probability of temporarily overshooting that level earlier, generally implying 0.1-0.4°C higher peak warming than Below-1.5°C pathways		8
	Lower-2°C	Pathways limiting peak warming to below 2°C during the entire 21st century with greater than 66% likelihood		47

[1] Available at https://data.ene.iiasa.ac.at/iamc-1.5c-explorer/

Table A4. Number of scenarios from each model analyzed under the 1.5°C-compatible or 2°C-compatible pathways

Model	1.5°C-compatible	2°C-compatible
AIM/CGE 2.0	2	6
GCAM 4.2	2	5
IMAGE 3.0.1	2	7
MESSAGE v.3		3
MESSAGE-GLOBIOM 1.0	3	10
MESSAGEix-GLOBIOM 1.0	1	2
POLES ADVANCE		2
POLES EMF33	7	5
REMIND 1.7		1
REMIND-MAgPIE 1.7-3.0		10
WITCH-GLOBIOM 4.2		3
WITCH-GLOBIOM 4.4	2	1
Total	**19**	**55**

Table A5. Full list of models and scenarios identified as 1.5°C-compatible or 2°C-compatible in this report.

Pathway	Model	Scenario	Category
1.5C	AIM/CGE 2.0	SSP1-19	1.5C low overshoot
1.5C	AIM/CGE 2.0	SSP2-19	1.5C low overshoot
1.5C	AIM/CGE 2.1	TERL_15D_LowCarbonTransportPolicy	1.5C low overshoot
1.5C	AIM/CGE 2.1	TERL_15D_NoTransportPolicy	1.5C low overshoot
1.5C	IMAGE 3.0.1	IMA15-LiStCh	1.5C low overshoot
1.5C	IMAGE 3.0.1	SSP1-19	1.5C low overshoot
1.5C	MESSAGE-GLOBIOM 1.0	ADVANCE_2020_1.5C-2100	1.5C low overshoot
1.5C	MESSAGE-GLOBIOM 1.0	SSP1-19	1.5C low overshoot
1.5C	MESSAGE-GLOBIOM 1.0	SSP2-19	1.5C low overshoot
1.5C	MESSAGEix-GLOBIOM 1.0	LowEnergyDemand	1.5C low overshoot
1.5C	POLES EMF33	EMF33_1.5C_cost100	Below 1.5C
1.5C	POLES EMF33	EMF33_1.5C_limbio	Below 1.5C
1.5C	POLES EMF33	EMF33_1.5C_nofuel	Below 1.5C
1.5C	POLES EMF33	EMF33_WB2C_limbio	1.5C low overshoot
1.5C	POLES EMF33	EMF33_WB2C_nobeccs	1.5C low overshoot
1.5C	POLES EMF33	EMF33_WB2C_nofuel	1.5C low overshoot
1.5C	POLES EMF33	EMF33_WB2C_none	1.5C low overshoot
1.5C	WITCH-GLOBIOM 4.4	CD-LINKS_NPi2020_1000	1.5C low overshoot
1.5C	WITCH-GLOBIOM 4.4	CD-LINKS_NPi2020_400	Below 1.5C
2C	AIM/CGE 2.0	ADVANCE_2020_WB2C	Lower 2C
2C	AIM/CGE 2.0	ADVANCE_2030_Price1.5C	Lower 2C
2C	AIM/CGE 2.0	ADVANCE_2030_WB2C	Lower 2C
2C	AIM/CGE 2.0	SSP1-26	Lower 2C
2C	AIM/CGE 2.0	SSP2-26	Lower 2C
2C	AIM/CGE 2.0	SSP4-26	Lower 2C
2C	AIM/CGE 2.1	CD-LINKS_NPi2020_1000	Lower 2C
2C	AIM/CGE 2.1	EMF33_WB2C_cost100	1.5C high overshoot
2C	AIM/CGE 2.1	EMF33_WB2C_full	Lower 2C
2C	AIM/CGE 2.1	TERL_2D_LowCarbonTransportPolicy	Lower 2C
2C	AIM/CGE 2.1	TERL_2D_NoTransportPolicy	Lower 2C
2C	IMAGE 3.0.1	ADVANCE_2020_WB2C	Lower 2C
2C	IMAGE 3.0.1	ADVANCE_2030_WB2C	Lower 2C
2C	IMAGE 3.0.1	CD-LINKS_NPi2020_1000	Lower 2C
2C	IMAGE 3.0.1	IMA15-LoNCO2	1.5C high overshoot
2C	IMAGE 3.0.1	SSP1-26	Lower 2C
2C	IMAGE 3.0.1	SSP2-26	Lower 2C
2C	IMAGE 3.0.1	SSP4-26	Lower 2C
2C	MESSAGE-GLOBIOM 1.0	ADVANCE_2020_WB2C	Lower 2C
2C	MESSAGE-GLOBIOM 1.0	ADVANCE_2030_Price1.5C	1.5C high overshoot
2C	MESSAGE-GLOBIOM 1.0	ADVANCE_2030_WB2C	Lower 2C

2C	MESSAGEix-GLOBIOM 1.0	CD-LINKS_NPi2020_1000	Lower 2C
2C	MESSAGEix-GLOBIOM 1.0	CD-LINKS_NPi2020_400	1.5C high overshoot
2C	POLES ADVANCE	ADVANCE_2020_Med2C	Lower 2C
2C	POLES ADVANCE	ADVANCE_2030_Med2C	Lower 2C
2C	POLES EMF33	EMF33_Med2C_cost100	Lower 2C
2C	POLES EMF33	EMF33_Med2C_limbio	Lower 2C
2C	POLES EMF33	EMF33_Med2C_nobeccs	Lower 2C
2C	POLES EMF33	EMF33_Med2C_nofuel	Lower 2C
2C	POLES EMF33	EMF33_Med2C_none	Lower 2C
2C	REMIND 1.7	ADVANCE_2020_WB2C	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	CD-LINKS_NPi2020_1000	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	EMF33_WB2C_nobeccs	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	EMF33_WB2C_none	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	PEP_2C_full_eff	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	PEP_2C_full_netzero	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	PEP_2C_red_goodpractice	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	PEP_2C_red_netzero	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	SMP_2C_Def	Lower 2C
2C	WITCH-GLOBIOM 4.2	ADVANCE_2020_WB2C	Lower 2C
2C	WITCH-GLOBIOM 4.2	ADVANCE_2030_Price1.5C	Lower 2C
2C	WITCH-GLOBIOM 4.2	ADVANCE_2030_WB2C	Lower 2C
2C	WITCH-GLOBIOM 4.4	CD-LINKS_NPi2020_1600	Lower 2C
2C	MESSAGE V.3	GEA_Eff_1p5C	Lower 2C
2C	MESSAGE V.3	GEA_Eff_1p5C_Delay2020	Lower 2C
2C	MESSAGE V.3	GEA_Eff_AdvNCO2_1p5C	Lower 2C
2C	MESSAGE-GLOBIOM 1.0	EMF33_Med2C_nobeccs	Lower 2C
2C	MESSAGE-GLOBIOM 1.0	EMF33_Med2C_none	Lower 2C
2C	MESSAGE-GLOBIOM 1.0	EMF33_tax_hi_full	Lower 2C
2C	MESSAGE-GLOBIOM 1.0	EMF33_WB2C_cost100	1.5C high overshoot
2C	MESSAGE-GLOBIOM 1.0	EMF33_WB2C_full	1.5C high overshoot
2C	MESSAGE-GLOBIOM 1.0	EMF33_WB2C_limbio	1.5C high overshoot
2C	MESSAGE-GLOBIOM 1.0	EMF33_WB2C_nofuel	1.5C high overshoot
2C	REMIND-MAgPIE 1.7-3.0	PEP_2C_red_NDC	Lower 2C
2C	REMIND-MAgPIE 1.7-3.0	SMP_2C_early	Lower 2C

A.3 Alternative approaches for defining 1.5°C- and 2°C-consistent pathways

We considered two approaches for defining 1.5°C and 2°C pathways for fossil fuels: the methodology used in the 2018 Emissions Gap Report (EGR) and the one outlined in the 2018 Climate Action Tracker (CAT) Warming Projections Global Update report (Climate Action Tracker et al. 2018). The difference between the two approaches is summarized in Table A6.

Each approach has its strengths. The EGR approach excludes “delay” scenarios that inevitably must rely on potentially infeasible levels of carbon dioxide removal (CDR). The CAT approach explicitly includes limits for bioenergy with carbon capture and storage (BECCS) and agriculture, forestry, and land use (AFOLU) based on an extensive review of feasibility and sustainability constraints cited in the SR1.5 report. The EGR approach adds a more nuanced approach to assessing below 1.5°C and 2°C carbon budgets, adding an intermediate below 1.8°C category, while the CAT approach more closely aligns with the below 1.5°C and 2°C distinctions used by the IPCC. The CAT approach restricts itself to the scenarios included in the SR1.5 report and database, whereas the EGR approach is more expansive, considering a wider range of scenarios.

Table A6. Comparison of Emissions Gap Report (UNEP 2018) and Climate Action Tracker (2018) approaches to scenario groupings

	Emissions Gap Report	**Approach used here (following CAT, 2018)**
Source of scenarios	SR1.5 report and accompanying open access database, as well as additional models and scenarios not considered by the IPCC in SR1.5	SR1.5 report and accompanying open access database
Scenario grouping	Pathways are grouped based on three temperature outcomes, using max. cumulative CO_2 emissions (from 2018 onward) as a proxy (rather than the SR 1.5 classifications): Cat1: Below 1.5°C in 2100 Cat2: Below 1.8°C Cat3: Below 2.0°C	Pathways are grouped according to the IPCC SR1.5 Report Summary for Policymakers, as follows: 1.5°C compatible (Below 1.5, and 1.5 low overshoot) 2°C compatible (Below 2.0, and 1.5 high overshoot)
Additional criteria applied	Scenarios: simulating full century not peaking before 2020 assuming immediate action after 2020 (*manually selected) models reporting all greenhouse gases models with 2010 Kyoto Gas Emissions within 49 +/- 4.5 $GtCO_2$	Scenarios: with less than the high end of feasible and sustainable range of carbon dioxide removal over the 2040-2060 period, as follows: BECCS: 5000 $MtCO_2$/yr on average for 2040, 2050, and 2060 AFOLU: 3600 $MtCO_2$/yr on average for 2040, 2050, and 2060

We ultimately opted to follow the CAT approach because the scenario data are available in the open access database, and thus the analysis is more transparent and easily reproducible. However, we did analyze and compare both CAT and EGR approaches, with the caveat that we did not consider output from two models included in the EGR analysis (DNE21+ V1.4E2 and GRAPE-15 1.0) as these are not publicly available from the IPCC 1.5°C scenario database.

Figure A1 shows the 2015-2040 median and interquartile range of the implied extraction-based CO_2 emissions from total primary fossil fuel production under 1.5°C- and 2°C-compatible pathways using CAT versus EGR methods at 10-year intervals between 2010-2040. Figure A2 shows the 2015-2040 median and interquartile range of each temperature limit and fuel, comparing primary coal, oil, and gas production (EJ/yr) for each temperature limit. As shown the medians are all quite similar in overall trajectory through 2040.[2] The EGR approach generally leads to smaller interquartile ranges given that a smaller number of model-scenario pairs are selected for each temperature limit (19 for CAT and 13 for EGR under 1.5°C; 55 for CAT and 29 for EGR under 2°C).

[2] A fuller comparison would consider trajectories through 2100.

Figure A1. Median (line) and interquartile range (shaded range) of extraction-based CO_2 emissions ($GtCO_2$/year) from total primary fossil fuel production calculated from 1.5°C and 2°C-compatible mitigation pathways using the Climate Action Tracker (CAT) versus Emissions Gap Report (EGR) selection criteria. For the 2°C pathway, the dotted line shows the results for combining the EGR "less than 2°C" and "less than 1.8°C" pathways (EGR).*

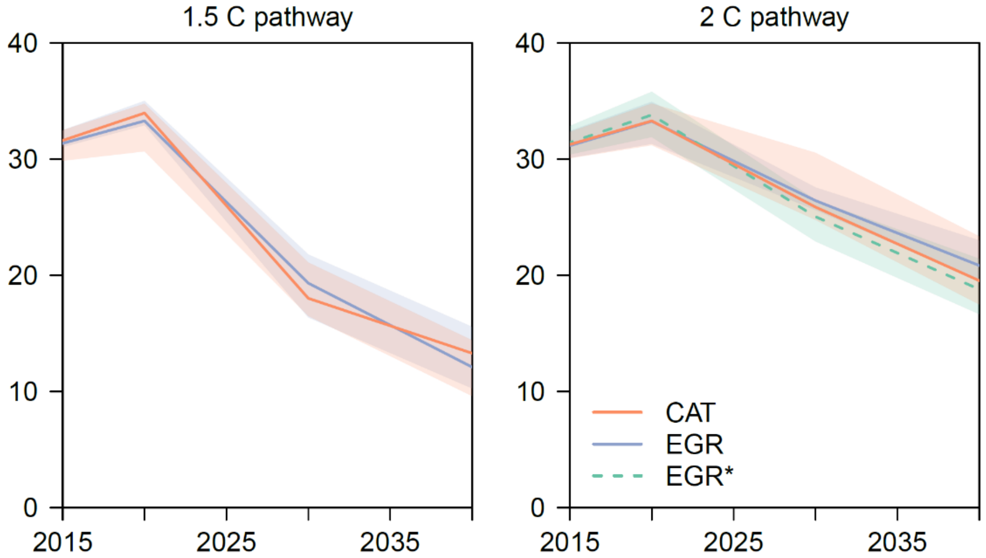
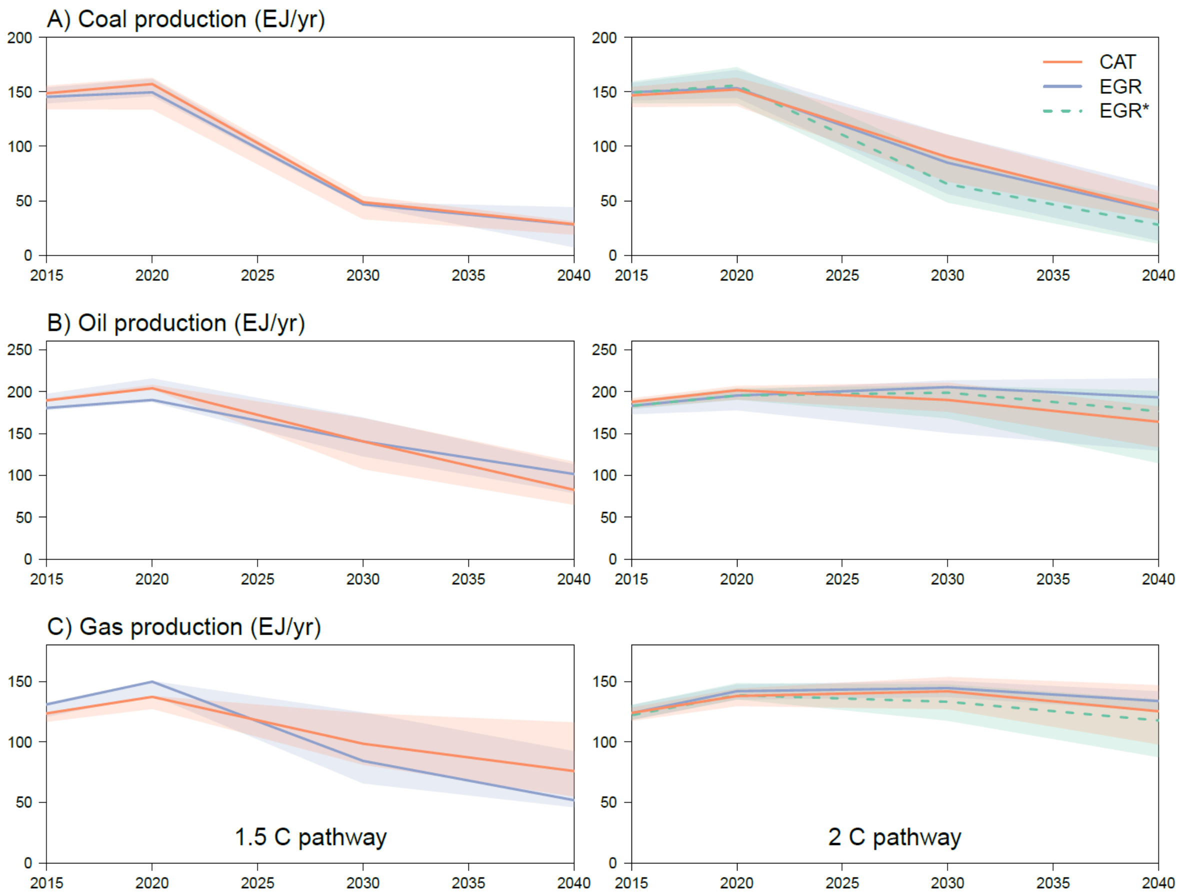


Figure A2. Median (line) and interquartile range (shaded range) of primary fuel production (EJ/year) calculated from 1.5°C and 2°C-compatible mitigation pathways using the Climate Action Tracker (CAT) versus Emissions Gap Report (EGR) selection criteria. For the 2°C pathway, the dotted lines show the results for combining the EGR "less than 2°C" and "less than 1.8°C" pathways (EGR).*



Appendix B: Accounting for greenhouse gas emissions associated with the extraction of fossil fuels

B.1 Introduction

Current greenhouse gas (GHG) emissions accounting frameworks, including those under the United Nations Framework Convention on Climate Change (UNFCCC), typically attribute GHG emissions from the burning of fossil fuels to the country or entity where the fuels are burned ("territorial" emissions). The emissions attributed to fossil fuel production (largely methane and CO_2) are only those occurring when fuels are used or GHGs are released, vented, or flared ("fugitive" emissions) to locate, extract, process, and transport coal, oil, and gas.

While this approach tracks "upstream" emissions and can encourage actions to reduce them, it fails to provide a framework to track the overall supply of fossil fuels and actions that support winding down their production. A complementary "extraction-based" accounting approach, as presented here, can enable countries to track the "downstream" emissions that will ultimately result from the combustion extracted fuels and therefore help to align the supply of fossil fuels with climate goals (see Davis et al. 2011; Erickson and Lazarus 2013; Steininger et al. 2016 for examples of alternative accounting frameworks).

This appendix shows how an extraction-based accounting approach can be put into practice as an easy-to-implement complement to the standard territorial emissions presented in national inventories and international compilations of emissions data. Under the UNFCCC, countries are required to report inventories of territorial emissions from fuel combustion and of fugitive emissions from fuel extraction following standardized guidelines developed by the IPCC (IPCC 2006). These guidelines could be readily expanded to include methods for extraction-based emissions accounting.

As with current IPCC Guidelines, the methods could follow a tiered approach, encouraging increased accuracy and precision where data are available, while also ensuring that data limitations do not preclude simpler estimates. Indeed, as report figures and the tables below illustrate, the data required for simpler estimates already exist, and many producing countries have published their own production statistics and fuel quality data that would enable more precise estimates. As a next step, the IPCC could be asked to develop draft guidelines for extraction-based emissions accounting, drawing upon the general approaches outlined below if and as helpful.

Most of the carbon that is immediately or ultimately emitted from fossil fuel combustion is in the form of carbon dioxide (CO_2) (IPCC 2006). While the main elements of estimating extraction-based CO_2 emissions (i.e. emissions that will be generated downstream from extracted fuels) are straightforward, there are a number of related issues that would benefit from further analysis and deliberation, such as:

a) *Fugitive emissions.* Globally, fugitive emissions constitute around 7% of total greenhouse emissions (Fig 1.1), though the percentage can be much larger for major fossil fuel-producing nations. Major sources of fugitive emissions include CO_2 vented from natural gas processing, CO_2 from gas flaring at oil production sites, and fugitive or vented methane from oil and gas operations and from the mining, processing, storage, and transportation of coal. These are already covered in national inventories and the IPCC Guidelines provide default emission factors for estimating fugitive emissions. However, there remains substantial uncertainties as to their magnitude, especially with respect to fugitive methane emissions from hydraulic fracturing, and much of the monitoring and analysis has been confined to a handful of countries. How should extraction-based emissions estimates include fugitive emissions?

b) *Non-energy uses and emissions.* To accurately estimate the downstream emissions resulting from combustion of extracted fuels, the quantity of primary fuels produced that go toward feedstock, reductant, or non-energy uses (such as coal used in steel production and oil used in plastic production) – some of which may then result in GHG emissions (such as oxidation of lubricants, waxes, and petrochemicals) – needs to be accounted for. Although national statistics on these "excluded carbon flows" exist, there are complexities in applying them to estimate extraction-based emissions due to the international trade of fossil fuels and inconsistencies in the allocation of emissions to "energy" or "industrial" processes between different international guidelines. For example, coke oven coke, coke oven gas, blast furnace gas, and other recovered gases delivered to the iron and steel industry are reported as emissions from industrial processes and product use sector under the 2006 IPCC Guidelines, but as emissions from the energy sector under the IEA's *CO_2 Emissions from Fuel Combustion* statistics. How should emissions from non-energy uses of fossil fuels be included in extraction-based emissions inventories? Should default values of excluded carbon flows that take into account emissions from non-energy uses be developed?

The following guidelines focus solely on estimating the emissions that will be generated downstream from combustion of extracted fuels, including a simple approach to account for excluded carbon flows. Fugitive emissions along the fossil fuel supply chain that individual countries already report to the UNFCCC, following the 2006 IPCC Guidelines, can be added in terms of CO_2-equivalent units to the national estimates presented below.

B.2 Methodological approaches and data requirements for extraction-based emissions accounting

In essence, extraction-based emissions are simply a reallocation of emissions from the location of fuel combustion to the location of fuel production. In other words, the global sum of extraction-based emissions equals the global sum of territorial CO_2 emissions from fossil fuel combustion over a given timeframe. This means that estimating extraction-based emissions at a national level can be approached via a top-down or bottom-up method:

a) *Top-down.* This is the simplest methodological approach. National fossil fuel production statistics are combined with globally averaged emission rates per unit of coal, oil, and gas produced. This method has the advantage of aligning with territorial emissions estimates at a global level. However, it makes a simplifying assumption that the emissions factors for each primary fuel type are the same in all countries, which can lead to over- or under-estimates since the energy and carbon contents per physical unit of fuel can vary considerably between countries and between fuel subtypes (e.g. coking coal versus lignite).

b) *Bottom-up.* This allows for a tiered approach with increasing levels of methodological complexity and data requirements, in a way that is consistent with the IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006). This method involves combining national fossil fuel production statistics with default or country-specific emission factors derived from the energy and carbon contents per physical unit of fuel subtype, and accounting for the fraction of produced fuel that goes toward non-combustion uses.

Since primary fossil fuels may be directly consumed or transformed into another fuel or energy source, estimating the CO_2 emissions that will be generated downstream from extracted fuels should only consider data on primary fuel production (and not secondary or processed fuels such as coke oven gas or petroleum products) in order to avoid potential double-counting. Methods and available data sources for each of these two approaches are presented below.

Top-down extraction-based CO_2 emissions estimate

Assigning annual emissions from fossil fuel combustion to the year that the fuels are extracted[3], the basic equation of the top-down method is:

$$\text{Extraction-based } CO_2 \text{ Emissions}_{\text{year}} = \sum_{all\ fuels}\left[Fuel\ Production_{fuel,year} \times Emission\ Factor_{fuel,year}\right]$$

Where:

- Fuel is divided into three fossil fuel types: coal, oil, and natural gas
- CO_2 Emissions = annual sum of extraction-based CO_2 emissions from all fuel types for a given country
- Fuel Production = annual production of primary fuels by fuel type (in physical or energy units)
- Emission Factor = default emission factor calculated as the ratio of the global annual sum of CO_2 emissions from fuel combustion to the global annual sum of fuel production by fuel type.

The emission factors listed by fuel type in Table B1, derived from International Energy Agency (IEA) data, can be used as defaults to calculate annual extraction-based emissions between 1990 and 2016. Variations in CO_2 emission factor value for coal and oil over time is mainly a function of changes in the ratios of primary and secondary fuel types used globally. For example, the effective emissions per kt of coal has risen by ~10% since 1990 as the global fractions of anthracite, bituminous, and sub-bituminous coal use have each increased while that of lignite has decreased, leading to a higher effective energy content per kt of total primary coal.

Table B1. Default top-down emission factors for calculating annual extraction-based CO_2 emissions between 1990 and 2016. See text below for data sources.

Year	Coal ($ktCO_2/kt$)	Oil ($ktCO_2/kt$)	Natural gas (tCO_2/TJ)
1990	1.79	2.69	46.8

[3] Although this simplification does not account for stock changes from year to year, and thus that fossil fuel production and consumption may not match in a given year, this effect is generally small. Between 1990 and 2016, global annual stock changes of each fuel were less than 3% of production values (IEA 2019b). Moreover, year-to-year changes in the effective emission factors per unit of fuel produced are relatively small.

1991	1.85	2.71	47.4
1992	1.84	2.69	47.1
1993	1.89	2.68	46.9
1994	1.86	2.68	46.7
1995	1.88	2.67	47.3
1996	1.87	2.67	47.3
1997	1.89	2.68	47.9
1998	1.91	2.66	47.5
1999	1.90	2.76	47.6
2000	1.94	2.68	47.4
2001	1.90	2.69	47.1
2002	1.92	2.71	47.5
2003	1.94	2.64	47.5
2004	1.93	2.62	47.5
2005	1.93	2.62	47.2
2006	1.93	2.62	47.0
2007	1.96	2.68	47.7
2008	1.93	2.64	47.2
2009	1.90	2.63	47.4
2010	1.91	2.67	47.7
2011	1.90	2.65	47.1
2012	1.88	2.62	47.3
2013	1.91	2.66	46.9
2014	1.92	2.62	46.4
2015	1.91	2.61	46.3
2016	2.00	2.60	46.8

Data sources:

- National primary fossil fuel production from the IEA's *World Energy Statistics and Balances* (IEA 2019b). Primary coal production data are divided into five subtypes (anthracite, coking coal, other bituminous coal, sub-bituminous coal, and lignite) and provided in physical units (metric tonne). Primary oil production data are divided into crude oil and natural gas liquids (NGLs) and provided in physical units (metric tonne). Natural gas data are provided as gross production in units of energy (TJ). The latest year of available data for the 2018 Edition is 2017.
- Global CO_2 emissions from fuel combustion by fuel type (coal, oil, and natural gas) from the IEA's *CO_2 Emissions from Fuel Combustion Statistics* (IEA 2019a). These global estimates are the sum of emissions from national territorial fuel combustion and international marine and aviation bunker fuel combustion. The latest year of available data for the 2018 Edition is 2016.

Bottom-up extraction-based CO_2 emissions estimate

The equation for calculating CO_2 emissions from fuel combustion using the reference approach in the IPCC Guidelines (Equation 6.1 in Volume 2, Chapter 6, IPCC 2006) can be adapted to estimate national extraction-based emissions as follows:

$$\text{Extraction-based } CO_2 \text{ Emissions}_{year} = \sum_{all\ fuels} \left[Fuel\ Production_{fuel,year} \times \left(1 - Excluded\ Carbon\ Fraction_{fuel,year}\right) \times Conv\ Factor_{fuel} \times CC_{fuel} \times COF_{fuel} \times 44/12 \right]$$

Where:

- Fuel is divided into the following types and subtypes to account for varying energy contents per physical unit of fuel subtype: coal (anthracite, coking coal, other bituminous coal, sub-bituminous coal, and lignite); oil (crude oil and NGLs); and natural gas
- CO_2 Emissions = annual sum of extraction-based CO_2 emissions from all fuel types for a given country
- Fuel Production = annual production of primary fuels by fuel type (in physical units)
- Excluded Carbon Fraction = the fraction of extracted fuel that is not ultimately combusted (i.e. lost along the supply chain or used for non-combustion purposes) in a given year
- Conv Factor = conversion factor for the fuel to energy units on a gross or net calorific basis (depending on the production units)
- CC = carbon content (carbon mass per unit energy)
- COF = carbon oxidation factor (the IPCC Guidelines' recommended value is 1, reflecting complete oxidation, unless detailed data are available)
- 44/12 = molecular weight ratio of CO_2 to C.

Note that if fuel production data are provided in energy units (instead of physical units), which is common for natural gas, then the equation simplifies to:

$$\text{Extraction-based } CO_2 \text{ Emissions}_{year} = \sum_{all\ fuels} \left[Fuel\ Production_{fuel,year} \times \left(1 - Fraction\ of\ Excluded\ Carbon_{fuel,year}\right) \times CC_{fuel} \times COF_{fuel} \times 44/12 \right]$$

In this bottom-up approach, the estimates can be increasingly refined by requiring that national and time-varying values be used for the energy and carbon contents of extracted fuels, for example. In a simple estimate, the default net calorific values and effective CO_2 emission factors by fuel type or sub-type from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (see Volume 2, Chapter 1, see Tables 1.2 and 1.4) can be applied, as shown in Table B2.

Table B2. Net calorific values and effective CO_2 emission factors by fuel type or sub-type, reproduced from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories.

Fuel type	**Fuel subtype**	**Conversion Factor, i.e. net calorific value (TJ/kt)**	**Effective CO_2 Emission Factor, i.e. CC x COF x 44/12 (kg CO_2/TJ)**

Coal	Anthracite	26.7	98300
	Coking coal	28.2	94600
	Other bituminous coal	25.8	94600
	Sub-bituminous coal	18.9	96100
	Lignite	11.9	101000
Oil	Crude oil	42.3	73300
	Natural Gas Liquids	44.2	64200
Natural Gas		48.0[1]	56100

[1] The IEA provides natural gas production data in units of TJ-gross, which can be converted to TJ-net by apply a scaling factor of 0.9.

In theory, detailed data on the international trade, supply, and consumption of primary and derived fossil fuels are needed to accurately estimate the amount of fuels extracted in a given country that are not eventually combusted downstream in that country or elsewhere, but are instead lost along the supply chain or used for non-combustion purposes. Examples of non-combustion uses that effectively store carbon include coal (metallurgic coke) used in iron and steel production and oil and gas used for petrochemical feedstocks, lubricants, and paraffin waxes.

In practice, a simplifying approach can be taken to estimate the "potential" downstream emissions of fuels extracted in a given country by applying globally averaged annual values of excluded carbon fractions that account for losses along the supply chain and non-combustion uses of fuels. In a simple estimate, the default fractions of excluded carbon shown in Table B3 can be applied.

Table B3. Default annual values of excluded carbon fractions.

Year	Anthracite, Bituminous coal, Sub-bituminous coal, Lignite	Coking coal[1]	Crude Oil, NGLs	Natural gas
1990	0.018	0.614	0.115	0.066
1991	0.017	0.604	0.12	0.064
1992	0.017	0.613	0.12	0.067
1993	0.016	0.634	0.116	0.064
1994	0.015	0.65	0.123	0.061
1995	0.014	0.667	0.127	0.059
1996	0.014	0.682	0.129	0.058
1997	0.012	0.688	0.132	0.06
1998	0.011	0.693	0.129	0.059
1999	0.011	0.686	0.136	0.059
2000	0.011	0.706	0.133	0.061
2001	0.01	0.723	0.135	0.057
2002	0.01	0.74	0.14	0.056
2003	0.011	0.735	0.14	0.054
2004	0.01	0.7	0.141	0.057
2005	0.011	0.696	0.139	0.061

2006	0.012	0.707	0.144	0.058
2007	0.012	0.699	0.146	0.058
2008	0.011	0.682	0.14	0.056
2009	0.011	0.67	0.144	0.059
2010	0.011	0.643	0.147	0.062
2011	0.011	0.646	0.145	0.063
2012	0.012	0.647	0.146	0.063
2013	0.013	0.655	0.145	0.061
2014	0.013	0.634	0.15	0.06
2015	0.014	0.614	0.147	0.06
2016	0.017	0.645	0.146	0.062

[1] Recommended excluded carbon fractions for applying to coal production data from the IEA. See details in text below.

These values were calculated using data from the IEA's World Energy Balances (IEA 2019b) with the following approximations and assumptions:

- For oil, the fraction is calculated as the sum of "Total Primary Energy Supply (TPES) Distribution Losses" and "Total Final Consumption (TFC) Non-Energy Use" of "Crude oil, NGL, and feedstocks" and "Oil products" divided by the "Production" of "Crude oil, NGL, and feedstocks" and "Oil products".
- For natural gas, the fraction is calculated as the sum of "TPES Distribution Losses" and "TFC Non-Energy Use" divided by the "Production". (Note that the *World Energy Balances* provide natural gas data in net-TJ units, whereas the production data provided in the *World Energy Statistics* are in gross-TJ units.)
- For coal, applying a similar approach as used for oil and natural gas above, leads to global 1980-2016 bottom-up emissions estimates exceeding top-down estimates by 10-24%. This suggests that the excluded carbon fractions derived from the IEA's *World Energy Balances* may not sufficiently account for the amount of coal used for non-combustion purposes and/or lost along the supply chain, especially for coking coal. One of the major derived products from coking coal is coke oven coke, which is used mainly in the iron and steel industry as an energy source and a chemical agent. The global bottom-up and top-down extraction-based estimates for coal are more consistent (differences range between -1 to 11%) when the excluded carbon fraction for coking coal is approximated by the global ratio of coke oven coke to coking coal production (i.e. assuming that all coke oven coke produced are used as a chemical agent in steel production). For other primary coal subtypes (anthracite, bituminous coal, sub-bituminous coal, and lignite), the fractions are calculated as the sum of "TPES Distribution Losses" and "TFC Non-Energy Use" divided by the "Production", as for oil and natural gas.

Note: Approximating the fraction of excluded carbon using data in energy units assumes that the average carbon content per energy unit of the primary fuel production mixture (e.g. crude oil + NGL) does not differ considerably from that of the fuel consumption mixture (e.g. crude oil, NGL, and oil products). The losses in distribution, transmission, and transport estimated from energy units may also not fully account for other losses along the supply chain from extraction to final consumption, such as loss of physical mass during transport.

B.3 National extraction-based estimates of CO_2 emissions

Table B4 shows estimates of 2017 national extraction-based CO_2 emissions, using a top-down versus bottom-up approach, for countries with non-zero emissions. Values from 2016 are applied if 2017 data (territorial emissions and carbon storage factors) are not available. The extraction-based CO_2 emissions estimates shown in the main report are all derived using the top-down approach.

Table B4. Estimates of 2017 global and national extraction-based CO_2 emissions, derived via a top-down versus bottom-up approach.

	Top-down ($MtCO_2$)	Bottom-up ($MtCO_2$)
World	32749	32851
China	7103	7567
United States	4248	4176
Russia	3466	3440
Saudi Arabia	1622	1639
India	1618	1785
Australia	1236	1072
Indonesia	1226	1205
Iran	991	1000
Canada	947	916
Iraq	598	609
United Arab Emirates	571	575
Qatar	520	517
South Africa	519	614
Kazakhstan	482	499
Norway	468	473
Kuwait	416	422
Mexico	362	360
Brazil	416	421
Venezuela	347	352
Germany	370	227
Algeria	345	347
Colombia	317	345
Nigeria	321	326
Poland	264	222
Angola	219	223
Malaysia	229	233
United Kingdom	205	209
Oman	189	192
Turkmenistan	171	173
Turkey	161	99
Argentina	153	154
Egypt	165	167

Azerbaijan	141	143
Vietnam	138	161
Thailand	134	121
Uzbekistan	114	113
Ukraine	88	91
Czech Republic	91	56
Netherlands	75	76
Serbia	83	50
Trinidad & Tobago	77	78
Pakistan	75	76
Ecuador	71	72
Romania	80	59
Libya	123	125
Mongolia	99	73
Greece	76	45
Bulgaria	69	41
North Korea	38	45
Bahrain	53	54
Bangladesh	53	54
Peru	51	51
Bolivia	45	45
Myanmar (Burma)	36	37
Brunei	36	37
Congo - Brazzaville	39	40
Philippines	32	30
Gabon	27	27
Bosnia & Herzegovina	28	17
Denmark	27	27
Hungary	22	15
Mozambique	32	27
Italy	21	21
New Zealand	19	18
Israel	17	18
South Sudan	14	15
Sudan	11	11
Ghana	23	23
Cameroon	11	11
Tunisia	10	10
Macedonia	10	6
Syria	9	10
Côte d'Ivoire	8	8
Japan	9	10
Cuba	8	9
Chile	8	9

Slovenia	7	4
Ireland	6	6
Croatia	5	5
Belarus	5	5
Austria	4	4
Kyrgyzstan	4	3
Spain	6	6
Slovakia	4	2
South Korea	4	5
Botswana	4	5
Yemen	6	6
Zimbabwe	6	6
Albania	3	3
Montenegro	3	2
Tajikistan	4	4
Congo - Kinshasa	2	3
Niger	3	2
France	2	2
Tanzania	3	3
Suriname	2	2
Guatemala	1	1
Georgia	1	0
Zambia	1	1

Appendix C. Illustrative list of supply-side policies and measures adopted by national governments

Category	*Supply-side policy*	*Examples*	*Name of policy/measure*	*Date of decision*	*Implementation period*	*References*
Regulatory approach	Limit exploration, production, or export (e.g., via moratoria, bans or quotas)	Belize's moratorium on offshore oil exploration and drilling	*Petroleum Operations (Maritime Zone Moratorium) Act, 2017*	30 Dec 2017	2018-indefinite	https://www.elaw.org/petroleum-operations-maritime-zone-moratorium-act-2017
		Bulgaria's ban on shale gas exploration and production, and conditional ban on the application of hydraulic fracturing methods	*РЕШЕНИЕ за забрана върху прилагането на технологията хидравлично разбиване при проучване и/или добив на газ и нефт на територията на Република България (DECISION prohibiting the application of hydraulic fracturing technology to exploration and/or the extraction of gas and oil in the territory of the Republic of Bulgaria)*	18 Jan 2012 (amended on 14 June 2012 to allow conventional oil and gas activities)	2012-indefinite	http://shalegas-bg.eu/download/documents/2012-br7-Reshenie-Zabrana-Hidravlichno-Razbivane.pdf.pdf https://www.cms-lawnow.com/ealerts/2012/06/bulgaria-eases-ban-on-fracking?cc_lang=en
		Canada's moratorium on offshore oil and gas activities in Arctic waters (building off a moratorium on issuing new oil and gas licenses announced in 2016)	Government of Canada legislation, PC Number: 2019-1121	28 July 2019	2019-2021	https://orders-in-council.canada.ca/attachment.php?attach=38451&lang=en
		Canada's ban on oil and gas activities in designated marine protected areas	Part of the Government of Canada's Marine Protection Standards	25 Apr 2019	2019-indefinite	https://www.dfo-mpo.gc.ca/oceans/mpa-zpm/standards-normes-eng.html
		China's Five-Year Plan includes supply-side structural reform (closure of coal mines)	煤炭工业发展"十三五"规划 *(13th Five-Year Plan for the Coal Industry Development)*	22 Dec 2016	2016-2020	https://policy.asiapacificenergy.org/node/3047
		Costa Rica's national moratorium on oil exploration and exploitation	(latest) *Reforma Declara Moratoria Nacional para la explotación petrolera*	1 Aug 2011 (extended on 25 July 2014, 25 Feb 2019)	2011-2050	https://presidencia.go.cr/comunicados/2019/02/presidente-alvarado-extiende-moratoria-petrolera-hasta-el-ano-2050/

			N° 41578-MINAE (Executive Decree No. 41578 extending the national moratorium on oil exploration and exploitation)			http://www.pgrweb.go.cr/scij/Busqueda/Normativa/Normas/nrm_resultado_simple.aspx?param1=NER&param2=1&param3=FECHA&param4=DESC&param5=Moratoria%20Nacional%20para%20la%20explotacion%20petrolera
		Denmark's ban on exploration and drilling for oil, gas, and shale gas on land and in inland waters	Part of Danish government's 2018 Energy Proposal: *Energy – for a green Denmark*	22 Feb 2018	2018-indefinite	https://presse.ens.dk/news/regeringen-lukker-for-efterforskning-og-boring-efter-olie-og-gas-paa-land-i-danmark-295546 https://en.kefm.dk/media/11857/energiudspillet_eng.pdf
		France no longer issues new or renews exploration permits for conventional and unconventional fossil fuels, and will phase out all oil and gas production within the country and its overseas territories by 2040	Part of France's Climate Plan	19 Dec 2017	2017-indefinite	https://www.ecologique-solidaire.gouv.fr/projet-loi-hydrocarbures-est-adopte-parlement
		Italy's 18-month moratorium on offshore oil and gas exploration permits	Legislative Decree 989 – Decree-simplification Law n. 135. Amendments	24 Jan 2019	2019-2020	http://www.infoparlamento.it/tematiche/disegni-di-legge/ddl-989-decretolegge-semplificazione-n-135-emendamenti-approvati-nella-seduta-del-24-gennaio-in-commissione-1a-e-8a-riunite
		Mexico prohibits the activities of exploration and extraction of hydrocarbons in Safeguard Zones (biodiverse areas)	*Hydrocarbons Law*	11 Aug 2014	2014-indefinite	http://www.eisourcebook.org/cms/December%202015/Mexico%20Hydrocarbons%20Law%202014.pdf
		The Netherlands' ban on shale gas exploration	Announcement from Minister of Economic Affairs	2013	2013-indefinite	https://www.dutchnews.nl/news/2018/02/dutch-minister-confirms-ban-on-drilling-shale-gas-not-an-option/ https://www.government.nl/latest/n

						ews/2015/07/10/no-extraction-of-shale-gas-during-the-next-five-years
		New Zealand’s ban on new offshore oil and gas exploration permits	*Crown Minerals (Petroleum) Amendment Bill*	12 Nov 2018	2018-indefinite	https://www.parliament.nz/en/pb/bills-and-laws/bills-proposed-laws/document/BILL_80358/crown-minerals-petroleum-amendment-bill
		Norway closes certain offshore areas for drilling (including Lofoten archipelago, other coastal and sensitive areas, and in the Arctic)	Integrated management plan for the Barents Sea / Lofoten areas (St.meld. nr. 8, 2005-2006)	Mar 2005	2005-indefinite (renewed political commitment for each new government period)	https://www.regjeringen.no/no/dokumenter/stmeld-nr-8-2005-2006-/id199809/
		USA’s moratorium on oil and gas exploration in Arctic and Atlantic areas	Presidential Memorandum – Withdrawal of Certain Areas of the United States Outer Continental Shelf Offshore Alaska from Leasing Disposition	27 Jan 2015	2015-indefinite	https://obamawhitehouse.archives.gov/the-press-office/2015/01/27/presidential-memorandum-withdrawal-certain-areas-united-states-outer-con
	Prohibit development or limit permits for specific resources, infrastructure (oil pipelines and terminals, coal ports, etc.), or use of certain technologies	Ireland prohibits exploration for and extraction of onshore petroleum by hydraulic fracturing	*Petroleum and Other Minerals Development (Prohibition of Onshore Hydraulic Fracturing) Act 2017*	6 Jul 2017	2017-indefinite	https://www.oireachtas.ie/en/bills/bill/2016/37/
		Uruguay’s four-year moratorium on hydraulic fracturing	Law No. 19585: FRACTURA HIDRAULICA OBTENCION HIDROCARBUROS NO CONVENCIONALES. MORATORIA	28 Dec 2017	2018-2021	https://legislativo.parlamento.gub.uy/temporales/docu3771937218581.htm
Economic instrument	Remove or reform fossil fuel producer subsidies	Canada’s phase-out of the accelerated capital cost allowance for oil sands projects	Part of Natural Resources Canada’s Mining-Specific Tax Provisions	2013	2014-indefinite	https://www.nrcan.gc.ca/mining-materials/mining/taxation/mining-taxation-canada/mining-specific-tax-provisions/8892
		Canada’s phase-out of the Atlantic Investment Tax	Part of Canada Revenue Agency’s Investment tax credit policy	29 Mar 2012	2012-indefinite	http://www.cra-arc.gc.ca/tx/ndvdls/tpcs/ncm-

		Credits for use in oil and gas activities				tx/rtrn/cmpltng/ddctns/lns409-485/412/tlntc-eng.html
		Germany's phase-out of subsidies for domestic hard coal industry by 2018	*Hard Coal Funding Act*	7 Feb 2007	2007-indefinite	http://www.bmwi.de/EN/Topics/Energy/Conventional-energy-sources/coal.html
	Introduce fees or taxes for fossil fuel production or export, and increase royalties	India's tax on coal production	Part of *The Goods and Service Tax Compensation Cess Act, 2017* (formerly "Clean Energy Cess" and "Clean Environment Cess")	2010	2010-indefinite	http://gstcouncil.gov.in/sites/default/files/GST-Compensation-to-States-Law.pdf https://www.iisd.org/sites/default/files/publications/stories-g20-india-en.pdf
Government provision of goods and services	Assist workers and communities transitioning out of fossil fuel production	China's Five-Year Plan includes just transition support measures	煤炭工业发展"十三五"规划 *(13th Five-Year Plan for the Coal Industry Development)*	22 Dec 2016	2016-2020	https://policy.asiapacificenergy.org/node/3047
		Germany's just transition plan for the coal industry, compensation for coal mining provinces, and compensation and training for coal miners	Commission on Growth, Structural Change and Employment's Final Report (2019)	26 Jan 2019	Recommendations delivered; adoption planned for late 2019	https://www.bmwi.de/Redaktion/EN/Publikationen/commission-on-growth-structural-change-and-employment.html
		New Zealand's establishment of a "Just Transitions Unit", with a focus on supporting the regions most dependent on the oil and gas industry	Unit established within the Ministry of Business, Innovation & Employment	2018	N/A	https://www.mbie.govt.nz/business-and-employment/economic-development/just-transition/
		Spain's closure of domestic coal mines with Just Transition plan (compensation and re-training)	*ACUERDO MARCO PARA UNA TRANSICIÓN JUSTA DE LA MINERÍA DEL CARBÓN Y DESARROLLO SOSTENIBLE DE LAS COMARCAS MINERAS PARA EL PERIODO 2019-2027* (Framework agreement for a fair transition of coal mining and sustainable development of the mining communities for 2019-2027)	24 Oct 2018	Closure by end of 2018; Transition Plan 2019-2027	http://www.ugt-fica.org/images/20101024_Marco_para_una_Transici%C3%B3n_Justa_de_la_Mineria_del_Carb%C3%B3n_DEFINITIVO.pdf
	Divest state-controlled investment funds from	Divestment of the Ireland Strategic Investment Fund of its assets in fossil fuel companies within five years	*Fossil Fuel Divestment Act 2018*	17 Dec 2018	2018-indefinite	https://www.oireachtas.ie/en/bills/bill/2016/103/

	companies involved in fossil fuel production	Divestment of the Norwegian Government Pension Fund Global from coal (including upstream activities)	Recommendation 290 S (2014-2015)	27 May 2015	2016-indefinite	https://www.stortinget.no/en/In-English/About-the-Storting/News-archive/Front-page-news/2014-2015/hj9/
		Divestment of the Norwegian Government Pension Fund Global from oil and gas exploration and production companies	Meld.St. 14, 2018-2019 (white paper on energy stocks in the GPFG)	12 June 2019	Phase-out schedule in development	https://www.regjeringen.no/en/aktuelt/phaseout-of-exploration-and-production-companies-from-the-gpfg/id2662141/
	Restrict export credit agency or development finance for fossil fuel supply infrastructure	Canada ends financing for the development, construction, or expansion of thermal coal mines or dedicated thermal coal-related infrastructure; Ends new financing to companies for which thermal coal mining and/or thermal coal power generation account for more than 40% of their revenue	Part of Export Development Canada's Climate Change Policy	28 Jan 2019	2019-indefinite	https://www.edc.ca/EN/About-Us/News-Room/News-Releases/Pages/climate-change-policy-2019.aspx
		Agence française de développement (Development Finance Institution of the French Government) abstains from financing projects for the exploration or production of coal, or projects exclusively dedicated to transporting coal, gas, or oil (conventional or unconventional)	*Energy Transition Strategy 2019-2022*	June 2019	2019-2022	https://www.afd.fr/en/energy-transition-strategy-2019-2022
		Swedfund (Development Finance Institution of the Swedish government) adopts a ban on fossil fuel investments	Swedfund's Position Paper on Climate Impact	27 Oct 2017	2017-indefinite	https://www.swedfund.se/media/2015/swedfunds-position-paper-on-climate-2017-10-27.pdf

References

China Energy Group and Lawrence Berkeley National Laboratory (2016). *China Energy Databook Version 9.0*. Lawrence Berkeley National Laboratory, Berkeley, CA. https://china.lbl.gov/china-energy-databook

Climate Action Tracker, Ecofys and Climate Analytics (2018). Warming Projections Global Update: December 2018. , 11 December 2018. https://climateactiontracker.org/publications/warming-projections-global-update-dec-2018/

Davis, S. J., Peters, G. P. and Caldeira, K. (2011). The supply chain of CO2 emissions. *Proceedings of the National Academy of Sciences*, 108(45). 18554–59. DOI: 10.1073/pnas.1107409108

Department of Energy Statistics, National Bureau of Statistics (2018). China energy statistical yearbook 2018. , 2018.

Erickson, P. and Lazarus, M. (2013). *Accounting for Greenhouse Gas Emissions Associated with the Supply of Fossil Fuels*. Stockholm Environment Institute, Seattle, WA. http://www.sei-international.org/publications?pid=2419

Government of the Republic of Kazakhstan (2014). *Концепция Развития Топливно-Энергетического Комплекса Республики Казахстан До 2030 Года (KAZAKHSTAN: Concept for the Development of the Fuel and Energy Sector until 2030)*

Huppmann, D., Rogelj, J., Krey, V., Kriegler, E. and Riahi, K. (2018). A new scenario resource for integrated 1.5 °C research. *Nature Climate Change*, 8. 1027–30. DOI: 10.1038/s41558-018-0317-4

IEA (2018). *World Energy Outlook 2018*. International Energy Agency, Paris, France. https://www.iea.org/weo2018/

IEA (2019a). *CO2 Emissions from Fuel Combustion 2018*. OECD Publishing. https://doi.org/10.1787/co2_fuel-2018-en

IEA (2019b). World Energy Statistics and Balances (2018 Edition). , Paris, France, 2019. DOI: 10.1787/42865fbe-en

IPCC (2006). *2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Eggleston, H., Buendia, L., Miwa, K., Ngara, T., and Tanabe, K. (eds). Institute for Global Environmental Strategies (IGES) on behalf of the Intergovernmental Panel on Climate Change, Hayama, Japan. http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

IPCC (2018). *Global Warming of 1.5 °C*. Intergovernmental Panel on Climate Change. http://www.ipcc.ch/report/sr15/

Ministério de Minas e Energia (2018). *Plano Decenal de Expansão de Energia 2027 (The Ten-Year Energy Expansion Plan 2027)*. Empresa de Pesquisa Energética. http://www.mme.gov.br/documents/10584/1432059/Plano+Decenal+de+Expans%C3%A3o+de+Energia+2027+%28PDE+2027%29/66498aa7-5e33-47ea-b586-2a6b1b994f7f?version=1.1

Ministry of Energy of the Russian Federation (2017). *Draft Energy Strategy of the Russian Federation to 2035, Edition of 1 February 2017*. Ministry of Energy of the Russian Federation, Moscow, Russia. https://minenergo.gov.ru/node/1920

National Development and Reform Commission (NDRC) and National Energy Administration (NEA) (2016). Energy Production and Energy Consumption Strategy (2016-2030). , 2016. http://www.sdpc.gov.cn/gzdt/201704/t20170425_845304.html

National Energy Board (2018). *Canada's Energy Future 2018: Energy Supply and Demand Projections to 2040*. National Energy Board, Calgary. https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/index-eng.html

New Climate Institute, Ecofys and Climate Analytics (2018). *Some Progress since Paris, but Not Enough, as Governments Amble towards 3°C of Warming*. Climate Action Tracker. https://climateactiontracker.org

NITI Aayog (2017). *Draft National Energy Policy*. National Institution for Transforming India. https://niti.gov.in/writereaddata/files/new_initiatives/NEP-ID_27.06.2017.pdf

Norwegian Ministry of Finance (2019). *Revised National Budget 2018-2019*. Norwegian Ministry of Finance, Oslo, Norway. https://www.statsbudsjettet.no/upload/Revidert_2019/dokumenter/stm2.pdf

Office of the Chief Economist (2019). *Resources and Energy Quarterly - March 2019*. Office of the Chief Economist, Department of Industry Innovation and Science. https://publications.industry.gov.au/publications/resourcesandenergyquarterlymarch2019/documents/Resources-and-Energy-Quarterly-March-2019.pdf

Piggot, G., Erickson, P., Lazarus, M. and van Asselt, H. (2017). *Addressing Fossil Fuel Production under the UNFCCC: Paris and Beyond*. Stockholm Environment Institute, Seattle, WA. https://www.sei.org/publications/fossil-fuel-production-unfccc/

PPIPE and BPPT (2018). *Indonesia Energy Outlook 2018*. Center of Assessment for Process and Energy Industry (PPIPE) and Agency for the Assessment and Application of Technology (BPPT), Jakarta, Indonesia. https://d1io3yog0oux5.cloudfront.net/_d7a71c03e5d9d1d6e246eb7c02ef1111/continentalenergy/db/337/2200/pdf/BPPT+Outlook+Energi+Indonesia+2018

Rogelj, J., Shindell, D., Jiang, K., Fifita, S., Forster, P., Ginzburg, V., et al. (2018). Chapter 2: Mitigation pathways compatible with 1.5°C in the context of sustainable development. In Global warming of 1.5 °C: *An IPCC special report on the impacts of global warming of 1.5 °C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty.* Geneva, Switzerland: World Meteorological Organization.

Secretaría de Energía SENER (2017a). *L.P. Gas Outlook 2017-2031* Mexico. https://www.gob.mx/cms/uploads/attachment/file/325633/LP_Gas_Outlook_2017-2031.pdf

Secretaría de Energía SENER (2017b). *Natural Gas Outlook 2017-2031*Mexico. https://www.gob.mx/cms/uploads/attachment/file/325635/NG_Outlook_2017-2031.pdf

Secretaría de Energía SENER (2017c). *Oil and Oil Products Outlook 2017-2031*Mexico. https://www.gob.mx/cms/uploads/attachment/file/325632/Crude_Oil_and_Oil-Products_Outlook_2017-2031.pdf

Secretario de Gobierno de Energía (2018). *National Energy Plan*. https://www.argentina.gob.ar/sites/default/files/energy_plan_-_october_2018_0.pdf

Sinopec Economic Technology Research Institute (2018). 2050 World and China Energy Outlook (2018 Edition), 2018.

Steininger, K. W., Lininger, C., Meyer, L. H., Muñoz, P. and Schinko, T. (2016). Multiple carbon accounting to support just and effective climate policies. *Nature Climate Change*, 6. 35–41. DOI: 10.1038/nclimate2867

Syed, A. (2014). *Australian Energy Projections to 2049-50*. Bureau of Resources and Energy Economics, Canberra, Australia. https://industry.gov.au/Office-of-the-Chief-Economist/Publications/

The People's Republic of China (2016). 煤炭工业发展"十三五"规划 (13th Five-Year Plan for Coal Industry Development). 2016. http://www.ndrc.gov.cn/fzgggz/fzgh/ghwb/gjjgh/201706/t20170605_850004.html

UNEP. (2018). The Emissions Gap Report 2018. Nairobi, Kenya: United Nations Environment Programme. https://www.unenvironment.org/resources/emissions-gap-report-2018

U.S. EIA (2018). *Monthly Energy Review*. U.S. Energy Information Administration, Washington, DC. http://www.eia.gov/totalenergy/data/monthly/archive/00351605.pdf

U.S. EIA (2019). *Annual Energy Outlook 2019*. U.S. Energy Information Administration, Washington, DC. http://www.eia.gov/forecasts/aeo/