We provide estimates for combined upstream and midstream leakage from conventional natural gas production below. Table A.9 presents leakage estimates from the literature, expressed as the percentage of CH_4 produced over the lifecycle of a well. As with the unconventional production estimates above, we assumed the rates effectively address the mass of natural gas being leaked and used it to calculate CO_2 leakage as well as CH_4 leakage. The estimates in the studies included leakage rates that range from 0.4% to 2.0%, as we present in Table A.9.

Table A.9. Estimates of upstream and midstream methane emissions from conventional gas systems (% CH_4 produced over the lifecycle of a well)[a]

U.S. EPA (2011)	1.6%
Howarth et al. (2011)	1.4%
Hayhoe et al. (2002)	1.2%
Hultman et al. (2011)	1.3%
Venkatesh et al. (2011)	1.8%
Burnham et al. (2011)	2.0%
Stephenson et al. (2011)	0.4%
Cathles et al. (2012)	0.9%

a. The CH_4 estimates from each study were reviewed in Howarth et al. (2012b).

Using the lowest and highest combined upstream and midstream leakage estimates from the studies listed above in Table A.9, we calculated the resulting CH_4 and CO_2 leakage that may be associated with natural gas produced conventionally on public lands. Table A.10 presents the low-leakage rate scenario and Table A.11 presents the high-leakage rate scenario for upstream and midstream emissions.

Table A.10. CH_4 and CO_2 emissions associated with natural gas production from public lands: Conventional gas, upstream and midstream, low-leakage rate scenario (0.4% CH_4 leakage)

Emissions (metric tons)	2008	2009	2010	2011	2012
CH_4	102,852	76,172	76,568	60,288	55,494
CH_4–CO_2e	2,571,293	1,904,301	1,914,211	1,507,212	1,387,359
CO_2	1,984	1,469	1,477	1,163	1,070

Table A.11. CH_4 and CO_2 emissions associated with natural gas production from public lands: Conventional gas, upstream and midstream, high-leakage rate scenario (2.0% CH_4 leakage)

Emissions (metric tons)	2008	2009	2010	2011	2012
CH_4	522,655	387,078	389,093	306,364	282,002
CH_4–CO_2e	13,066,366	9,676,958	9,727,318	7,659,098	7,050,048
CO_2	10,082	7,466	7,505	5,910	5,440

Recent estimates in peer-reviewed literature for downstream leakage of CH_4 from natural gas systems range from 0.07% to 10% of the CH_4 produced over the lifecycle of a well. Downstream leakage refers to leakage that occurs in storage, and transmission and distribution pipelines. Table A.12 presents the range of downstream CH_4 leakage rates from various studies.

Table A.12. Estimates of downstream methane emissions (% CH_4 produced over the lifecycle of a well)[a]

Hayhoe et al. (2002)	0.2–10%
Lelieveld et al. (2005)	1.0–2.5%
Howarth et al. (2011)	1.4–3.6%
U.S. EPA (2011)	0.9%
Jiang et al. (2011)	0.4%
Hultman et al. (2011)	0.9%
Venkatesh et al. (2011)	0.4%
Burnham et al. (2011)	0.6%
Stephenson et al. (2011)	0.07%
Cathles et al. (2012)	0.7%

a. The CH_4 estimates from each study were reviewed in Howarth et al. (2012b) and Caulton et al. (2014).

Tables A.13 and A.14 present the low and high scenarios for CH_4 and CO_2 emissions for downstream emissions, respectively, for natural gas produced unconventionally from public lands. The low scenarios are based on using the lowest leakage rates for the combined upstream and midstream leakage rates as well as the lowest downstream leakage rate (see Tables 6 and 12). The high scenarios are based on using the highest leakage rates for the combined upstream and midstream leakage rates as well as the highest downstream leakage rate (see Tables 6 and 12).

Table A.13. CH_4 and CO_2 emissions associated with natural gas production from public lands: Unconventional gas, downstream, low scenario (0.07% CH_4 leakage)

Emissions (metric tons)	2008	2009	2010	2011	2012
CH_4	13,619	12,624	14,987	16,898	17,729
CH_4–CO_2e	340,481	315,590	374,666	422,443	443,219
CO_2	69	64	75	85	89

Table A.14. CH4 and CO_2 emissions associated with natural gas production from public lands: Unconventional gas, downstream, high scenario (10.0% CH_4 leakage)

Emissions (metric tons)	2008	2009	2010	2011	2012
CH_4	2,338,490	2,167,534	2,573,284	2,901,421	3,044,116
CH_4–CO_2e	58,462,253	54,188,354	64,332,090	72,535,514	76,102,912
CO_2	11,768	10,907	12,949	14,600	15,318

Tables A.15 and A.16 present the corresponding low and high scenarios for CH_4 and CO_2 emissions for downstream emissions, respectively, for natural gas produced conventionally from public lands.

Table A.15. CH_4 and CO_2 emissions associated with natural gas production from public lands: Conventional gas, downstream, low scenario (0.07% CH_4 leakage)

Emissions (metric tons)	2008	2009	2010	2011	2012
CH_4	21,334	15,800	15,882	12,505	11,511
CH_4–CO_2e	533,347	394,997	397,053	312,632	287,771
CO_2	107	80	80	63	58

Table A.16. CH_4 and CO_2 emissions associated with natural gas production from public lands: Conventional gas, downstream, high scenario (10.0% CH_4 leakage)

Emissions (metric tons)	2008	2009	2010	2011	2012
CH_4	3,097,458	2,293,979	2,305,918	1,815,634	1,671,255
CH_4–CO_2e	77,436,459	57,349,482	57,647,939	45,390,845	41,781,378
CO_2	15,587	11,544	11,604	9,136	8,410

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Exhibit 28

Independent Statistics & Analysis
U.S. Energy Information Administration

Sales of Fossil Fuels Produced from Federal and Indian Lands, FY 2003 through FY 2014

July 2015

Independent Statistics & Analysis
www.eia.gov

U.S. Department of Energy
Washington, DC 20585

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Sales of Fossil Fuels Produced from Federal and Indian Lands, FY 2003 through FY 2014

Summary

The U.S. Energy Information Administration (EIA) estimates that total sales of fossil fuels from production[1] on federal and Indian lands increased slightly (less than 0.2%) during fiscal year[2] (FY) 2014. Total fossil fuels production on federal lands decreased by 24 trillion British thermal units (Btu) in FY 2014 (Table 1), while total fossil fuels production on Indian lands increased by 52 trillion Btu (Table 2).

In FY 2014 (compared with FY 2013), crude oil and lease condensate production on federal and Indian lands increased 7%, natural gas production declined 7%, natural gas plant liquids production increased by 8%, and coal production increased slightly.

Land	Crude Oil and Lease Condensate	Natural Gas	Natural Gas Plant Liquids	Coal	All Fossil Fuels
Federal	Up 37 mmbbl, +6%	Down 284 bcf, -7%	Up 9 mmbbl, +8%	Up 1 mmst, +0.2%	-24 trillion Btu,-0.2%
Indian	Up 10 mmbbl, +22%	Up 0.3 bcf, +0.1%	Up 0.6 mmbbl, +16%	Down 0.3 mmst,-1.6%	+52 trillion Btu,+5.7%

Notable developments in FY 2014 include:

- A 46.5 million barrel increase (7%) in oil production on federal and Indian lands, led by increases in the federal offshore Gulf of Mexico, North Dakota, and New Mexico
- A 284 billion cubic feet decline (-7%) in natural gas production, with most of that decrease in the federal offshore Gulf of Mexico and Wyoming

Breakdowns by state and area of the fuel production volumes on federal and Indian lands show that:

- The federal Gulf of Mexico produced 68% of the federal and Indian lands crude oil total in FY 2014
- Wyoming, the federal Gulf of Mexico, New Mexico, and Colorado together represented 86% of total production of natural gas on federal and Indian lands in FY 2014
- Wyoming produced 80% of the coal on federal and Indian lands in FY 2014

EIA's estimates are based on data provided by the U.S. Department of the Interior's (DOI) Office of Natural Resources Revenue (ONRR) and include sales of production from federal onshore and offshore lands, and from Indian lands.[3] EIA summarizes total sales of fossil fuels produced on federal and Indian lands in common energy units (British thermal units, or Btu) to allow for aggregation across fuels, including crude oil and lease condensate, natural gas, natural gas plant liquids(NGPL), and coal (Tables 1 and 2). The data presented in this report update the data previously reported by EIA[4] for FY 2003 through FY 2013.

The sales reported by ONRR are a reasonable proxy for marketed production for a fiscal year. Sales are assigned to the fiscal year in which the sales were made rather than when royalties were collected. They also include production leaving the lease that is exempt from royalty payments under various royalty relief programs.

[1] Throughout this report, the term *production* means sales from production.

[2] The U.S. government's fiscal year runs from October 1 through September 30.

[3] Includes offshore and onshore areas the federal government owns or administers, including American Indian lands.

[4] Sales of Fossil Fuels Produced from Federal and Indian Lands, FY 2003 through FY 2013, EIA, June 2014, found at http://www.eia.gov/analysis/requests/archive/2013/pdf/eia-federallandsales_061914.pdf

Table 1. Fossil fuel sales of production from federal lands, FY 2003-14

	Crude Oil and Lease Condensate			Natural Gas Plant Liquids [2]			Natural Gas			Coal			Fossil Fuels	
Fiscal Year	Million Barrels [1]	Trillion Btu	Percent of U.S. Total	Million Barrels [1]	Trillion Btu	Percent of U.S. Total	Billion Cubic Feet [1]	Trillion Btu	Percent of U.S. Total	Million Short Tons [1]	Trillion Btu	Percent of U.S. Total	Trillion Btu	Percent of U.S. Total
2003	679	3,939	33.0%	93	347	14.7%	6,798	6,981	35.7%	436	8,960	40.6%	20,227	36.1%
2004	670	3,884	33.3%	104	386	15.7%	6,376	6,545	34.0%	451	9,226	41.0%	20,041	35.8%
2005	638	3,698	32.8%	96	358	14.7%	6,057	6,223	33.1%	447	9,110	39.6%	19,390	34.8%
2006	571	3,313	31.3%	85	315	13.8%	5,373	5,523	29.6%	429	8,715	37.2%	17,867	32.4%
2007	618	3,584	33.3%	103	383	16.1%	5,557	5,709	29.2%	443	9,017	38.6%	18,692	33.2%
2008	565	3,276	30.7%	103	382	15.5%	5,532	5,681	27.6%	483	9,771	41.6%	19,110	33.3%
2009	648	3,761	34.0%	93	342	13.8%	5,380	5,518	26.1%	462	9,260	41.5%	18,881	33.0%
2010	724	4,201	36.4%	131	482	17.6%	5,086	5,206	24.4%	457	9,188	42.8%	19,076	33.3%
2011	645	3,742	31.8%	131	481	16.6%	4,588	4,690	20.5%	447	9,016	41.1%	17,929	30.0%
2012	601	3,489	26.4%	130	478	14.9%	4,261	4,361	17.8%	442	8,924	42.1%	17,251	27.7%
2013	614	3,558	23.1%	108	402	11.7%	3,835	3,936	15.9%	401	8,103	40.3%	15,999	25.1%
2014	651	3,774	21.4%	117	434	11.3%	3,551	3,649	14.1%	402	8,118	40.8%	15,975	23.7%

[1] Includes sales volumes for production from federal lands including all classes of land owned by the federal government, including acquired military, Outer Continental Shelf, and public lands.

[2] Includes only those quantities for which the royalties were paid on the basis of the value of the natural gas plant liquids produced. Additional quantities of natural gas plant liquids were produced; however, the royalties paid were based on the value of natural gas processed. These latter quantities are included with natural gas.

Notes: Total fossil fuels are the sum of crude oil and lease condensate, natural gas plant liquids, natural gas, and coal. In addition, the sales volumes are reported for the fiscal year in which the sales occurred as opposed to the date of the royalty payment. Volumes include fossil fuels for which royalties were paid, as well as those amounts exempt from royalty payments, such as additions to the Strategic Petroleum Reserve.

Sources: **Physical Data:** U.S. Department of the Interior, Office of Natural Resources Revenue, ONNR Statistical Information Site (http://statistics.onrr.gov).

Btu Data: U.S. Energy Information Administration. Btu are calculated using average, calendar-year heat rates for production of each fossil fuel, as reported in the *Monthly Energy Review* (March 2015). The total Btu-content per fossil fuel is calculated by multiplying the physical data by the approximate heat content. The fossil fuel total is the sum of the total heat content for crude oil and lease condensate, natural gas plant liquids, natural gas, and coal.

Percent of Total: Percentages are calculated by dividing sales of production from federal by total U.S. production, then multiplying by 100. Fiscal year values for total U.S. production are the sum of October-September values from the *Monthly Energy Review* (March 2015) and reflect EIA's current data updates.

Table 2. Fossil fuel sales of production from Indian lands, FY 2003-14

Fiscal Year	Crude Oil and Lease Condensate			Natural Gas Plant Liquids [2]			Natural Gas			Coal			Fossil Fuels	
	Million Barrels [1]	Trillion Btu	Percent of U.S. Total	Million Barrels [1]	Trillion Btu	Percent of U.S. Total	Billion Cubic Feet [1]	Trillion Btu	Percent of U.S. Total	Million Short Tons [1]	Trillion Btu	Percent of U.S. Total	Trillion Btu	Percent of U.S. Total
2003	10	59	0.5%	2	6	0.3%	283	291	1.5%	30	616	2.8%	972	1.7%
2004	10	58	0.5%	2	7	0.3%	312	320	1.7%	33	667	3.0%	1,052	1.9%
2005	10	59	0.5%	2	7	0.3%	327	336	1.8%	34	698	3.0%	1,100	2.0%
2006	10	56	0.5%	2	8	0.3%	308	317	1.7%	29	593	2.5%	974	1.8%
2007	10	56	0.5%	3	10	0.4%	284	292	1.5%	27	558	2.4%	916	1.6%
2008	10	57	0.5%	3	11	0.4%	272	279	1.4%	26	527	2.2%	874	1.5%
2009	10	61	0.5%	3	10	0.4%	266	273	1.3%	26	521	2.3%	864	1.5%
2010	13	77	0.7%	3	11	0.4%	251	257	1.2%	22	435	2.0%	781	1.4%
2011	20	115	1.0%	3	12	0.4%	254	260	1.1%	22	444	2.0%	831	1.4%
2012	31	182	1.4%	4	13	0.4%	253	259	1.1%	19	383	1.8%	837	1.3%
2013	46	269	1.8%	4	14	0.4%	241	247	1.0%	19	387	1.9%	916	1.4%
2014	56	324	1.8%	4	16	0.4%	241	247	1.0%	19	380	1.9%	968	1.4%

[1] Includes sales volumes for production from Indian lands.

[2] Includes only those quantities for which the royalties were paid on the basis of the value of the natural gas plant liquids produced. Additional quantities of natural gas plant liquids were produced; however, the royalties paid were based on the value of natural gas processed. These latter quantities are included with natural gas.

Notes: Total fossil fuels equals the sum of crude oil and lease condensate, natural gas plant liquids, natural gas, and coal. In addition, the sales volumes are reported for the fiscal year in which the sales occurred as opposed to the date of the royalty payment. Volumes include fossil fuels for which royalties were paid, as well as those amounts exempt from royalty payments, such as additions to the Strategic Petroleum Reserve.

Sources: **Physical Data:** U.S. Department of the Interior, Office of Natural Resources Revenue, ONNR Statistical Information Site (http://statistics.onrr.gov).

Btu Data: U.S. Energy Information Administration. Btu are calculated using average, calendar-year heat rates for production of each fossil fuel, as reported in the *Monthly Energy Review* (March 2015). The total Btu-content per fossil fuel is calculated by multiplying the physical data by the approximate heat content. The fossil fuel total is the sum of the total heat content for crude oil and lease condensate, natural gas plant liquids, natural gas, and coal.

Percent of Total: Percentages are calculated by dividing sales of production from Indian lands by total U.S. production, then multiplying by 100. Fiscal year values for total U.S. production are the sum of October-September values from the *Monthly Energy Review* (March 2015) and reflect EIA's current data updates.

Sales from production on federal and Indian lands

Federal lands

Coal represented 51% of fossil fuel sales from production on federal lands in FY 2014, measured in common Btu units, followed by crude oil and lease condensate (24%), natural gas (23%), and natural gas plant liquids (NGPL) (3%). Total fossil fuels sales from production on federal lands decreased slightly from 15,999 trillion Btu in FY 2013 to 15,975 trillion Btu in FY 2014 (Table 1). On federal lands (only) in FY 2014:

- Sales of crude oil[5] from federal lands increased 6%, from 614 million barrels in FY 2013 to 651 million barrels in FY 2014. Federal offshore and onshore oil production increased by 5% and 9%, respectively (Table 3). Despite this increase, crude oil production from federal lands as a share of total U.S. crude oil production decreased from 23% in FY 2013 to 21% in FY 2014. This decrease in the federal lands share of total production was the result of the 16% increase in total U.S. crude oil production.[6]
- Sales of natural gas from federal lands decreased 7%, from 3,835 billion cubic feet in FY 2013 to 3,551 billion cubic feet in FY 2014. Both offshore (11%) and onshore volumes (6%) declined (Table 4). Natural gas production on federal lands dropped to 14% of the U.S. total in FY 2014 from 16% in FY 2013. The largest portion of the drop in natural gas production on federal lands was from declines in the Gulf of Mexico and Wyoming.
- Sales of natural gas plant liquids (NGPL) produced on federal lands increased 8%, from 108 million barrels in FY 2013 to 117 million barrels in FY 2014. Both onshore (9%) and offshore volumes (7%) increased (Table 5). NGPL production from federal lands decreased from 12% to 11% of the U.S. total in FY 2014.
- Coal sales from production on federal lands increased slightly (0.2%) from 401 million short tons in FY 2013 to 402 million short tons in FY 2014 (Table 6). Coal produced on federal lands accounted for 41% of the U.S. total in FY 2014, up from 40% in FY 2013.

Indian Lands

Coal represented 39% of fossil fuel sales from production on Indian lands in FY 2014, measured in common Btu units, followed by crude oil (33%), natural gas (26%), and NGPL (2%). Total fossil fuels sales from production on Indian lands increased 6% from 916 trillion Btu in FY 2013 to 968 trillion Btu in FY 2014 (Table 2), as oil and NGPL production increased, natural gas production remained level, and coal production declined. On Indian lands (only) in FY 2014:

- Sales of crude oil produced on Indian lands increased 22%, increasing from 46 million barrels in FY 2013 to 56 million barrels in FY 2014 (Table 3). The increase in Indian lands oil production was attributable mostly to gains on tribal lands in North Dakota (Bakken formation) and, to a lesser extent, gains on tribal lands in New Mexico and Utah.
- Sales of natural gas from Indian lands remained at 241 billion cubic feet in FY 2014 (Table 4).

[5] Throughout this report, the term *crude oil* includes lease condensate.

[6] http://www.eia.gov/dnav/pet/pet_crd_crpdn_adc_mbblpd_a.htm.

- Sales of NGPL increased slightly and coal production decreased slightly on Indian lands in FY 2014, but these changes were negligible in the context of reported units (million short tons) in the tables of this report. Therefore, the production of NGPL and coal from Indian lands in FY 2014 matches that of FY 2013, 4 million barrels and 19 million short tons, respectively (Tables 5 and 6).

Trends in federal and Indian lands production from FY 2003 through FY 2014

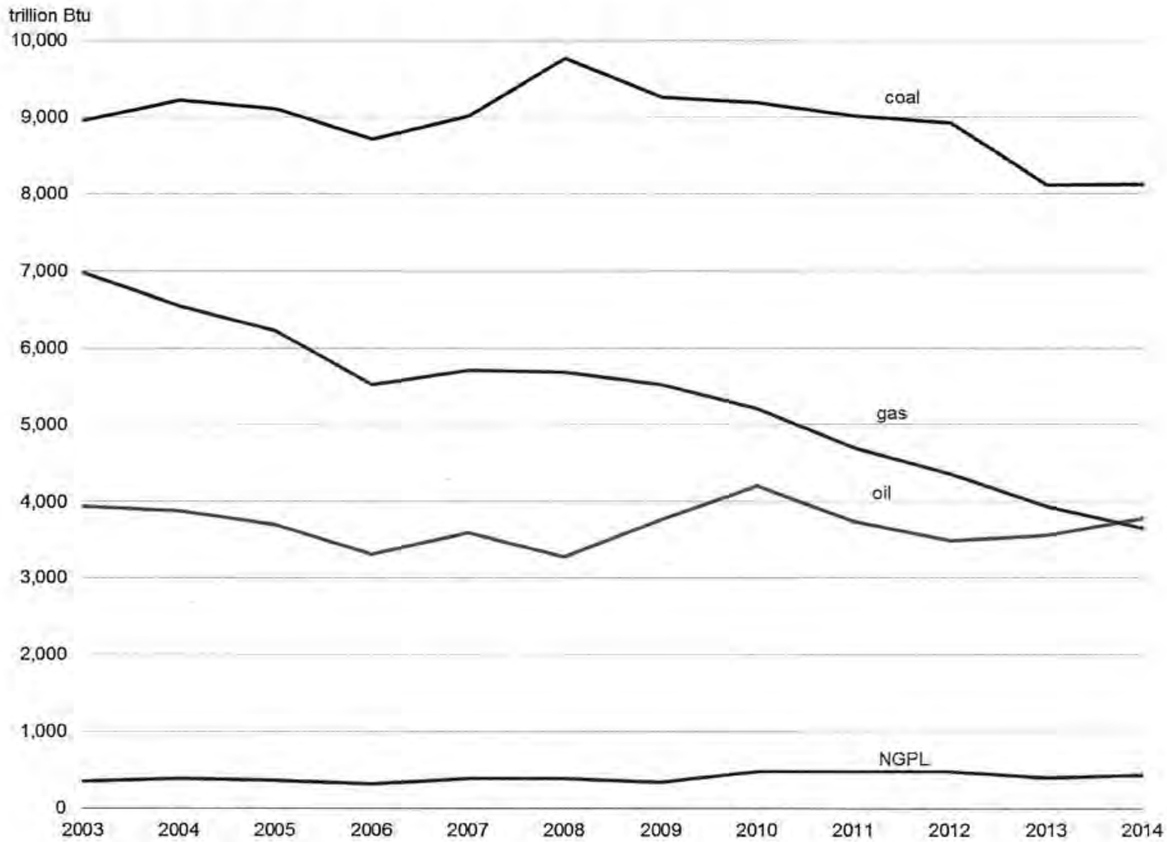
Overall fossil fuel production from federal lands generally declined between FY 2003 and FY 2014, down 21% in FY 2014 compared with FY 2003 (Table 1). This trend is primarily the result of a steady decline in federal offshore natural gas production between FY 2003 and FY 2014 and the 9% drop in coal production from federal lands from FY 2012 to FY 2013.

Conversely, overall fossil fuel production from Indian lands has risen since 2009 because of increasing crude oil and NGPL production. Total fossil fuels production on Indian lands in FY 2014 fell just short of surpassing the amount produced in FY 2003 (less than a 1% difference).

- Crude oil production from federal lands decreased 4% between FY 2003 and FY 2014 (Figure 1, Table 3). Production in the federal offshore declined 13% over that period, which outweighs the 49% increase in the federal onshore volumes over the same period. In FY 2014, the federal offshore still had the majority (77%) of total federal crude oil production, but its share declined compared with FY 2003 when it comprised 85% of all federal crude oil production.
- For the past six consecutive fiscal years, 2009-2014, oil production on Indian lands has increased (Figure 2). Between FY 2003 and FY 2014, oil production on Indian lands increased 460%.
- Natural gas production from federal lands has declined steadily, down 48% in FY 2014 from 2003(Figure 1, Table 4). The once-larger federal offshore volumes declined every year through FY 2014, down 76% from FY 2003. That decrease was partially offset by the now-larger onshore volumes, which increased 9% over the same time period. This declining natural gas production from federal lands, coupled with increasing total U.S. natural gas production[7], steadily reduced the federal lands share of total U.S. natural gas production.
- NGPL production from federal lands increased 26% between FY 2003 and FY 2014 (Figure 1, Table 5). Following the natural gas trend, the once-larger federal offshore NGPL volumes declined 6%, while the now-larger onshore NGPL volumes increased 64% over the same period. NGPL production on Indian lands in FY 2014 was 4 million barrels, and while this level is twice the amount produced from Indian lands in FY 2003, it is a small volume compared with what was produced on federal lands (117 million barrels) in FY 2014.
- Federal land coal production declined 8% between FY 2003 and FY 2014 (Figure 1, Table 6). Coal production on Indian lands declined 37% over the same period. U.S. total coal production was an estimated 1,072 million short tons in 2003 and declined to 997 million short tons in 2014 (a 7% decline). Coal production from federal and Indian lands totaled 421 million short tons (42% of the U.S. total) in FY 2014.

[7] http://www.eia.gov/dnav/ng/ng_prod_sum_dcu_NUS_a.htm.

Figure 1. Fossil fuel production on federal lands, FY 2003-14

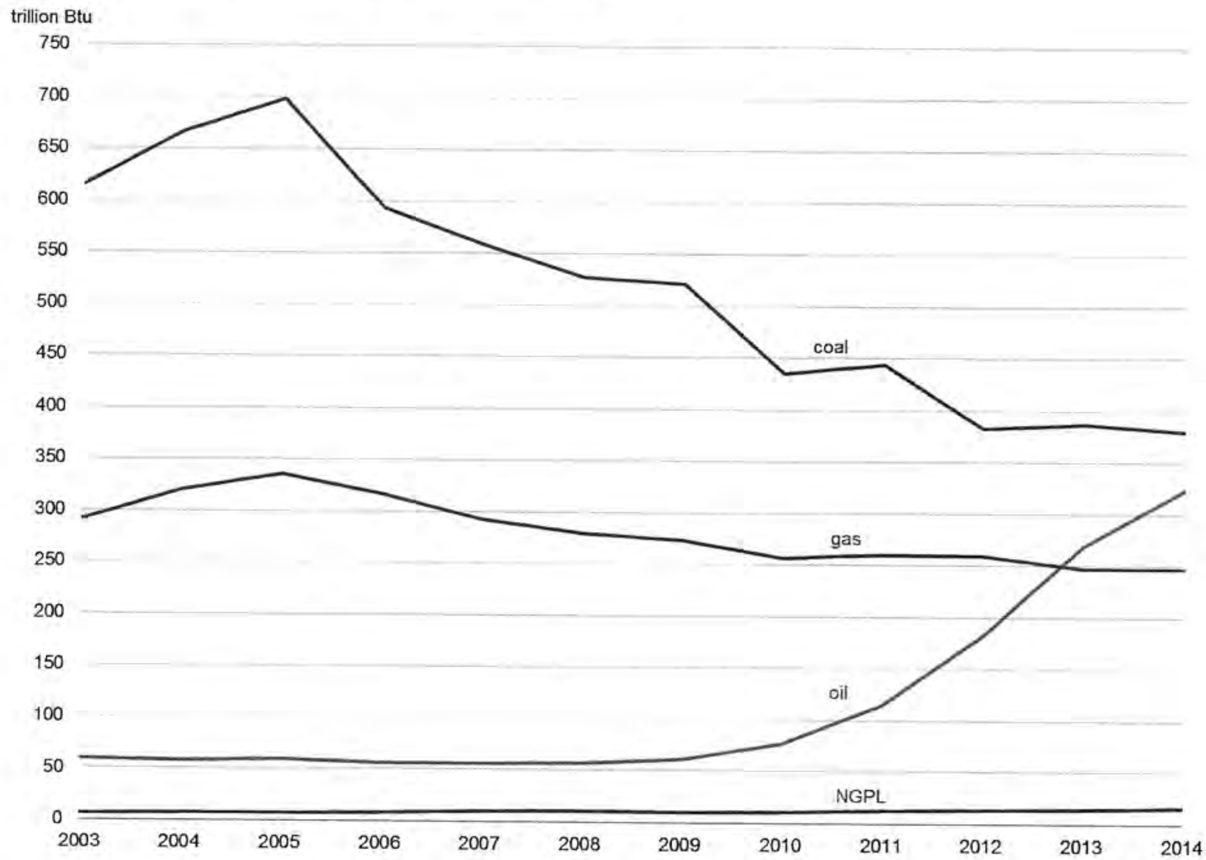


Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. ONNR Statistical Information Site (http://statistics.onrr.gov).

Total fossil fuel production from Indian lands increased each year since FY 2010. Increases in oil production have almost completely offset the decreases in coal production and natural gas production between FY 2003 and FY 2014 (Table 2). The annual totals are less than 1% different, but the FY 2003 level was slightly higher.

- Crude oil production from Indian lands increased 460% from 10 million barrels in FY 2003 to 56 million barrels in FY 2014. Almost all of this increase took place since FY 2010 (Figure 2, Table 3), and mostly in North Dakota (primarily the Fort Berthold Indian Reservation in the western part of the state, part of the Bakken/Three Forks tight oil play).
- Natural gas production and coal production from Indian lands declined between FY 2003 and FY 2014 by 15% and 37%, respectively. Except for a small deviation in FY 2011, natural gas and coal production have steadily declined since FY 2005 (Figure 2).

Figure 2. Fossil fuel production on Indian lands, FY 2003-14



Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

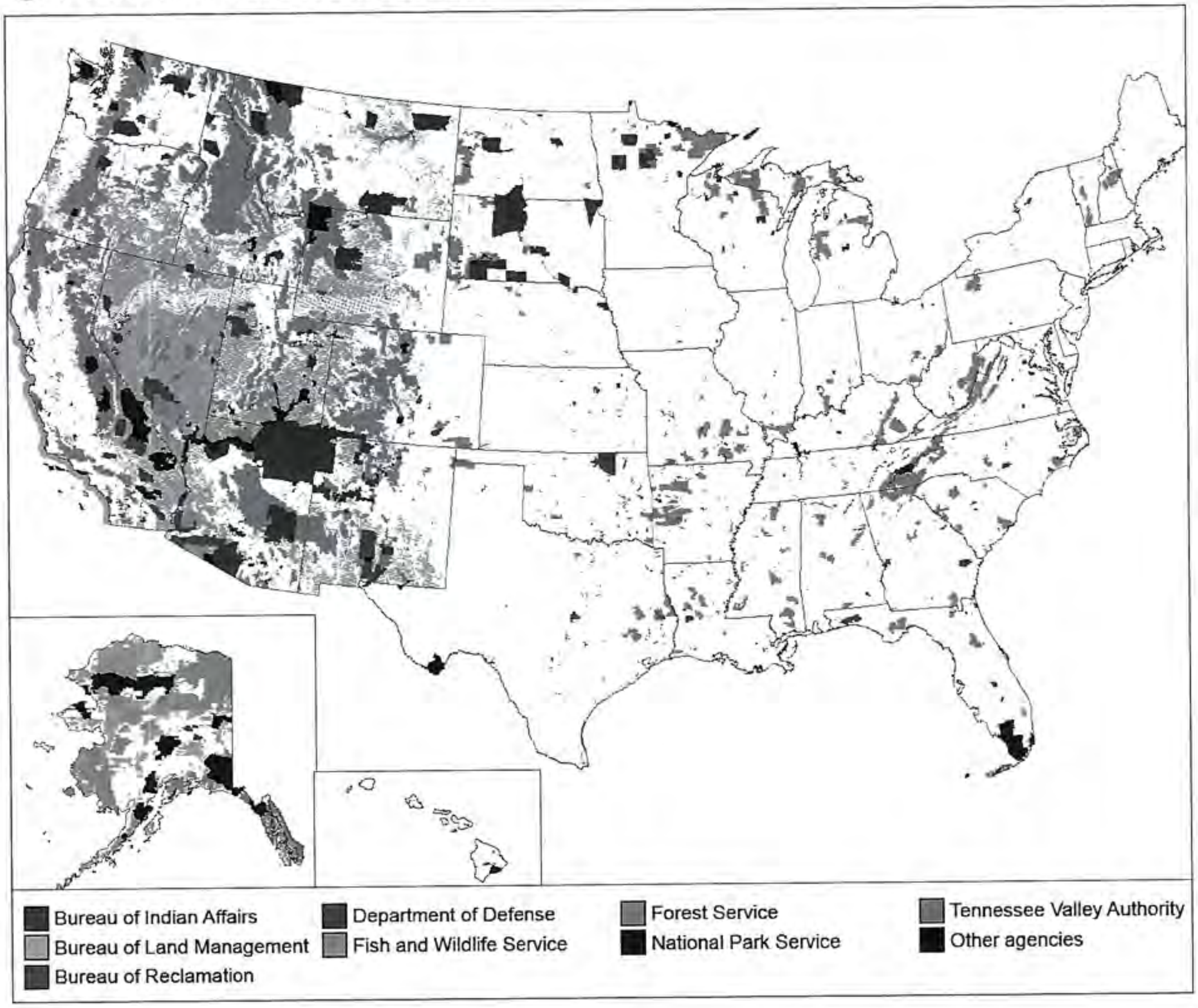
State/offshore trends

The federal government owns nearly 650 million acres of land—almost 30% of the land area of the United States (Figure 3). Four agencies—the National Park Service, the Fish and Wildlife Service, the Bureau of Land Management (BLM) in the Department of the Interior, and the U.S. Forest Service in the Department of Agriculture—administer about 95% of those federally owned lands.[8,9]

[8] Federal Land Ownership: Current Acquisition and Disposal Authorities, Congressional Research Service, December 13, 2012, found at https://www.fas.org/sgp/crs/misc/RL34273.pdf.

[9] Maps of the various kinds of federal lands can be seen at http://nationalatlas.gov/printable/fedlands.html.

Figure 3. Onshore federal and Indian lands



Source: Produced by U.S. Energy Information Administration from Federal Lands and Bureau of Indian Affairs map layers at http://nationalatlas.gov/maplayers.html?openChapters=chpbound#chpbound

Most production of fossil fuels from federal and Indian lands falls under the purview of BLM. BLM manages 248 million acres and is responsible for 700 million acres of subsurface mineral resources.[10]

Federal land ownership is heavily concentrated in 12 western states:

- 62% of Alaska is federally owned.

[10] Federal Land Ownership: Overview and Data, Congressional Research Service, February 8, 2012, found at https://www.fas.org/sgp/crs/misc/R42346.pdf.

- 47% of the 11 western states[11] in the Lower 48 states is federally owned. In calendar year 2013, those 11 western states represented approximately 20% of total U.S. reserves of crude oil and lease condensate and 23% of total U.S. reserves of wet natural gas.[12] Wyoming, Montana, Colorado, Utah, and New Mexico are the leading states producing fossil fuels from federal and Indian lands.
- Only 4% of the total area of all the other states combined is federally owned.

Indian lands are primarily in the western United States, with concentrations in the four corners region of Arizona, New Mexico, Colorado, and Utah; North and South Dakota; and a few other states (Figure 3).

Figures 4 through 8 provide summary information for production from federal and Indian lands for leading states and offshore areas. Complete state-level data on production from federal and Indian lands are provided in Tables 7 through11.[13] The relative and absolute contribution of each state and offshore region in federal and Indian lands production varies significantly across fuels. Some notable observations include:

- Wyoming and the federal Gulf of Mexico together produced 72% of the federal and Indian lands fossil fuels total in FY 2014 (Table 7, Figure 4). New Mexico, Colorado, and Utah were the next largest production states.
- The federal Gulf of Mexico produced 67% of the federal and Indian lands crude oil total in FY 2014 (Figure 5, Table 8). New Mexico, North Dakota, and Wyoming were the next largest crude oil producers on federal and Indian lands.
- Wyoming, the federal Gulf of Mexico, New Mexico, and Colorado together represented 86% of total production of natural gas on federal and Indian lands in FY 2014 (Figure 6, Table 9).
- The federal Gulf of Mexico, New Mexico, and Wyoming together produced 82% of NGPL from federal and Indian lands NGPL in FY 2014 (Figure 7, Table 10).
- Production of coal on federal and Indian lands is dominated by Wyoming, which accounted for 80% of the total in FY 2014 (Figure 8, Table11). Montana, Colorado, Utah, and New Mexico were the next biggest coal producers on federal and Indian lands. In FY 2014, coal production in Montana increased by 3 million short tons, and New Mexico production decreased by 2 million short tons.

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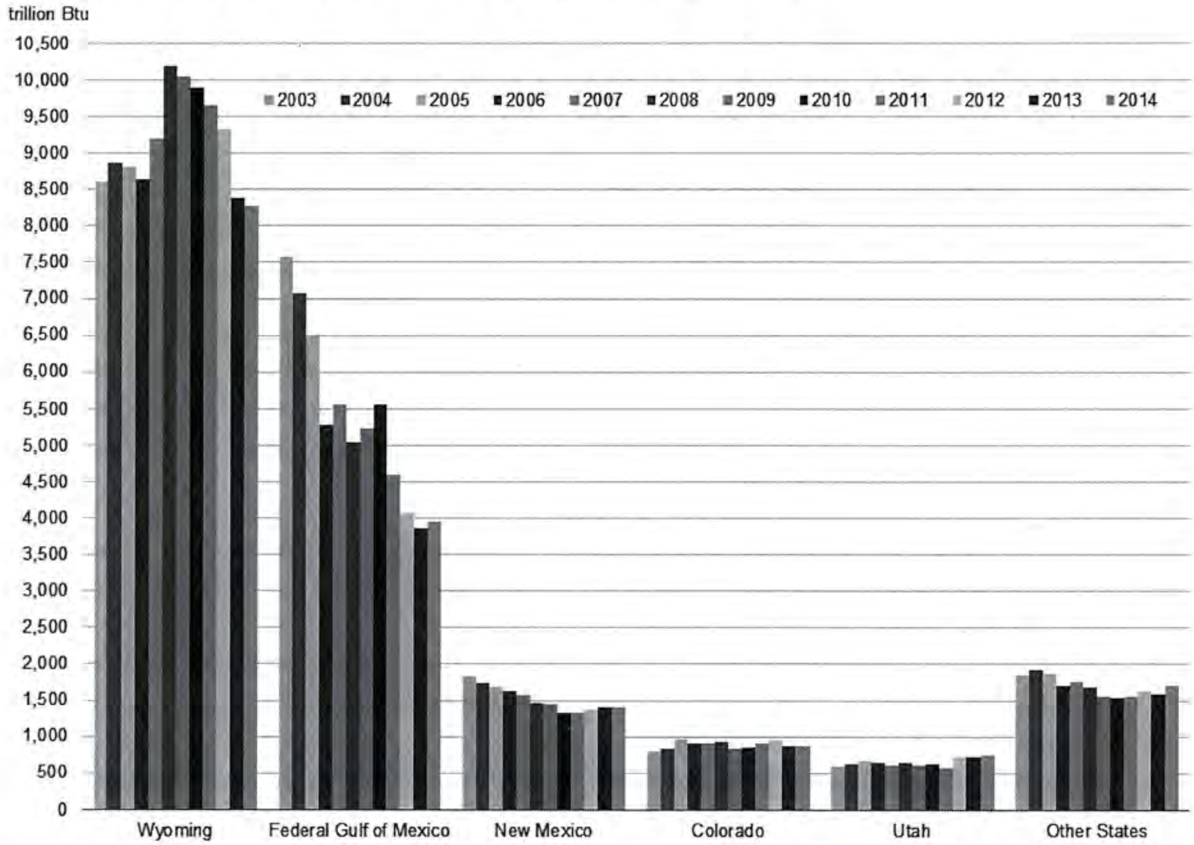
[11] Montana, Wyoming, Colorado, New Mexico, Idaho, Utah, Arizona, Washington, Oregon, Nevada, and California.

[12] U.S. Crude Oil and Natural Gas Proved Reserves, 2013, Tables 6 and 10, EIA, December 2014, found at http://www.eia.gov/naturalgas/crudeoilreserves/.

[13] The Appendix presents information from these tables in the form of maps of the latest state-level production levels and changes.

Figure 4. Fossil fuel production on federal and Indian lands, FY 2003-14



Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Data sources

U.S. Department of Interior program offices continually collect sales and royalty payment data on fossil fuel sales of production from federal and Indian lands. Near the end of the first quarter of each calendar year, ONRR issues the sales data it collected for the previous sales year. Sales are assigned to the fiscal year in which they occur, not necessarily the same year royalties were collected. Audits conducted by ONNR result in revisions to data previously reported.

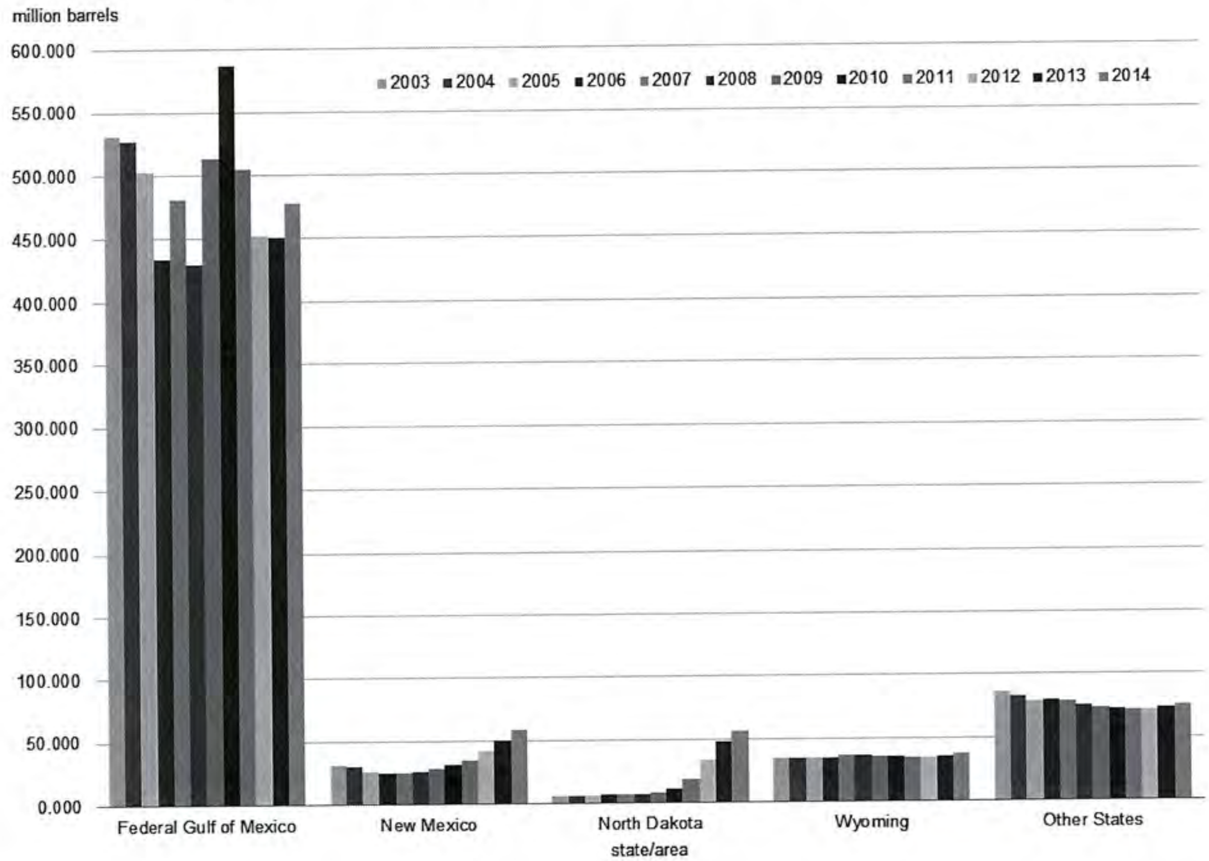
This report is based on information reported to and processed by ONRR as of March 31, 2015. ONRR updates the data values it reports for prior years. The recently updated data provided by ONRR for FY 2003 through FY 2014 generally fall within 2% of the volumes EIA reported previously, although updates for some NGPL volumes slightly exceeded that threshold (e.g., FY 2013 NGPL production volume was revised upward 3.3% in May 2013).

Additional data, background information, and discussions of methodology and key drivers contributing to trends in sales from production on federal lands during the FY 2003 through FY 2013 period are available in *Sales of Fossil Fuels Produced on Federal and Indian Lands, FY 2003 through 2013* and on the ONRR website.

The following table shows the fuels (commodities) listed on the ONRR website and the associated products, which were included in this report:

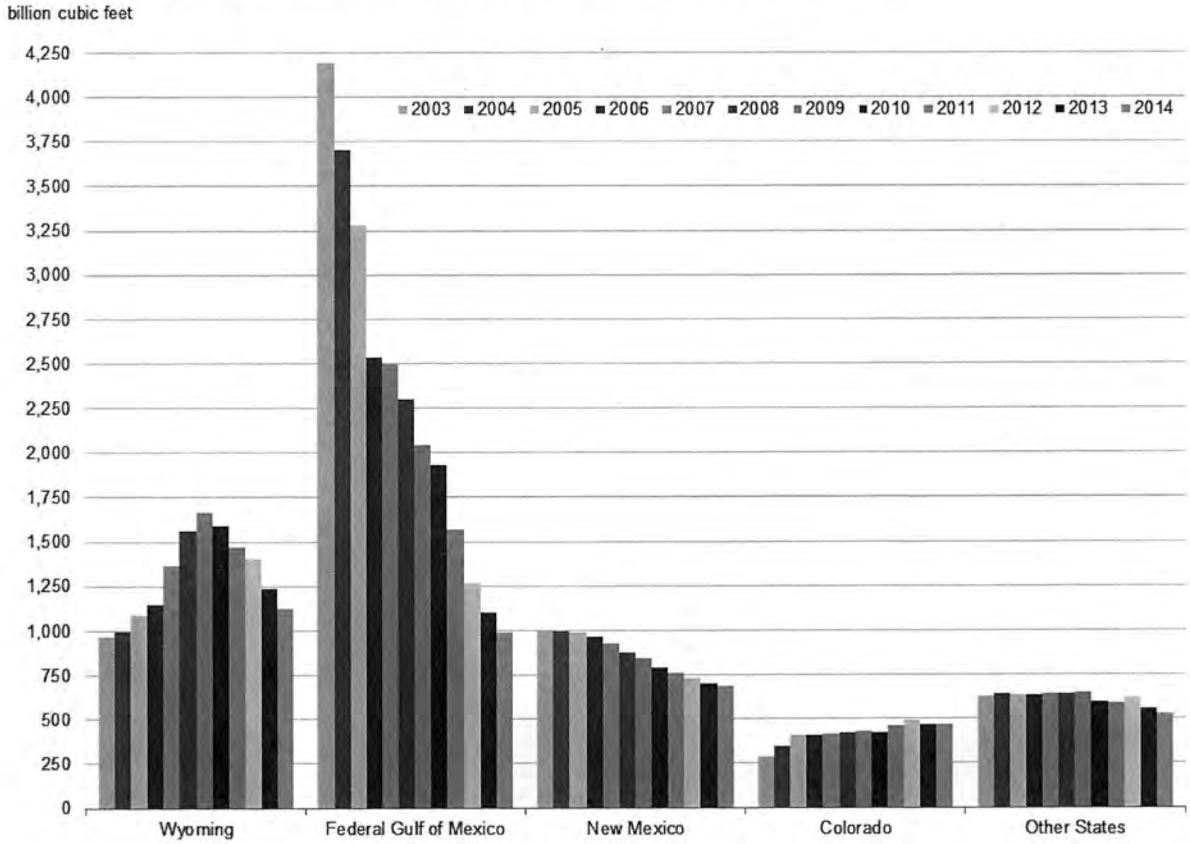
Fuel (commodity)	Product
Coal	Coal
	Coal-Bituminous-Raw
Natural Gas	Coal Bed Methane
	Flash Gas
	Fuel Gas
	Gas Lost - Flared or Vented
	Processed (Residue) Gas
	Unprocessed (Wet) Gas
NGPL	Gas Plant Products
Oil	Condensate
	Drip or Scrubber Condensate
	Fuel Oil
	Inlet Scrubber
	Oil
	Oil Lost
	Other Liquid Hydrocarbons

Figure 5. Crude oil production on federal and Indian lands, FY 2003-14



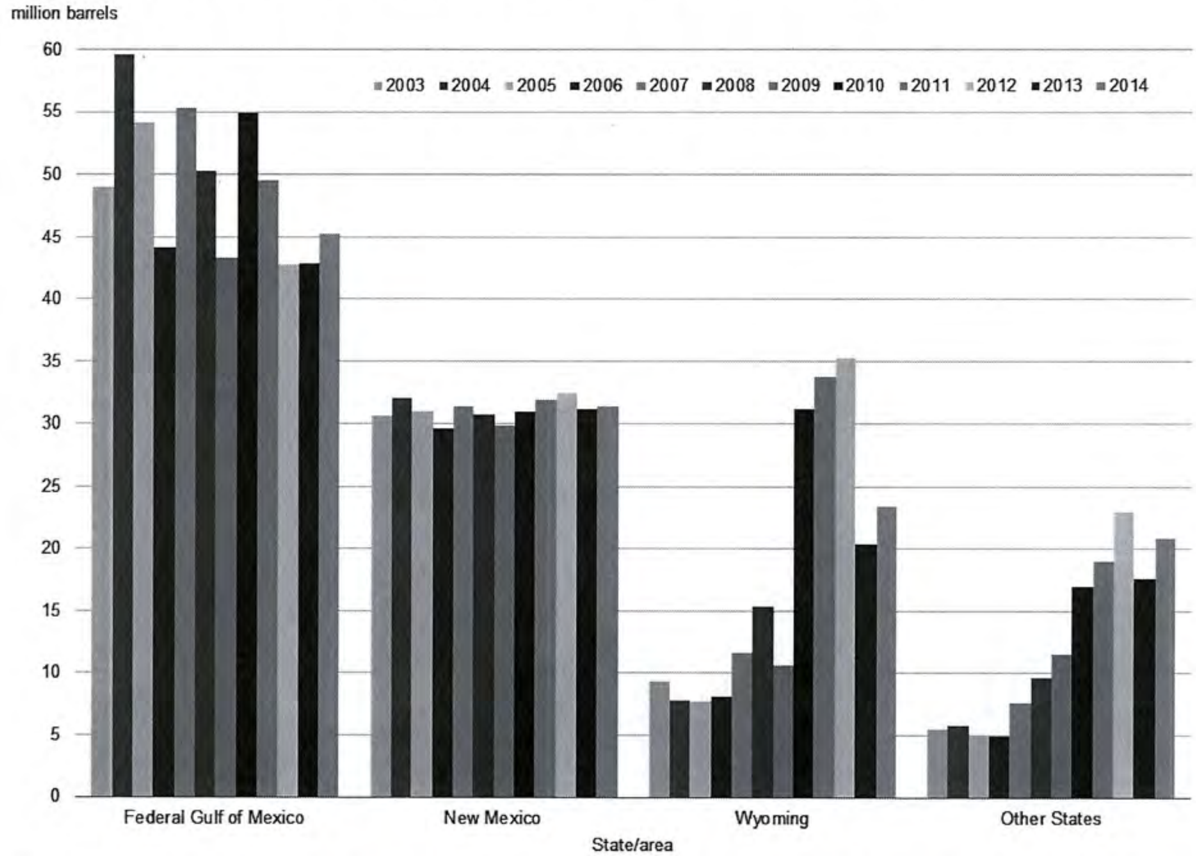
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure 6. Natural gas production on federal and Indian lands, FY 2003-14



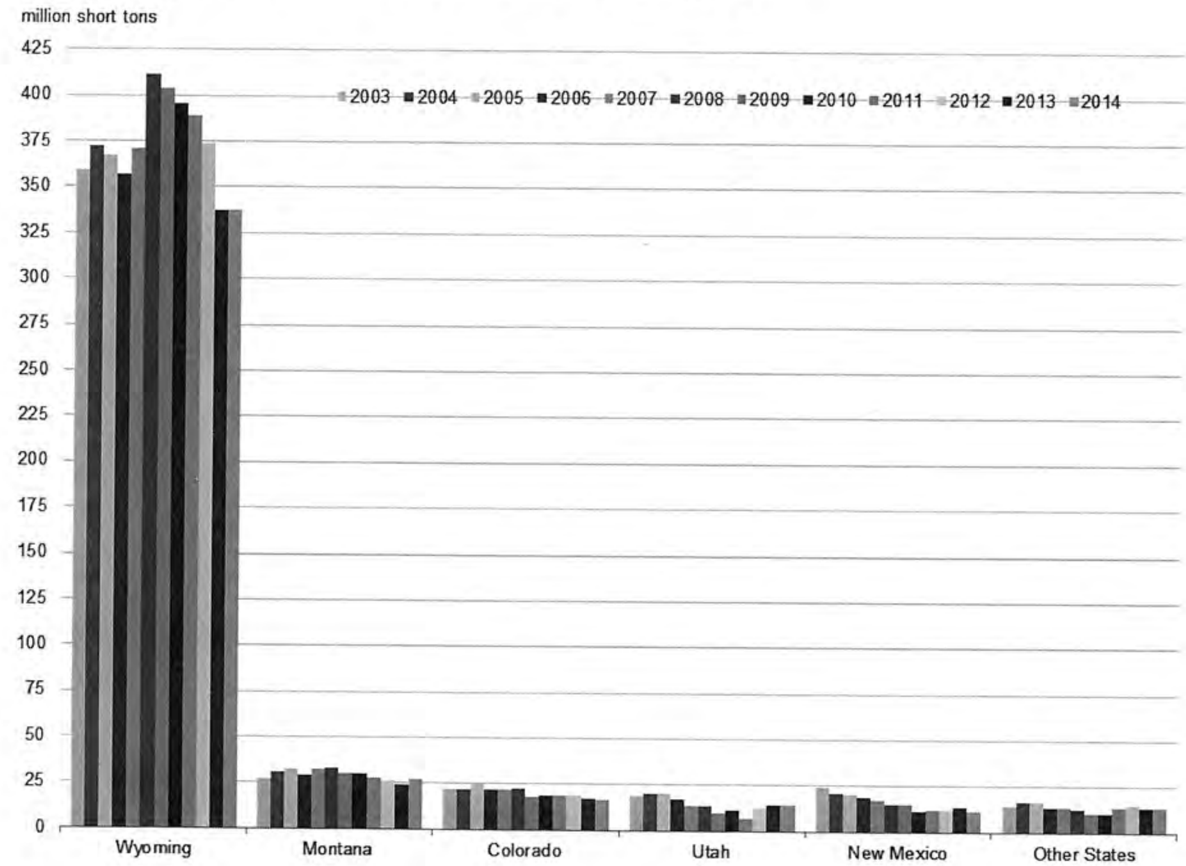
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure 7. Natural gas liquids production on federal and Indian lands, FY 2003-14



Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure 8. Coal production on federal and Indian lands, FY 2003-14



Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Table 3. Sales of crude oil and lease condensate production from federal and Indian lands, FY 2003-14

million barrels

Fiscal Year	Offshore Federal	Onshore Federal	Total Federal	Indian Lands
2003	579	100	679	10
2004	572	97	670	10
2005	541	96	638	10
2006	471	100	571	10
2007	514	104	618	10
2008	462	103	565	10
2009	544	105	649	10
2010	616	108	724	13
2011	532	113	645	20
2012	476	125	601	31
2013	476	137	614	46
2014	502	149	651	56

Notes: Totals may not equal sum of components because of independent rounding. Onshore federal excludes volumes on Indian lands. Offshore federal only includes areas in federal waters.
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Table 4. Sales of natural gas production from federal and Indian lands, FY 2003-14

billion cubic feet

Fiscal Year	Offshore Federal	Onshore Federal	Total Federal	Indian Lands
2003	4,522	2,276	6,798	283
2004	4,025	2,351	6,376	312
2005	3,523	2,534	6,057	327
2006	2,754	2,619	5,373	308
2007	2,700	2,857	5,557	284
2008	2,483	3,049	5,532	272
2009	2,213	3,167	5,380	266
2010	2,080	3,006	5,086	251
2011	1,692	2,896	4,588	254
2012	1,374	2,887	4,261	253
2013	1,198	2,637	3,835	241
2014	1,069	2,482	3,551	241

Notes: Totals may not equal sum of components because of independent rounding. Onshore federal excludes volumes on Indian lands. Offshore federal only includes areas in federal waters.
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Table 5. Sales of natural gas plant liquids production from federal and Indian lands, FY 2003-14

million barrels

Fiscal Year	Offshore Federal	Onshore Federal	Total Federal	Indian Lands
2003	51	42	93	2
2004	62	41	104	2
2005	56	40	96	2
2006	46	39	85	2
2007	59	44	103	3
2008	53	50	103	3
2009	45	47	93	3
2010	58	73	131	3
2011	52	79	131	3
2012	45	85	130	4
2013	45	63	108	4
2014	48	69	117	4

Notes: Totals may not equal sum of components because of independent rounding. Onshore federal excludes volumes on Indian lands. Offshore federal only includes areas in federal waters.
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Table 6. Sales of coal from federal and Indian lands, FY 2003-14

million short tons

Fiscal Year	Federal	Indian Lands
2003	436	30
2004	451	33
2005	447	34
2006	429	29
2007	443	27
2008	483	26
2009	462	26
2010	457	22
2011	447	22
2012	442	19
2013	401	19
2014	402	19

Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Table 7. Sales of fossil fuel production from federal and Indian lands by state/area, FY 2003-14

trillion Btu

State	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Alabama	75	57	51	47	40	42	60	88	86	71	46	29
Alaska	61	66	68	52	32	28	27	23	21	19	18	21
Arizona	258	273	280	193	180	162	157	154	164	163	167	158
Arkansas	7	8	10	10	10	11	15	18	14	13	11	11
California	141	125	124	139	146	129	116	115	121	125	121	119
Colorado	785	842	960	906	905	931	846	868	917	952	875	877
Florida	0	-	-	-	-	-	-	-	-	-	-	-
Illinois	0	-	-	-	-	-	-	-	-	-	-	-
Indiana	0	-	-	-	-	-	-	-	-	-	-	-
Kansas	12	11	11	12	10	10	10	9	8	7	7	6
Kentucky	0	-	-	6	18	8	4	1	3	5	6	-
Louisiana	225	245	188	164	167	162	146	127	116	111	106	88
Michigan	4	4	4	4	4	4	3	3	2	2	2	1
Mississippi	19	19	18	16	16	17	14	13	13	12	12	10
Montana	612	684	722	661	723	727	662	659	612	576	515	580
Nebraska	0	-	1	2	1	-	-	-	-	-	-	-
Nevada	3	3	3	2	2	2	3	3	2	2	2	2
New Mexico	1,823	1,750	1,696	1,627	1,570	1,474	1,447	1,333	1,339	1,365	1,408	1,403
New York	0	-	-	-	-	-	-	-	-	-	-	-
North Dakota	70	92	88	111	121	126	77	83	165	291	387	469
Offshore Gulf	7,570	7,086	6,484	5,289	5,553	5,046	5,235	5,587	4,713	4,078	3,907	3,949
Offshore Pacific	170	156	145	144	138	131	129	123	107	92	98	97
Ohio	1	1	1	1	1	1	1	1	1	1	1	-
Oklahoma	56	57	56	57	59	57	60	60	63	63	62	63
Pennsylvania	0	-	-	-	-	-	-	-	-	-	-	-
South Dakota	1	1	1	1	1	1	1	1	1	2	1	1
Texas	119	113	90	87	87	67	64	49	54	76	62	50
Utah	586	637	677	654	621	647	622	632	570	734	733	738
Virginia	0	-	1	1	-	-	-	-	-	-	-	-
Washington	4	-	-	-	-	-	-	-	-	-	-	-
West Virginia	1	1	1	2	1	1	1	1	1	-	-	-
Wyoming	8,596	8,863	8,813	8,653	9,197	10,198	10,048	9,908	9,665	9,331	8,369	8,270
Total	**21,200**	**21,096**	**20,493**	**18,841**	**19,607**	**19,984**	**19,748**	**19,859**	**18,760**	**18,091**	**16,915**	**16,944**

Note: Totals may not equal sum of components because of independent rounding.

Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov)

Table 8. Sales of crude oil and lease condensate production from federal and Indian lands by state/area, FY 2003-14

million barrels

State	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Alabama	0	0	0	0	0	0	0	0	0	0	0	0
Alaska	4	5	5	3	0	0	0	1	1	0	1	1
Arizona	0	0	0	0	0	0	0	0	0	0	0	0
Arkansas	0	0	0	0	0	0	0	0	0	0	0	0
California	23	21	21	23	24	21	19	19	19	19	19	19
Colorado	4	4	5	6	5	5	5	4	4	5	4	5
Florida	0	-	-	-	-	-	-	-	-	-	-	-
Illinois	0	0	0	0	0	0	0	0	0	0	0	0
Indiana	0	0	0	0	0	0	0	0	0	0	0	0
Kansas	0	0	0	1	0	0	0	0	0	0	0	0
Kentucky	0	0	0	0	0	0	0	0	0	0	0	0
Louisiana	13	13	8	7	7	7	7	7	6	7	7	6
Michigan	0	0	0	0	0	0	0	0	0	0	0	0
Mississippi	1	0	0	0	0	0	0	0	0	0	0	0
Montana	4	4	4	4	4	4	4	4	3	3	3	3
Nebraska	0	0	0	0	0	0	0	0	0	0	0	0
Nevada	0	0	0	0	0	0	0	0	0	0	0	0
New Mexico	32	30	26	25	25	26	28	31	35	42	51	59
New York	0	0	0	0	0	0	0	0	0	0	0	0
North Dakota	6	6	6	7	7	7	8	12	19	34	48	57
Offshore Gulf	531	527	502	435	480	430	513	587	505	452	451	477
Offshore Pacific	23	22	20	20	19	19	19	18	16	14	15	15
Ohio	0	0	0	0	0	0	0	0	0	0	0	0
Oklahoma	1	1	1	1	1	1	1	1	1	2	2	2
Pennsylvania	0	0	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	0	0	0	0	0	0	0	0
Texas	1	1	1	1	1	1	1	1	1	1	1	0
Utah	10	10	12	13	14	16	17	18	19	20	21	24
Virginia	-	-	-	-	-	-	-	-	-	-	-	-
Washington	-	-	-	-	-	-	-	-	-	-	-	-
West Virginia	-	-	-	0	-	-	-	-	-	-	-	-
Wyoming	34	34	34	35	36	36	35	35	35	35	36	38
Total	**689**	**680**	**648**	**581**	**628**	**575**	**659**	**738**	**665**	**633**	**660**	**706**

Note: Totals may not equal sum of components because of independent rounding.
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Table 9. Sales of natural gas production from federal and Indian lands by state/area, FY 2003-14

billion cubic feet

State	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Alabama	71	53	48	44	36	34	30	32	27	20	21	20
Alaska	35	37	40	35	28	25	24	20	16	16	13	13
Arizona	0	0	0	0	0	0	0	0	0	0	-	-
Arkansas	7	8	9	10	10	10	15	18	14	12	11	10
California	6	5	5	7	7	7	7	7	10	13	8	8
Colorado	290	348	406	404	412	424	431	425	461	487	469	465
Florida	-	-	-	-	-	-	-	-	-	-	-	-
Illinois	-	-	-	-	-	-	-	-	-	-	-	-
Indiana	-	-	-	-	-	-	-	-	-	-	-	-
Kansas	11	10	9	8	8	8	7	7	6	5	4	4
Kentucky	0	0	0	0	0	0	0	0	0	0	0	0
Louisiana	140	161	132	116	111	108	96	79	72	66	61	49
Michigan	4	4	4	4	4	3	3	2	2	2	2	1
Mississippi	15	16	15	13	14	15	12	11	11	10	9	8
Montana	22	26	30	34	34	33	31	27	23	18	14	13
Nebraska	0	-	1	2	1	0	0	-	0	0	0	0
Nevada	-	-	-	-	-	-	-	-	-	-	-	-
New Mexico	1,005	997	986	966	926	875	848	792	760	735	704	688
New York	0	0	0	0	0	0	0	0	0	0	0	0
North Dakota	8	8	9	10	10	9	9	9	10	15	22	31
Offshore Gulf	4,194	3,706	3,277	2,533	2,495	2,304	2,046	1,934	1,569	1,270	1,103	986
Offshore Pacific	32	27	25	26	25	21	20	20	15	12	12	11
Ohio	1	1	1	1	1	1	1	1	1	0	0	0
Oklahoma	32	32	32	35	33	33	38	39	40	41	38	39
Pennsylvania	0	0	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	0	0	0	0	0	0	0	0
Texas	108	102	80	76	75	58	57	43	47	69	56	45
Utah	135	147	188	209	243	270	300	280	289	315	290	274
Virginia	0	0	1	1	0	0	0	0	0	0	0	0
Washington	-	-	-	-	-	-	-	-	-	-	-	-
West Virginia	1	1	1	2	1	1	1	1	1	0	0	0
Wyoming	964	997	1,083	1,144	1,366	1,563	1,670	1,590	1,468	1,406	1,238	1,125
Total	**7,081**	**6,688**	**6,383**	**5,681**	**5,841**	**5,804**	**5,646**	**5,337**	**4,843**	**4,514**	**4,076**	**3,792**

Note: Totals may not equal sum of components because of independent rounding.

Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Table 10. Sales of natural gas plant liquids production from federal and Indian lands by state/area, FY 2003-14

million barrels

State	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Alabama	0	0	0	0	1	1	1	1	1	1	1	1
Alaska	0	0	0	0	0	0	0	0	-	-	-	0
Arizona	-	-	-	-	-	-	0	0	0	0	-	-
Arkansas	-	-	-	-	-	-	-	-	-	-	-	-
California	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	1	1	1	1	1	3	5	8	9	11	6	7
Florida	-	-	-	-	-	-	-	-	-	-	-	-
Illinois	-	-	-	-	-	-	-	-	-	-	-	-
Indiana	-	-	-	-	-	-	-	-	-	-	-	-
Kansas	0	0	0	0	0	0	0	0	0	0	0	0
Kentucky	-	-	-	-	-	-	0	0	0	-	-	-
Louisiana	1	2	2	1	3	3	2	2	1	1	1	1
Michigan	0	0	0	0	0	0	0	0	0	0	0	0
Mississippi	0	0	-	-	-	-	-	-	-	0	0	-
Montana	0	0	0	0	0	0	0	0	0	0	0	0
Nebraska	-	-	-	-	-	0	-	-	-	-	-	-
Nevada	-	-	-	-	-	-	-	-	-	-	-	-
New Mexico	31	32	31	30	31	31	30	31	32	32	31	31
New York	-	-	-	-	-	-	-	-	-	-	-	-
North Dakota	0	0	0	0	0	0	0	0	0	1	1	2
Offshore Gulf	49	60	54	44	55	50	43	55	50	43	43	45
Offshore Pacific	0	0	0	0	0	0	0	0	0	0	0	0
Ohio	-	-	-	-	-	-	-	-	-	0	0	-
Oklahoma	0	0	0	0	0	0	0	0	0	1	1	0
Pennsylvania	-	-	-	-	-	-	-	-	-	0	0	0
South Dakota	-	-	-	-	-	-	-	-	-	-	-	-
Texas	0	0	0	0	0	0	0	0	0	0	0	0
Utah	1	1	1	1	1	2	4	5	6	8	7	8
Virginia	-	-	-	-	-	-	-	-	-	-	-	-
Washington	-	-	-	-	-	-	-	-	-	-	-	-
West Virginia	-	-	-	-	-	-	-	-	-	-	-	-
Wyoming	9	8	8	8	12	15	11	31	34	35	20	23
Total	**94**	**105**	**98**	**87**	**106**	**106**	**95**	**134**	**134**	**133**	**112**	**121**

Note: Totals may not equal sum of components because of independent rounding.
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Table 11. Sales of coal production from federal and Indian lands by state/area, FY 2003-14

million short tons

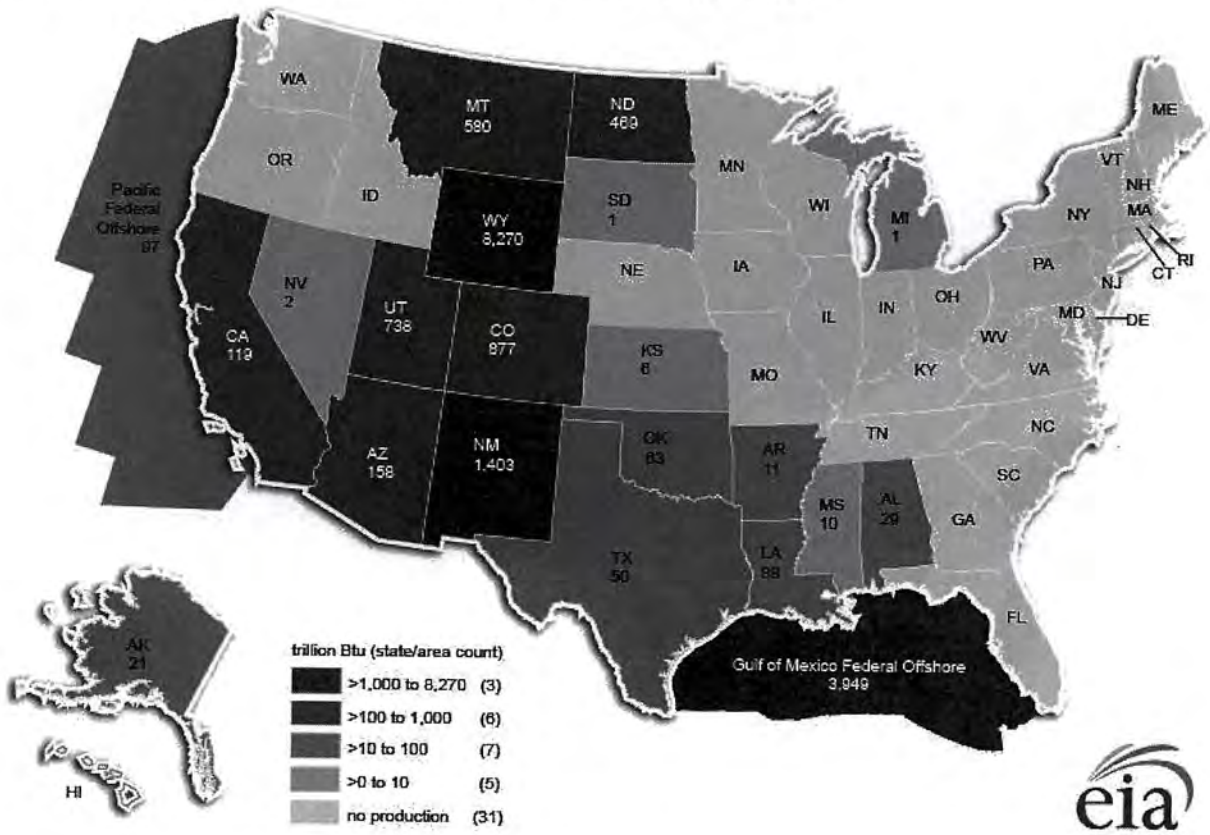
State	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Alabama	0	0	0	0	0	0	1	3	3	2	1	0
Alaska	0	0	0	0	0	0	0	0	0	0	0	0
Arizona	13	13	14	9	9	8	8	8	8	8	8	8
Arkansas	0	0	0	0	0	0	0	0	0	0	0	0
California	0	0	0	0	0	0	0	0	0	0	0	0
Colorado	22	22	25	22	22	23	18	19	19	19	17	17
Florida	0	0	0	0	0	0	0	0	0	0	0	0
Illinois	0	0	0	0	0	0	0	0	0	0	0	0
Indiana	0	0	0	0	0	0	0	0	0	0	0	0
Kansas	0	0	0	0	0	0	0	0	0	0	0	0
Kentucky	0	0	0	0	1	0	0	0	0	0	0	0
Louisiana	0	0	0	0	0	0	0	0	0	0	0	0
Michigan	0	0	0	0	0	0	0	0	0	0	0	0
Mississippi	0	0	0	0	0	0	0	0	0	0	0	0
Montana	28	31	33	30	33	33	30	30	28	27	24	27
Nebraska	0	0	0	0	0	0	0	0	0	0	0	0
Nevada	0	0	0	0	0	0	0	0	0	0	0	0
New Mexico	24	21	20	19	17	15	15	11	12	12	14	12
New York	0	0	0	0	0	0	0	0	0	0	0	0
North Dakota	1	2	2	3	3	4	1	0	2	4	4	5
Offshore Gulf	0	0	0	0	0	0	0	0	0	0	0	0
Offshore Pacific	0	0	0	0	0	0	0	0	0	0	0	0
Ohio	0	0	0	0	0	0	0	0	0	0	0	0
Oklahoma	1	1	1	1	1	1	1	1	1	0	1	1
Pennsylvania	0	0	0	0	0	0	0	0	0	0	0	0
South Dakota	0	0	0	0	0	0	0	0	0	0	0	0
Texas	0	0	0	0	0	0	0	0	0	0	0	0
Utah	19	21	20	18	14	14	10	11	7	13	14	14
Virginia	0	0	0	0	0	0	0	0	0	0	0	0
Washington	0	0	0	0	0	0	0	0	0	0	0	0
West Virginia	0	0	0	0	0	0	0	0	0	0	0	0
Wyoming	359	372	367	356	371	411	404	396	389	374	337	337
Total	**466**	**484**	**482**	**458**	**471**	**509**	**488**	**478**	**470**	**461**	**420**	**421**

Note: Totals may not equal sum of components because of independent rounding.
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Map Appendix

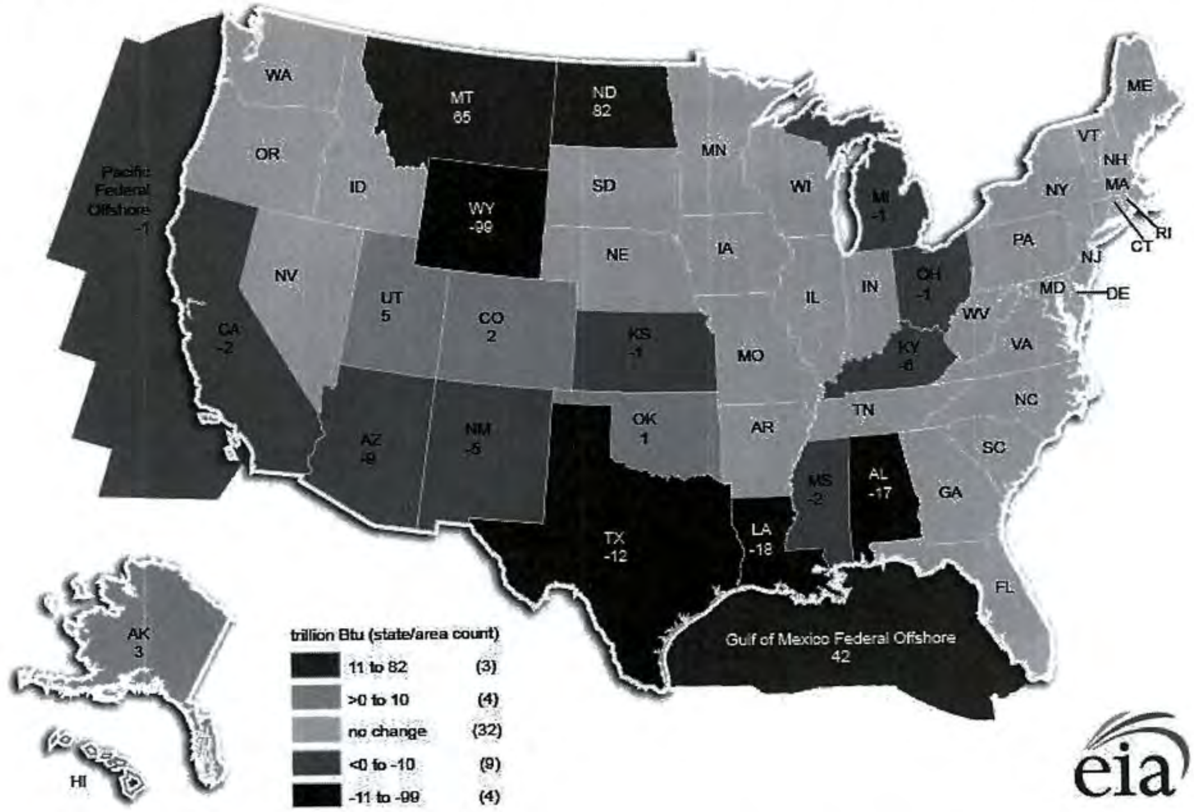
State/area maps

Figure A1. Fossil fuel production on federal and Indian lands, FY 2014



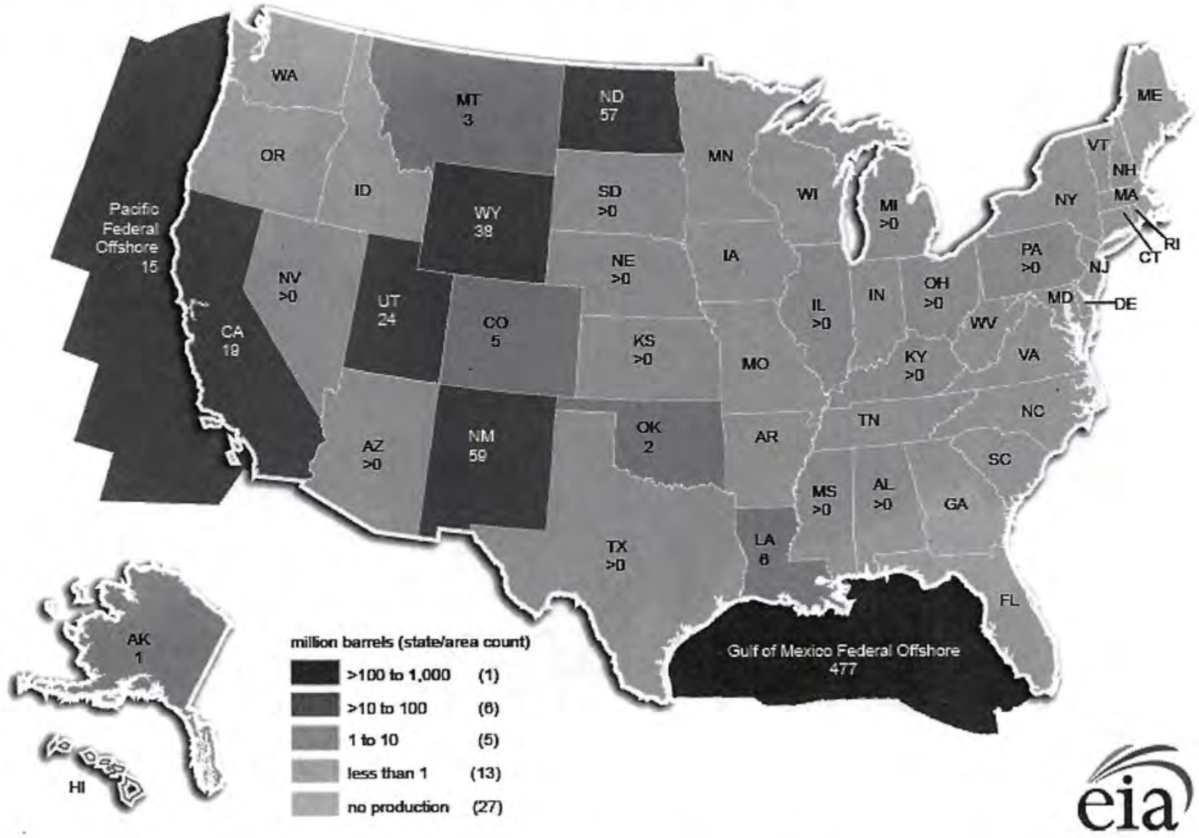
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A2. Changes in fossil fuels production (trillion Btu) on federal and Indian lands, FY 2013-14



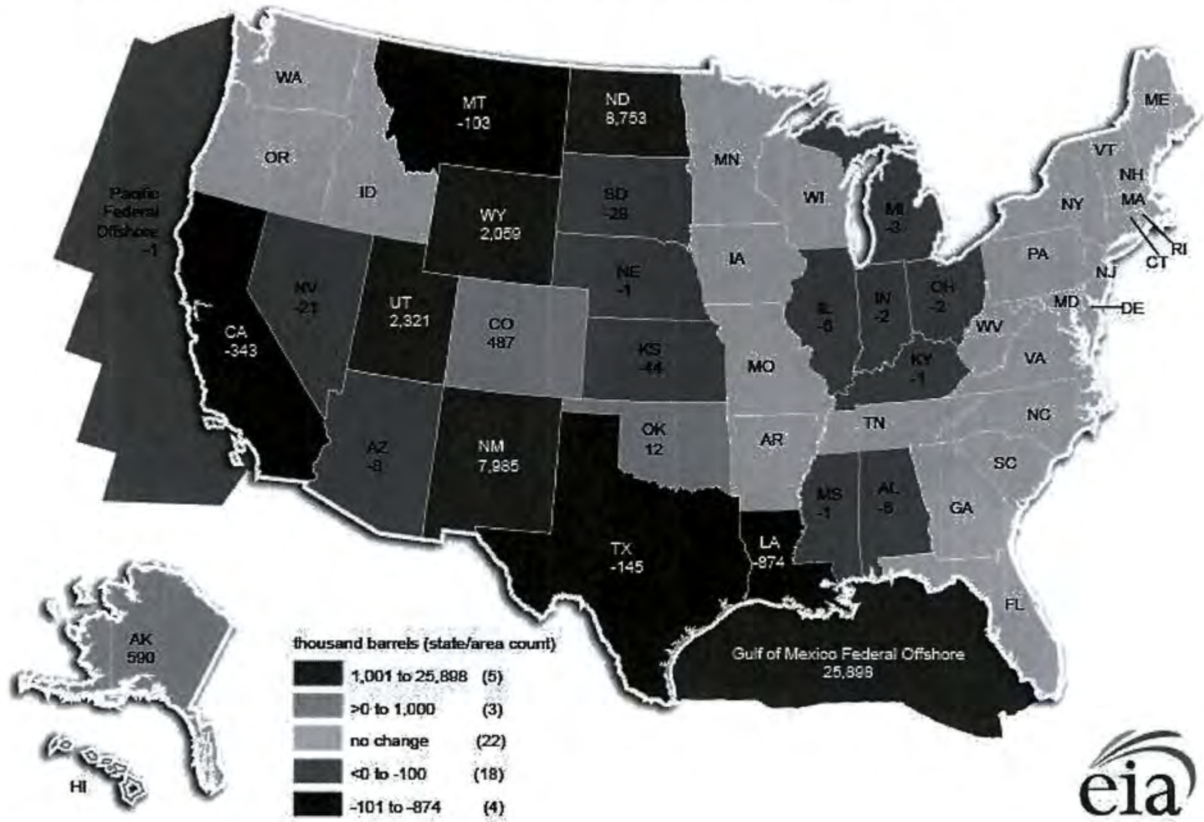
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A3. Crude oil production on federal and Indian lands, FY 2014



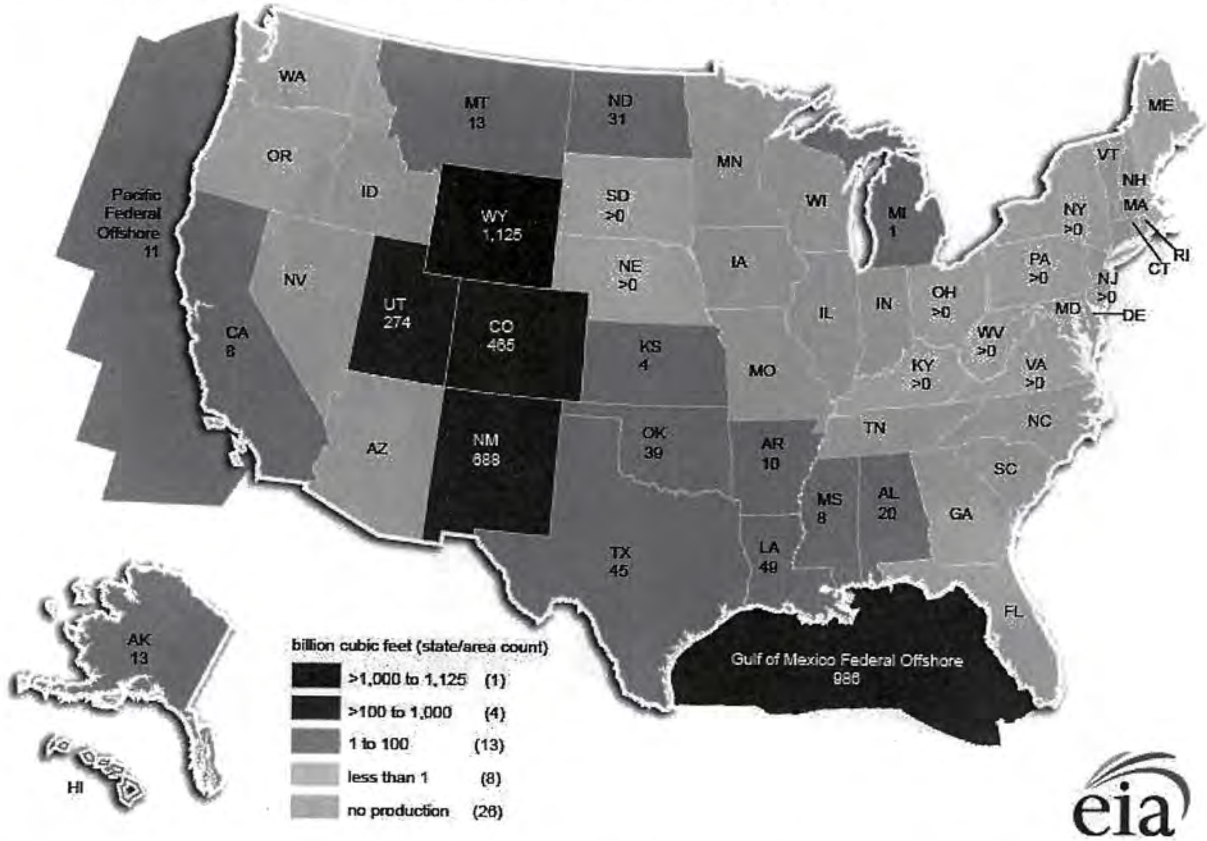
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A4. Changes in crude oil production on federal and Indian lands, FY 2013-14



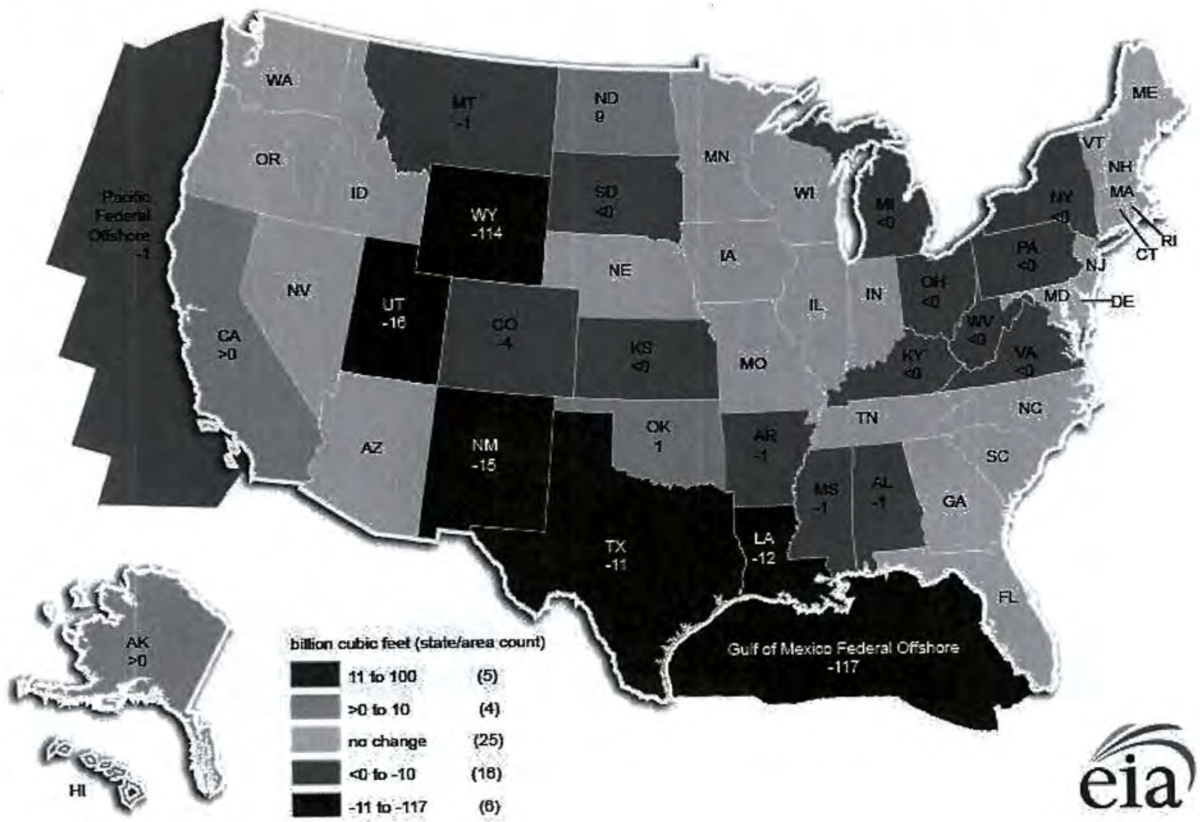
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A5. Natural gas production on federal and Indian lands, FY 2014



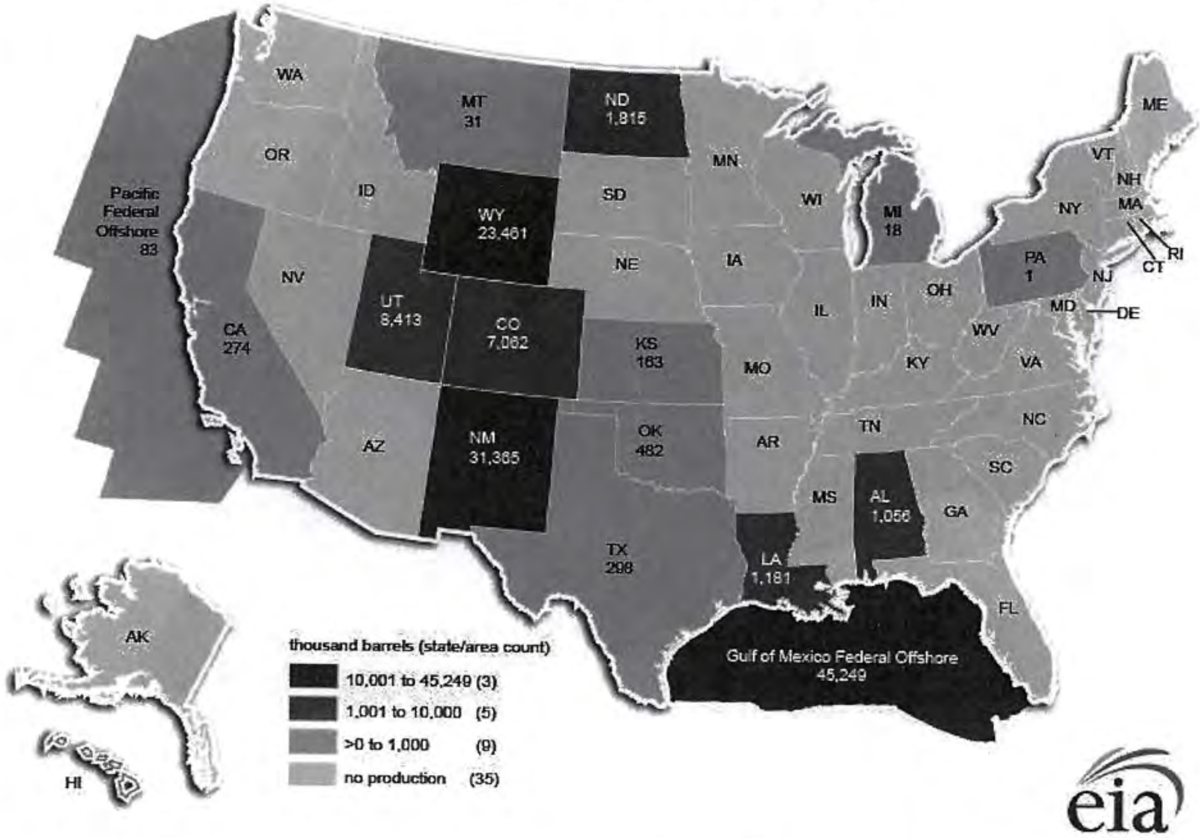
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A6. Changes in natural gas production on federal and Indian lands, FY 2013-14



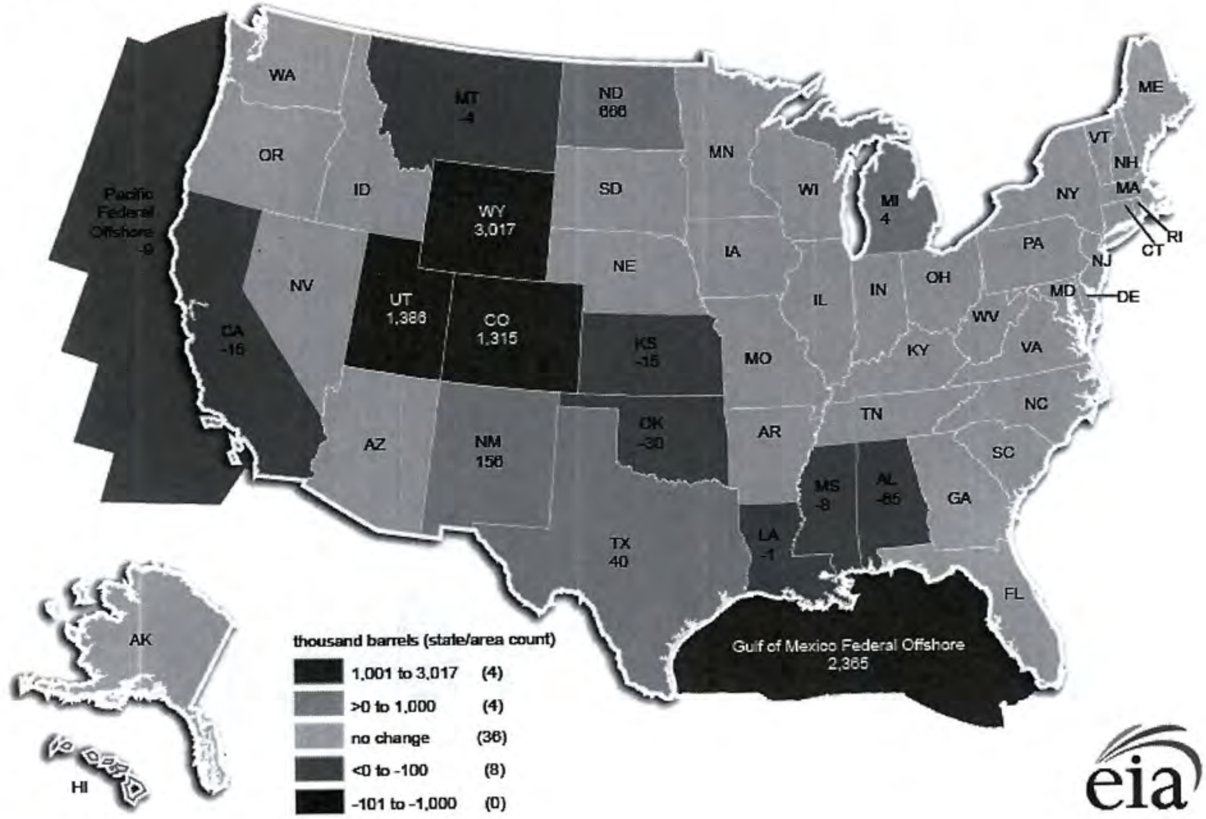
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A7. Natural gas liquids production on federal and Indian lands, FY 2014



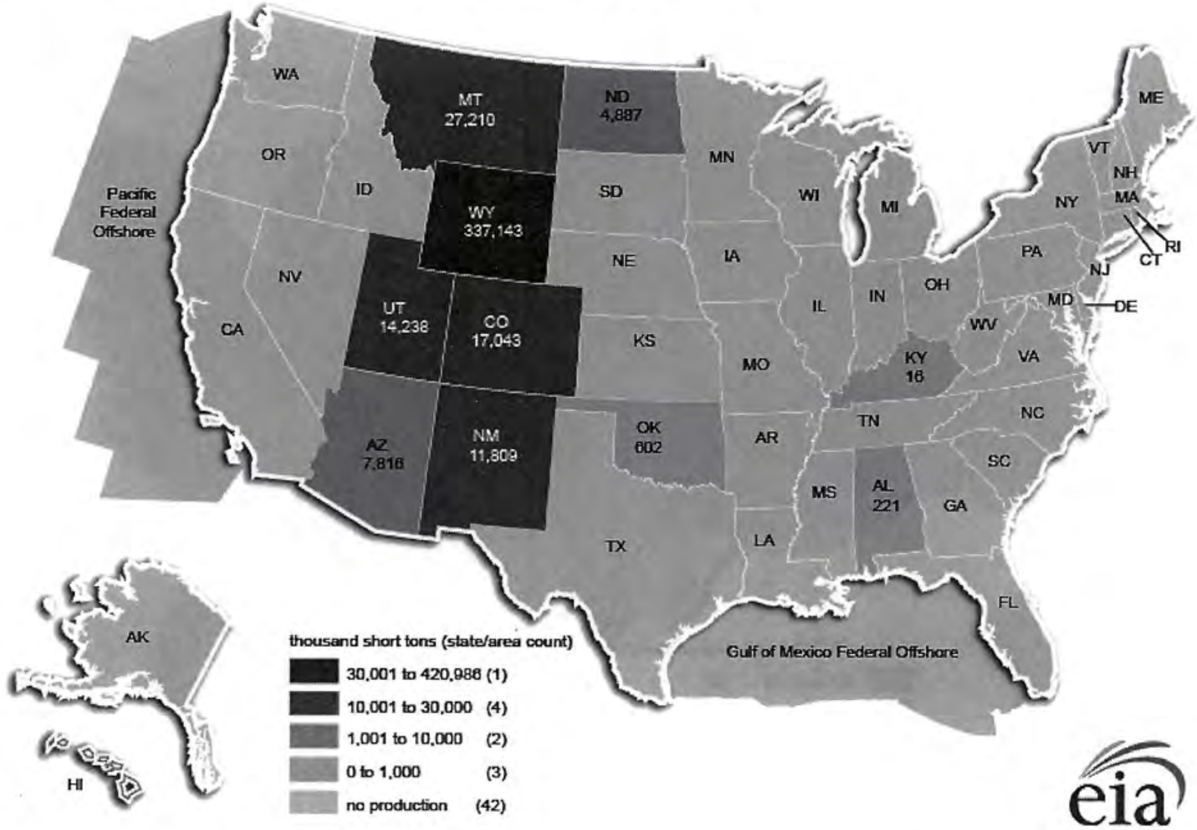
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A8. Changes in natural gas liquids production on federal and Indian lands, FY 2013-14



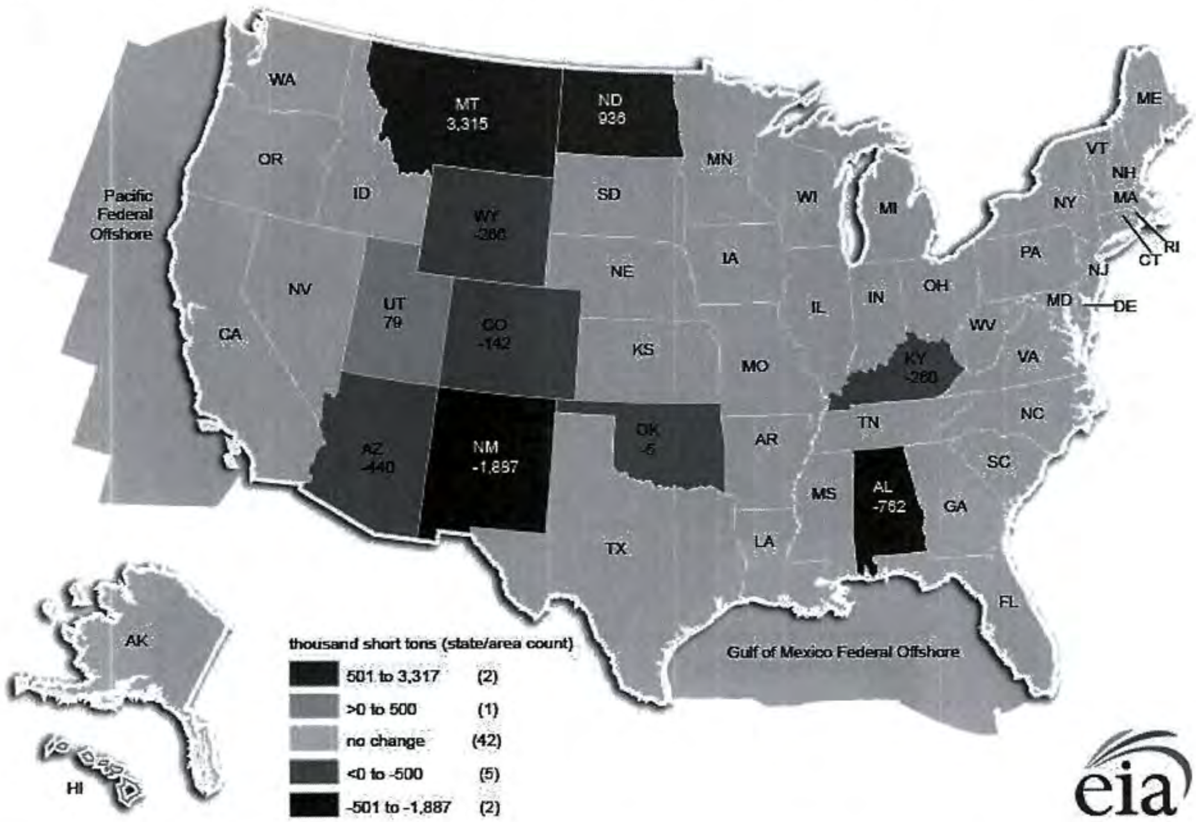
Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A9. Coal production on federal and Indian lands, FY 2014



Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Figure A10. Changes in coal production on federal and Indian lands by state, FY 2013-14



Source: U.S. Energy Information Administration based on U.S. Department of the Interior, Office of Natural Resources Revenue. "ONNR Statistical Information Site" (http://statistics.onrr.gov).

Exhibit 29

UNEP

The Emissions Gap Report 2015

A UNEP Synthesis Report

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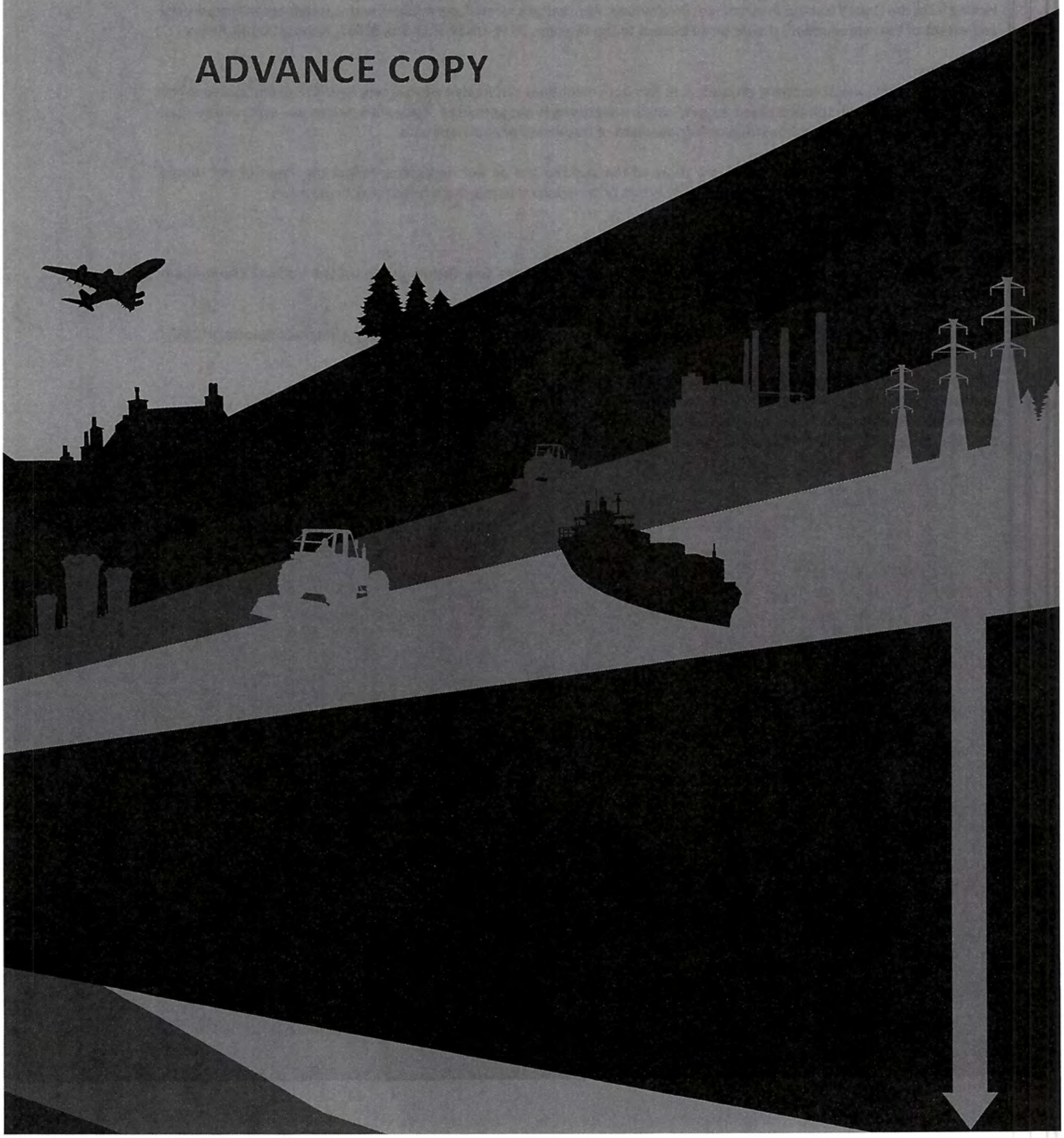

Published by the United Nations Environment Programme (UNEP), November 2015

ISBN: 978-92-807-3491-1
Job Number: DEW/1896/NA

Citation This document may be cited as: UNEP (2015). The Emissions Gap Report 2015. United Nations Environment Programme (UNEP), Nairobi

A digital copy of this report along with supporting appendices are available at http://www.unep.org/emissionsgapreport2015/

This project is part of the International Climate Initiative. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safely supports this initiative on the basis of a decision adopted by the German Bundestag.

Supported by:

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Based on a decision of the Parliament of the Federal Republic of Germany

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The Emissions Gap Report 2015

A UNEP Synthesis Report

November 2015

Acknowledgements

The United Nations Environment Programme (UNEP) would like to thank the members of the steering committee, the lead and contributing authors, reviewers and the secretariat for their contribution to the preparation of this assessment report.

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Thanks also to

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Contents

Glossary

This glossary is compiled according to the Lead Authors of the report drawing on glossaries and other resources available on the websites of the following organizations, networks and projects: Center for International Forestry Research, Food and Agriculture Organization of the United Nations, Intergovernmental Panel on Climate Change, Non-State Actor Zone for Climate Action, United Nations Environment Programme, United Nations Framework Convention on Climate Change and World Resources Institute.

Adaptation: The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects.

Additionality: A criterion sometimes applied to projects aimed at reducing GHG emissions. It stipulates that the emission reductions accomplished by the project must not have happened anyway had the project not taken place.

Afforestation: Planting of new forests on lands that historically have not contained forests.

Agriculture, forestry and other land use: AFOLU plays a central role for food security and sustainable development. The main mitigation options within AFOLU involve one or more of three strategies: prevention of emissions to the atmosphere by conserving existing carbon pools in soils or vegetation or by reducing emissions of methane and nitrous oxide; sequestration—increasing the size of existing carbon pools and thereby extracting carbon dioxide (CO_2) from the atmosphere; and substitution—substituting biological products for fossil fuels or energy-intensive products, thereby reducing CO_2 emissions. Demand-side measures (for example, reducing losses and wastes of food, changes in human diet, or changes in wood consumption) may also play a role. FOLU (Forestry and Other Land Use)—also referred to as LULUCF (Land Use, Land-Use Change, and Forestry)—is the subset of AFOLU emissions and removals of GHGs resulting from direct human-induced land use, land-use change, and forestry activities excluding agricultural emissions.

Annex I Parties: The industrialized countries listed in Annex I to the Convention, which committed to returning their GHG emissions to 1990 levels by the year 2000 as per Article 4.2(a) and (b). They have also accepted emission targets for the period 2008-12 as per Article 3 and Annex B of the Kyoto Protocol. They include the 24 original OECD members, the European Union, and 14 countries with economies in transition (Croatia, Liechtenstein, Monaco and Slovenia joined Annex I at COP 3, and the Czech Republic and Slovakia replaced Czechoslovakia). *See also Non-Annex I Parties.*

Annex II Parties: The countries listed in Annex II to the Convention which have a special obligation to provide financial resources and facilitate technology transfer to developing countries. Annex II Parties include the 24 original OECD members plus the European Union.

Baseline/reference: The state against which change is measured. In the context of transformation pathways, the term 'baseline scenarios' refers to scenarios that are based on the assumption that no mitigation policies or measures will be implemented beyond those that are already in force and/or are legislated or planned to be adopted. Baseline scenarios are not intended to be predictions of the future, but rather counterfactual constructions that can serve to highlight the level of emissions that would occur without further policy effort. Typically, baseline scenarios are then compared to mitigation scenarios that are constructed to meet different goals for GHG emissions, atmospheric concentrations or temperature change. The term 'baseline scenario' is used interchangeably with 'reference scenario' and 'no policy scenario'. In much of the literature the term is also synonymous with the term 'business-as-usual (BAU) scenario', although the term 'BAU' has fallen out of favour because the idea of 'business-as-usual' in century-long socioeconomic projections is hard to fathom.

Biomass: The total mass of living organisms in a given area or volume, including products, by-products, and waste of biological origin (plants or animal matter) and excluding material embedded in geological formations and transformed to fossil fuels or peat.

Biomass plus carbon capture and storage (BioCCS or BECCS): Use of energy produced from biomass where the combustion gases are then captured and stored underground or used, for example, in industrial processes. It excludes gases generated through, for example, a fermentation process (as opposed to combustion).

Black carbon: The substance formed through the incomplete combustion of fossil fuels, biofuels, and biomass, which is emitted in both anthropogenic and naturally occurring soot. It consists of pure carbon in several linked forms. Black carbon warms the Earth by absorbing heat in the atmosphere and by reducing albedo – the ability to reflect sunlight – when deposited on snow and ice.

Bottom-up model: In the context of this assessment, a model that represents a system by looking at its detailed underlying parts. Compared to so-called top-down models, which focus on economic interlinkages, bottom-up models of energy use and emissions can provide greater resolution with regards to sectors or mitigation technologies.

Business-as-usual: A scenario that describes future GHG emission levels in the absence of additional mitigation efforts and policies (with respect to an agreed set). In the 2014 EGR (page 5, para 2), BAU scenarios were based on an extrapolation of current economic, social and technological trends. They only took into account climate policies implemented up to around 2005-10 (that is, more recent country pledges and policies were not considered) and therefore served as a reference point for what would happen to emissions if planned climate mitigation policies were not implemented. See *Baseline/reference.*

Bunker fuels: A term used to refer to fuels consumed for international marine and air transport.

Cancun pledge: During 2010, many countries submitted their existing plans for controlling GHG emissions to the Climate Change Secretariat and these proposals were formally acknowledged under the UNFCCC. Developed countries presented their plans in the shape of economy-wide targets to reduce emissions, mainly up to 2020, while developing countries proposed ways to limit their growth of emissions in the shape of plans of action.

Carbon credits: An entitlement allocated by a government to a legal entity (company or other type of emitter) to emit a specified amount of a substance. These entitlements, which may be transferrable and tradable, can be used to reduce emissions of GHGs (by giving them a monetary value) or can be used for accounting of emissions.

Carbon dioxide emission budget: For a given temperature rise limit, for example a 1.5°C or 2°C long-term limit, the corresponding carbon budget reflects the total amount of carbon emissions that can be emitted to stay within that limit. Stated differently, a carbon budget is the area under a GHG emission trajectory that satisfies assumptions about limits on cumulative emissions estimated to avoid a certain level of global mean surface temperature rise.

Carbon dioxide equivalent: A way to place emissions of various radiative forcing agents on a common footing by accounting for their effect on climate. It describes, for a given mixture and amount of GHGs, the amount of carbon dioxide that would have the same global warming ability, when measured over a specified time period. For the purpose of this report, GHG emissions (unless otherwise specified) are the sum of the basket of GHG listed in Annex A to the Kyoto Protocol, expressed as carbon dioxide equivalents assuming a 100-year global warming potential.

Carbon intensity: The amount of emissions of carbon dioxide released per unit of another variable such as gross domestic product (GDP), output energy use or transport.

Carbon market: A popular (but misleading) term for a trading system through which countries may buy or sell units of GHG emissions in an effort to meet their national limits on emissions, either under the Kyoto Protocol or under other agreements, such as that among member states of the European Union. The term comes from the fact that CO_2 is the predominant GHG, and other gases are measured in units called 'CO_2 equivalents'.

Carbon offset: *See Offset.*

Carbon price: The price for avoided or released CO_2 or CO_2-equivalent emissions. This may refer to the rate of a carbon tax or the price of emission permits. In many models that are used to assess the economic costs of mitigation, carbon prices are used as a proxy to represent the level of effort in mitigation policies.

Carbon sequestration: The process of removing carbon from the atmosphere and depositing it in a reservoir.

Carbon sink: A pool (reservoir) that removes carbon from the active part of the carbon cycle.

Carbon stock: The quantity of carbon contained in a carbon pool.

Carbon tax: A levy on the carbon content of fossil fuels. Because virtually all of the carbon in fossil fuels is ultimately emitted as carbon dioxide, a carbon tax is equivalent to an emission tax on CO_2 emissions.

Co-benefits: The positive effects that a policy or measure aimed at one objective might have on other objectives, without yet evaluating the net effect on overall social welfare. Co-benefits are often subject to uncertainty and depend on, among others, local circumstances and implementation practices. Co-benefits are often referred to as ancillary benefits.

Conditional INDCs: INDCs proposed by some countries that are contingent on a range of possible conditions, such as the ability of national legislatures to enact the necessary laws, ambitious action from other countries, realization of finance and technical support, or other factors.

Conference of the Parties (COP): The supreme body of the Convention. It currently meets once a year to review the Convention's progress.

Current policy trajectory: This trajectory is based on estimates of 2020 emissions considering projected economic trends and current policy approaches including policies at least through 2012. Estimates may be based on either official data or independent analysis.

Decarbonization: The process by which countries or other entities aim to achieve a low-carbon economy, or by which individuals aim to reduce their carbon consumption.

Deforestation: The direct human-induced conversion of forested land to non-forested land (Marrakesh Accords). The conversion of forest to another land use or the long-term reduction of the tree canopy cover below the minimum 10 per cent threshold.

Degradation (forest): Changes within the forest that negatively affect the structure or function of the forest stand or site, and thereby lower its capacity to supply products and services.

Delayed-action scenarios: *See Later-action scenarios.*

Double counting: In the context of this assessment, double counting refers to a situation in which the same emission reductions are counted towards meeting two countries' pledges.

Emissions gap: The difference between the GHG emission levels consistent with having a likely chance (>66 per cent) of limiting the mean global temperature rise to below 2°C or 1.5°C in 2100 above pre-industrial levels and the GHG emission levels consistent with the global effect of the INDCs, assuming full implementation from 2020.

Emission pathway: The trajectory of annual GHG emissions over time.

Forest: Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than 10 per cent, or trees able to reach these thresholds *in situ*. It does not include land that is predominantly under agricultural or urban land use.

Forest landscape restoration: A process which aims to regain ecological integrity and enhance human wellbeing in deforested or degraded forest landscapes to meet present and future needs and accommodate multiple uses over time.

Global warming potential: An index representing the combined effect of the differing times GHGs remain in the atmosphere and their relative effectiveness in absorbing outgoing infrared radiation.

Greenhouse gases (GHGs): The atmospheric gases responsible for causing global warming and climatic change. The major GHGs are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Less prevalent, but very powerful, GHGs are hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6).

Grid parity: This occurs when an alternative energy source can generate power at a levelized cost of electricity (LCOE) that is less than or equal to the price of purchasing power from the electricity grid.

Gross domestic product (GDP): The sum of gross value added, at purchasers' prices, by all resident and non-resident producers in the economy, plus any taxes and minus any subsidies not included in the value of products in a country or geographic region for a given period, normally one year. GDP is calculated without deducting for depreciation of fabricated assets or depletion and degradation of natural resources.

'Hot air': Refers to the concern that some governments will be able to meet their targets for GHG emissions under any formal agreement with minimal effort and could then flood the market with emission credits, reducing the incentive for other countries to cut their own domestic emissions.

Integrated assessment models: Models that seek to combine knowledge from multiple disciplines in the form of equations and/or algorithms in order to explore complex environmental problems. As such, they describe the full chain of climate change, from production of GHGs to atmospheric responses. This necessarily includes relevant links and feedbacks between socio-economic and biophysical processes.

Intended nationally determined contribution (INDC): Submissions by Parties which identify actions each national government intends to take under the future UNFCCC climate agreement, due to be negotiated in Paris in December 2015. INDCs are, in effect, the basis of post-2020 global emission reduction commitments that will be included in the future climate agreement.

International cooperative initiatives (ICIs): Initiatives outside the United Nations Framework Convention on Climate Change aimed at reducing emissions of climate forcers by, for example, promoting actions that are less GHG intensive, compared to prevailing alternatives. Cooperative initiatives also involve national and sub-national partners (they are often referred to as, simply, 'cooperative initiatives').

Kyoto Protocol: An international agreement, standing on its own, and requiring separate ratification by governments, but linked to the UNFCCC. The Kyoto Protocol, among other things, sets binding targets for the reduction of GHG emissions by industrialized countries.

Land use, land-use change and forestry (LULUCF): A GHG inventory sector that covers emissions and removals of GHGs resulting from direct human-induced land use, land-use change and forestry activities.

Later-action scenarios: Climate change mitigation scenarios in which emission levels in the near term, typically up to 2020 or 2030, are higher than those in the corresponding least-cost scenarios.

Leakage: That portion of cuts in GHG emissions by developed countries – countries trying to meet mandatory limits under the Kyoto Protocol – that may reappear in other countries not bound by such limits. For example, multinational corporations may shift factories from developed to developing countries to escape restrictions on emissions.

Least-cost scenarios: Climate change mitigation scenarios assuming that emission reductions start immediately after the model base year, and are distributed optimally over time, sectors and regions, such that aggregate costs of reaching the climate target are minimized.

Likely chance: A likelihood greater than 66 per cent chance. Used in this assessment to convey the probabilities of meeting temperature limits.

Lock-in: Lock-in occurs when a market is stuck with a standard even though participants would be better off with an alternative.

Medium chance: A likelihood of 50–66 per cent chance. Used in this report to convey the probabilities of meeting temperature limits.

Mitigation: In the context of climate change, a human intervention to reduce the sources, or enhance the sinks of GHGs. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings and expanding forests and other 'sinks' to remove greater amounts of CO_2 from the atmosphere.

Monitoring, reporting and verification: A process/concept that potentially supports greater transparency in the climate change regime.

Montreal Protocol: The Montreal Protocol on Substances that Deplete the Ozone Layer is an international treaty that was designed to reduce the production and consumption of ozone-depleting substances in order to reduce their abundance in the atmosphere, and thereby protect the Earth's ozone layer.

Mosaic restoration: This integrates trees into mixed-use landscapes, such as agricultural lands and settlements, where trees can support people through improved water quality, increased soil fertility, and other ecosystem services. This type of restoration is more likely in deforested or degraded forest landscapes with moderate population density (10-100 people/km^2).

Net negative emissions: A situation of net negative emissions is achieved when, as a result of human activities, more GHGs are sequestered or stored than are released into the atmosphere.

No-policy scenario: *See Baseline/reference.*

Non-Annex I Parties: The countries that have ratified or acceded to the UNFCCC that are not included in Annex I of the Convention.

Non-state actor: In the context of climate action, 'non-state actor' includes companies, cities, subnational regions and investors. More broadly, non-state actors have been defined as entities that participate or act in international relations. They are organizations with sufficient power to influence and cause a change even though they do not belong to any state institution.

Offset (in climate policy): A unit of CO_2-equivalent emissions that is reduced, avoided, or sequestered to compensate for emissions occurring elsewhere.

Party: A state (or regional economic integration organization such as the EU) that agrees to be bound by a treaty and for which the treaty has entered into force.

Pledge case: This case identifies the maximum level of GHG emissions that each country or Party could emit in 2020 and still meet its pledge – without considering the use of offsets.

Readiness: REDD+ country actions – including capacity building, policy design, consultation and consensus building, and testing and evaluation of a REDD+ national strategy – that are taken prior to the comprehensive implementation of REDD+.

REDD+: Reducing emissions from deforestation and forest degradation in developing countries; and the role of conservation, sustainable management of forests and enhancement of forest carbon stocks in developing countries.

Reference scenario: *See Baseline/reference.*

Reforestation: Planting of forests on lands that have previously contained forests but that have been converted to some other use.

Rehabilitation (forest): Restoration of the capacity of degraded forest land to deliver forest products and services. Forest rehabilitation re-establishes the original productivity of the forest and some, but not necessarily all, of the plant and animal species thought to be originally present at a site.

Restoration forest: Restoration of a degraded forest to its original state – that is, to re-establish the presumed structure, productivity and species diversity of the forest originally present at a site.

Results-based payments: Payments for fully measured, reported and verified emission reductions (or removals), also conditional upon the country having a national strategy/action plan for REDD+, a national forest monitoring system, national forest reference emission level and/or forest reference level, a safeguard information system and a summary of information on how safeguards have been addressed and respected.

Scenario: A description of how the future may unfold based on 'if-then' propositions. Scenarios typically include an initial socio-economic situation and a description of the key driving forces and future changes in emissions, temperature or other climate change-related variables.

Sink: Any process, activity or mechanism which removes a GHG, an aerosol or a precursor of a GHG from the atmosphere. Forests and other vegetation are considered sinks because they remove CO_2 through photosynthesis.

Source: Any process, activity or mechanism that releases a GHG, an aerosol or a precursor of a GHG or aerosol into the atmosphere.

Sustainable development: Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

Technology transfer: A broad set of processes covering the flows of know-how, experience and equipment for mitigating and adapting to climate change among different stakeholders.

Temperature overshoot: An emission pathway that temporarily exceeds target temperature limits (2°C or 1.5°C) before falling below the limits again by 2100 with a given percentage chance.

Tipping point: A level of change in system properties beyond which a system reorganizes, often abruptly, and does not return to the initial state even if the drivers of the change are abated. For the climate system, it refers to a critical threshold when global or regional climate changes from one stable state to another stable state. The tipping point event may be irreversible.

Top-down model: A model that applies macroeconomic theory, econometric and/or optimization techniques to aggregate economic variables. Using historical data on consumption, prices, incomes, and factor costs, top-down models assess demand and emissions for goods and services from main sectors, such as energy conversion, transportation, buildings, agriculture and industry.

Transient climate response: Measure of the temperature rise that occurs at the time of a doubling of carbon dioxide concentration in the atmosphere.

Transient climate response to cumulative carbon emissions: Measure of temperature rise per unit of cumulative carbon emissions.

Uncertainty: A cognitive state of incomplete knowledge that can result from a lack of information or from disagreement about what is known or even knowable. It may have many types of sources, from imprecision in the data to ambiguously defined concepts or terminology, or uncertain projections of human behaviour. Uncertainty can therefore be represented by quantitative measures (for example a probability density function) or by qualitative statements (for example reflecting the judgement of a team of experts).

Unconditional INDCs: INDCs proposed by countries without conditions attached.

Wide-scale restoration: Aims to restore closed forests to the landscape. This type of restoration is more likely in deforested or degraded landscapes with low population density (<10 people/km^2) that are also areas where closed forests formerly dominated the landscape.

2020 pledge: *See Cancun pledge.*

20th–80th percentile range: Results that fall within the 20–80 per cent range of the frequency distribution of results in this assessment.

Acronyms

AFOLU	agriculture, forestry and other land use
AR5	fifth Assessment Report of the Intergovernmental Panel on Climate Change
BAU	business as usual
BC	black carbon
BECCS	biomass plus carbon capture and storage (or BioCCS)
BELC	Business Environmental Leadership Council
BRT	Bus Rapid Transit
CAIT	Climate Analysis Indicators Tool
CAT	Climate Action Tracker
CBD	Convention on Biological Diversity
cCR	carbon*n* Climate Registry
CCS	carbon capture and storage
CDKN	Climate and Development Knowledge Network
CDM	Clean Development Mechanism
CDP	Carbon Disclosure Project (now 'CDP')
CER	certified emission reduction
CFC	chlorofluorocarbon
CH_4	methane
CISL	Cambridge Institute for Sustainability Leadership
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CoM	Covenant of Mayors
COP	Conference of the Parties to the UNFCCC
CRF	common reporting format (of the UNFCCC)
C-ROADS	Climate Rapid Overview and Decision Support
CSI	Cement Sustainability Initiative
CSP	concentrating solar power
DEA	Danish Energy Agency
EDGAR	Emissions Database for Global Atmospheric Research
EEA	European Environment Agency
EHCC	Earth Hour City Challenge
ERI	Energy Research Institute
ER-PIN	Emission Reductions Program Idea Note (in FCPF)
ERU	emission reduction unit
EU-ETS	European Union Emissions Trading System
FAO	Food and Agriculture Organization of the United Nations
FCPF	Forest Carbon Partnership Facility
FF&I	fossil fuels and industry
FIA	Federation Internationale de l'Automobile
FLR	forest landscape restoration
FS-UNEP	Frankfurt School - UNEP Collaborating Centre for Climate and Sustainable Energy Finance
GDP	gross domestic product
GEA	Global Energy Assessment
GFEI	Global Fuel Economy Initiative
GHG	greenhouse gas
GLOBIOM	global biosphere management model
GPC	Global Protocol for Community-scale GHG Emissions
Gt	gigatonne
GWP	global warming potential
G4M	global forest model
HFC	hydrofluorocarbon
IAM	integrated assessment model
ICAO	International Civil Aviation Organization
ICI	international cooperative initiative
ICLEI	International Council for Local Environmental Initiatives
ICRAF	World Agroforestry Centre (formerly International Centre for Research in Agroforestry)
IDDRI	Institut du Developpement Durables et des Relations Internationales
IEA	International Energy Agency
IIASA	International Institute for Applied Systems Analysis
IIMA	Indian Institute of Management, Ahmedabad
IMO	International Maritime Organization
INDC	Intended Nationally Determined Contribution

INPE	National Institute for Space Research
IPCC	Intergovernmental Panel on Climate Change
IPPU	industrial processes and product use (IPCC sector)
IRENA	International Renewable Energy Agency
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre (European Commission)
LIMITS	**L**ow climate **IM**pact scenarios and the **I**mplications of required **T**ight emission control **S**trategies
LSE	London School of Economics and Political Science
LULUCF	land use, land-use change and forestry
MCPA	Mayors' Climate Protection Agreement (USA)
MRV	monitoring, reporting and verification
$MtCO_2e$	million metric tons of CO_2 equivalent
NAMA	Nationally Appropriate Mitigation Action
NAP	National Adaptation Plan
NAZCA	Non-State Actor Zone for Climate Action
NCSC	National Center for Climate Strategy and International Cooperation
NF_3	nitrogen trifluoride
NGO	non-governmental organization
NIES	National Institute for Environmental Studies
NYDF	New York Declaration on Forests
N_2O	nitrous oxide
OC	organic carbon
ODS	ozone-depleting substances
OECD	Organisation for Economic Cooperation and Development
OPIC	Overseas Private Investment Corporation
PAM	policies and measures
PFC	perfluorocarbon
PIK	Potsdam Institute for Climate Change Research
PRIMAP	**P**otsdam **R**eal-time **I**ntegrated **M**odel for probabilistic **A**ssessment of emission **P**aths
PV	photovoltaic
REALU	reducing emissions from all land uses
REDD+	Reduced Emissions from Deforestation and forest Degradation Plus in developing countries (includes sustainable management and enhancement of forest carbon stocks)
SBT	science-based targets
SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All
SEAP	Sustainable Energy Action Plan
SF_6	sulphur hexafluoride
SIDS	small island developing states
SLCF	short-lived climate forcers
SOC	soil organic carbon
TCR	transient climate response
UCL	University College London
UCLG	United Cities and Local Governments
ULCOS	ultra-low CO_2 steelmaking
UNCCD	United Nations Convention to Combat Desertification
UNEP	United Nations Environment Programme
UNEP-DTU	UNEP-Technical University of Denmark
UNEP-WCMC	UNEP-World Conservation Monitoring Centre
UNFCCC	United Nations Framework Convention on Climate Change
UNGA	United Nations General Assembly
UNORCID	United Nations Office for REDD+ Coordination in Indonesia
WBCSD	World Business Council for Sustainable Development
WHRC	Woods Hole Research Center
WMCCC	World Mayors Council on Climate Change
WRI	World Resources Institute
WWF	World Wildlife Fund

Foreword

Following the historic signing of the 2030 Agenda for Sustainable Development, this sixth edition of the UNEP Emissions Gap Report comes as world leaders start gathering in Paris to establish a new agreement on climate change.

The report offers an independent assessment of the mitigation contributions from the Intended Nationally Determined Contributions (INDC) committed to by 1 October 2015, by the 146 countries that account for around 90 per cent of global emissions. It compares the 2030 emission levels that would result from these commitments with what science tells us would keep average temperature increases on track to stay below 2°C by the end of the century; it provides data for an aspirational target of keeping that increase below 1.5°C; and it evaluates the INDCs in relation to progress on the 2020 pledges made in Cancun.

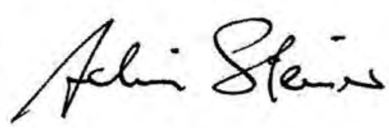
The INDCs demonstrate a significant increase in ambition and their successful delivery could reduce emissions by around 25 per cent compared to the level expected from current policies and pledges. However, this would still put long-term temperatures on track for an increase and lead to serious climate impact, so more action is required.

Therefore, the Emissions Gap Report also explores how available financial, technical and capacity building solutions can be scaled up, or even accelerated, to close the gap between the expected and required levels of emissions. This includes detailed assessments that look beyond the INDCs to identify the further gains being identified by the International Cooperative Initiatives and by Reducing Emissions from Deforestation and Forest Degradation (REDD+).

With many new emission reduction initiatives also generating substantial economic, social and environmental benefits, the INDC preparation process in most countries encouraged greater exploration of the links between development and climate. This is an important first step in a possible transition towards more low carbon economies.

The Emissions Gap Report makes it very clear that while reaching a meaningful global agreement in Paris is essential, it is not the end of the climate change story: it is a stepping stone on a much longer journey that requires us to stay alert to the science and remain dynamic in our response. The world has already tripled the expected performance on scaling up clean energy and been able to start reversing damage to the ozone layer.

I firmly believe that if we act on the findings of this report, there is nothing to stop us closing the emissions gap and creating a more inclusive and sustainable future for both the developed and the developing world.



Achim Steiner
UN Under-Secretary-General,
UNEP Executive Director

Executive Summary

The year 2015 has the potential to become a turning point in global efforts to transform the prevailing social and economic development paradigm into a more sustainable one.

The global community reached agreement in September 2015 on a set of 17 sustainable development goals to be achieved by 2030, including climate change. Countries will meet again at the United Nations Framework Convention on Climate Change (UNFCCC) 21st Conference of the Parties (COP 21) in Paris with the aim of establishing a new global agreement on climate change, hereafter the 'Paris Agreement', with the ambition of limiting changes in global temperatures to below 2°C or 1.5°C warming in 2100 compared to pre-industrial levels. The Paris Agreement will also aim to establish a framework to provide technological and financial support for developing countries to accelerate the transition towards low carbon and climate resilient development paths.

The architecture of a new climate agreement has many facets with an array of issues under negotiation that have become significantly more complex since the Framework Convention on Climate Change entered into force in 1994. The core structure of the Paris Agreement will comprise the "Intended Nationally Determined Contributions" (INDCs) as well as the process by which implementation of the agreement will proceed over time to advance the objectives of the UNFCCC. In addition, a number of key decisions will be required covering issues like adaptation, finance, technology, and capacity building.

1. What is covered in the 2015 Emissions Gap Report?

This sixth UNEP Emissions Gap Report provides a scientific assessment of the mitigation contributions from the submitted INDCs. As in the previous reports, it then compares the resulting emission levels in 2030 with what science tells us is required to be on track towards the agreed target of a global average temperature increase below 2°C by 2100. The Report also provides data for the aspirational target of keeping the temperature increase below 1.5°C. In addition, the Report presents selected areas where enhanced action can be taken, accelerated and scaled up to close the emissions gap.

The 2015 Emissions Gap Report addresses the following key questions:

- What are the latest estimates of 2025 and 2030 total global emissions levels consistent with the goal of holding the global average temperature rise below 2°C or 1.5°C above pre-industrial levels by 2100?
- What is the progress on implementation of the Cancun pledges for the period to 2020?
- Will the combined INDC commitments for 2030 (if fully implemented) be sufficient to stay within the range consistent with the 2°C temperature goal?
- What are possible contributions in selected key areas, where action can be accelerated to enhance the ambition of national pledges both in the period before and after the expected entry into force in 2020 of the Paris Agreement? This year the detailed assessment is on possible mitigation contributions from International Cooperative Initiatives (ICIs) and enhanced forest-related mitigation activities with a focus on Reducing Emissions from Deforestation and Forest Degradation (REDD+).

By 1 October 2015, a total of 119 INDCs had been submitted to the UNFCCC. Fifteen INDCs included only mitigation, while most included both adaptation and mitigation components. The report only presents qualitative information about the adaptation component of the INDCs submitted.

The report has been prepared by an international team of leading scientists assessing all available information, including that reviewed by the IPCC in its fifth assessment report, as well as more recent scientific studies. The assessment production process has been transparent and participatory. The assessment methodology and preliminary findings were made available to governments and stakeholders concerned during relevant international fora as well as on the UNEP Live website. The governments of the countries with specific mention in the report have been invited to comment on the assessment findings.

2. What are current emissions and what emission levels in 2030 are consistent with the 2°C and the 1.5°C targets?

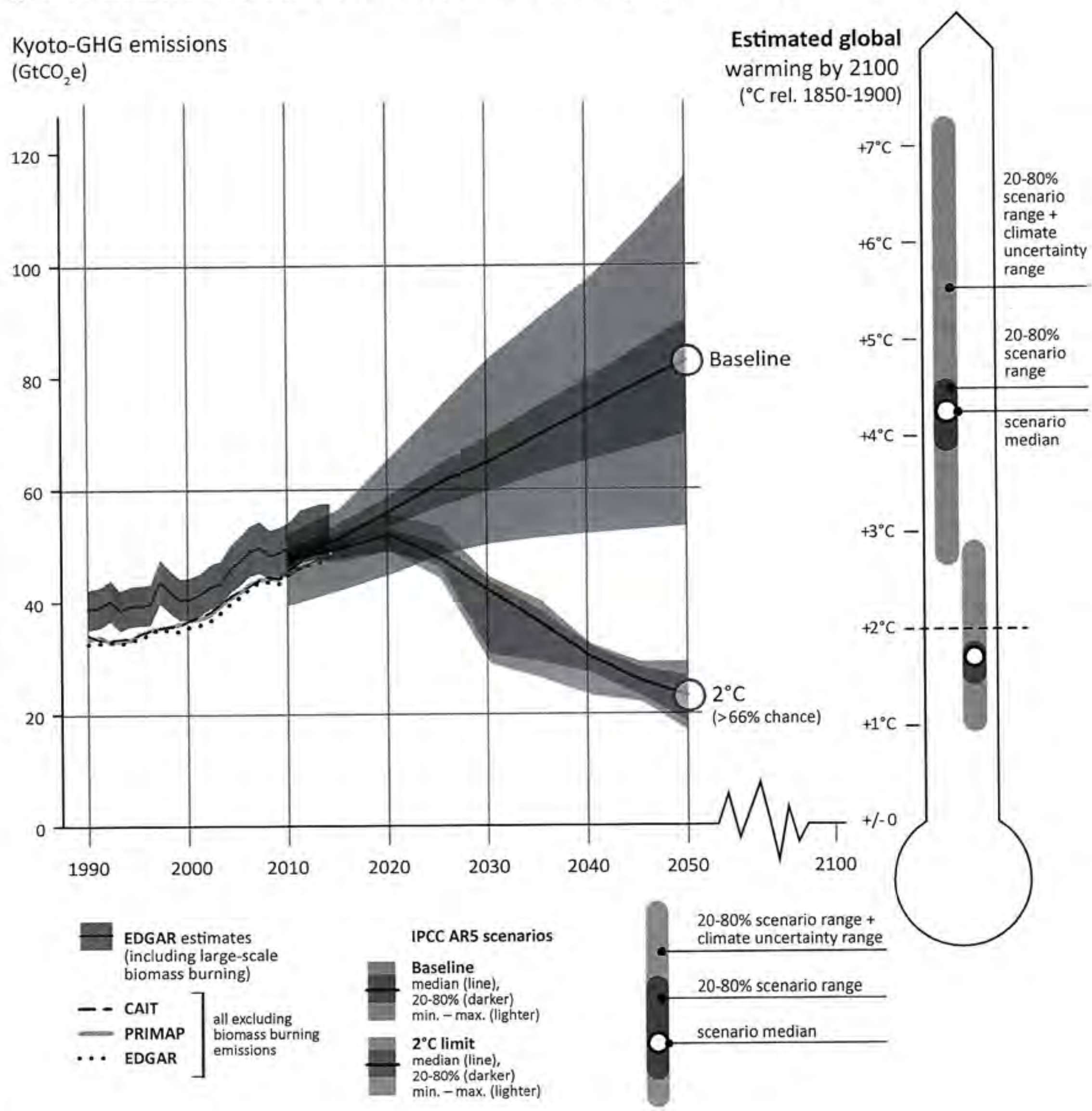
Over the past decades global GHG emissions have been increasing steadily, with small variations around a longer-term trend.

The most recent global emission estimates[1] are available for the year 2014. In that year, total global Kyoto-GHG emissions[2] amounted to about 52.7 $GtCO_2e$ (range: 47.9-57.5). Global carbon-dioxide (CO_2) emissions from fossil-fuel and industry were estimated at 35.5 $GtCO_2$ for 2014 (range: 32.5-38.5).

Staying below 2°C temperature rise implies that CO_2 emissions are reduced to net zero by 2060-2075.

The IPCC in its fifth assessment report concluded that to limit global warming to below 2°C, the remaining cumulative CO_2 emissions – the so-called carbon budget – are in the order of 1 000 $GtCO_2$. This remaining budget can be utilized in different ways, but given the most recent assessment of current trends, net global carbon emissions will eventually need to be reduced to zero between 2060 and 2075[3]. For a detailed discussion of the carbon budget, see the 2014 Emissions Gap Report.

Figure ES1: Historical greenhouse (GHG) emissions and projections until 2050



[1] Data for 2014 are available from EDGAR and PRIMAP, see Chapter 2.

[2] The six greenhouse gases covered by the UNFCCC/Kyoto Protocol — carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons and sulphur hexafluoride. Here aggregated with 100-year Global Warming Potentials (GWPs) of the IPCC Second Assessment Report.

[3] Based on the final released IPCC AR5 scenarios database data.

The 2015 Report presents an updated set of possible pathways to stay within this budget, and also includes an updated assessment of the pathways and requirements to stay within the more ambitious 1.5°C temperature goal.

The median emission level in 2030 in scenarios that have a >66 per cent chance of keeping temperature increase to below 2°C by the end of the century is 42 $GtCO_2e$ (range: 31-44). The similar level for a 1.5°C pathway is 39 $GtCO_2e$[4]. The trajectories for the two target levels are similar in many aspects, but earlier and much stronger action is necessary for the 1.5°C target to be kept.

As reflected in last year's report, the focus for the gap assessment has shifted from 2020 to 2030, reflecting that the underlying scenarios assume emission levels that are consistent with the Cancun pledges until 2020. Least-cost enhanced emission reduction pathways are only assumed from 2020. Earlier analysis assumed the world would move onto a least-cost pathway by 2010. Current trends indicate that this will not be the case, and accordingly the new set of scenarios from the IPCC, which are referenced in this report, include only those that assume least-cost pathways starting from 2020.

3. What are the implications of the scenarios that are consistent with the temperature goals?

The scenarios used in this Report as reference for meeting the 2°C and 1.5°C goals are all characterized by modest emissions reductions compared to current policies until 2020[5] that are in line with the ambition of Cancun pledges. This implies a need for deep and stringent emission reductions over later decades. Enhanced action before 2020 that would bring emission levels below the projected 2020 Cancun pledge level would ease the challenge and reduce overall cost of transitioning to least-cost pathways after 2020. It should be noted that in order to move to such pathways after 2020, the necessary policies and investment will need to be prepared well in advance.

The assessment of the pathways and target levels point at three key issues that have also been raised in previous gap reports:

- All scenarios analyzing 2°C pathways that follow the Cancun pledges until 2020 and with a least-cost starting point in 2020, require strong reductions after 2020. They also rely on so-called 'negative emission technologies' such as bioenergy combined with carbon capture and storage
- For scenarios analyzing the 1.5°C target, the reduction rates will need to be steeper
- The feasibility of large scale deployment of negative emission technologies is still a contentious issue.

4 As there are fewer than 10 scenarios available for the 1.5°C pathways, the 20th to 80th percentile range is not provided. However, the minimum and maximum values are 37 $GtCO_2e$ and 40 $GtCO_2e$ respectively.

5 Global emissions in 2020 under various pledge cases are estimated to be about 52-54 $GtCO_2e$. The least-cost 2020 scenarios used here have global emissions close to this range (49-56 $GtCO_2e$).

Enhanced early action (such as moving below the 2020 pledges) is associated with the following economic and technological advantages:

- Softening the requirement for very steep emission reductions over the medium term
- Facilitating mitigation in the medium to long term by reducing lock-in of carbon and energy intensive infrastructure in the energy system and society as a whole
- Encouraging near-term learning and development of technologies that will be essential in the long term
- Providing early policy signals which are needed for action later in the coming decades
- Reducing the overall costs and economic challenges in terms of, for example, upscaling of energy investments, during the transitional period
- Reducing the dependence on unproven technologies and increase the options society can choose from in terms of means to achieve stringent emission reductions in the long term.

Delaying stringent mitigation efforts until 2030 (in other words, not following a least-cost reduction trajectory after 2020) would with high confidence make the transition to longer-term emissions levels in line with the 2°C goal significantly more difficult. A significant number of models are not able to produce 2°C scenarios consistent with global emission levels in 2030 above 55 $GtCO_2e$, while other scenarios which delay enhanced mitigation action until after 2030 would imply massive cost increases coupled with a need for unprecedented political action.

4. Are G20 countries making progress on the implementation of 2020 pledges?

Among the G20 there are thirteen countries with pledges for 2020 (counting the EU members France, Germany, Italy and UK as one) and three countries without pledges. Six of these are assessed as being on track to meet pledges or extremely close, four are not, and three cannot be assessed, because there is insufficient evidence.

Pledges are self-determined. A country being on track does not necessarily mean that it undertakes more stringent action on mitigation than a country that is not on track – it depends on the ambition of the pledge.

The report presents an assessment of progress by G20 countries on the national pledges presented in the context of the Cancun agreement, and referred to here as the Cancun pledges.

The assessment compares projected 2020 emissions under three cases:

- Pledge case – projecting the maximum amount of emissions for 2020 compatible with the pledge
- Current policy trajectory – official national estimate
- Current policy trajectory – independent analysis.

Despite progress towards implementing policies in line with pledges, it is evident that work remains to be done to bring all G20 countries into pledge attainment.

5. What is the emissions gap in 2025 and 2030 assuming full implementation of the INDCs?

The emissions gap between what the full implementation of the unconditional INDCs contribute and the least-cost emission level for a pathway to stay below 2°C, is estimated to be 14 $GtCO_2e$ (range: 12-17) in 2030 and 7 $GtCO_2e$ (range: 5-10) in 2025. When conditional INDCs are included as fully implemented, the emissions gap in 2030 is estimated to be 12 $GtCO_2e$ (range: 10-15) and 5 $GtCO_2e$ (range: 4-8) in 2025.

If countries that have not yet submitted an INDC were to reduce their emissions at the same percentage below current policy trajectories as those that have already submitted, the projected global emissions would be further reduced, and the gap narrowed, by a further 0.5 $GtCO_2e$ in 2025 and 1 $GtCO_2e$ in 2030.

Full implementation of unconditional INDC results in emission level estimates in 2030 that are most consistent with scenarios that limit global average temperature increase to below 3.5°C until 2100 with a greater than 66 per cent chance. INDC estimates do, however, come with uncertainty ranges. When taking this into account the 3.5°C value could decrease to 3°C or increase towards 4°C for the low and high unconditional INDC estimates, respectively. When including the full implementation of conditional INDCs, the emissions level estimates become most consistent with long-term scenarios that limit global average temperature increase to <3-3.5°C by the end of the century with a greater than 66 per cent chance.

These numbers essentially tell two stories. Firstly the INDCs do present a real increase in the ambition level compared to a projection of current policies; all global modelling groups that have been assessed reached this conclusion. Secondly the submitted contributions are far from enough and the emissions gap in both 2025 and 2030 will be very significant.

The Report presents an assessment of the 119 INDCs submitted by 1 October 2015, covering 146 countries and 85-88 per cent of global GHG emissions in 2012. A final update of the assessment including later submissions will be presented on the UNEP Live website before the start of COP 21.

In the absence of agreed formats for reporting on mitigation contributions, including on the units in which those might be expressed, Parties have chosen a wide variety of forms and contributions: for example, targets used include:

- Economy-wide absolute reduction from historical base year emissions
- Emissions reduction relative to a baseline projection for the emissions associated with energy consumption
- Trajectory target for specific sectors or gases
- Specifying a peaking year
- Emissions intensity of GDP
- A fixed level target.

This has increased the analytical challenge of ensuring consistency when comparing and aggregating different mitigation contributions. The assessment builds on a combination of global and country-specific modelling studies from independent research teams, and official country-specific data sources.

The global emission levels in 2030 consistent with having a likely chance (>66 per cent) of staying below the 2°C goal in 2100, following a least-cost pathway from 2020 with only modest improvement of the GHG intensity until then, is 42 $GtCO_2e$ (range: 31-44). In 2025 this level is 48 $GtCO_2e$ (range: 46-50).

In comparison, global GHG emissions, based on assessment of the INDCs submitted by 1 October 2015, are for the unconditional INDCs projected to be at 54 $GtCO_2e$ (range: 53-58) in 2025, and 56 $GtCO_2e$ (range: 54-59) in 2030. If conditional INDCs are included, the global emissions projection is 53 $GtCO_2e$ (range: 52-56) in 2025 and 54 $GtCO_2e$ (range: 52-57) in 2030. The emission levels resulting from submitted INDCs are 4 to 6 $GtCO_2e$ lower than the current policy trajectory in 2030 of 60 $GtCO_2e$ (range: 58-62). They are 9 to 11 $GtCO_2e$ lower than the baseline of 65 $GtCO_2e$ (range: 60-70), which is based on IPCC AR5 scenarios and assumes no additional climate policies are put in place after 2010.

6. Can the INDC process become a foundation for enhancing ambition?

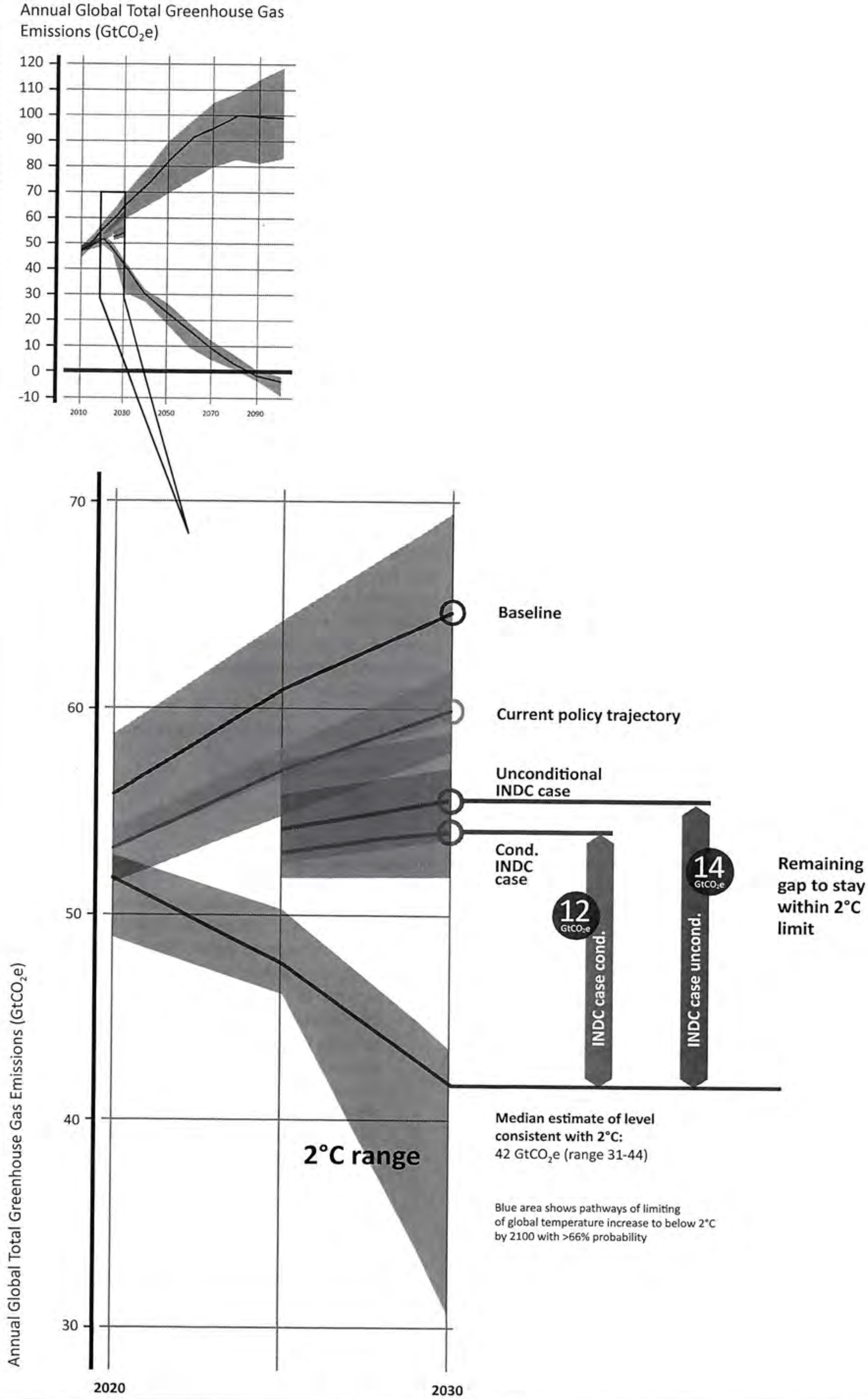
It is clear from the assessment of the mitigation contributions from the INDCs that much more needs to be done. This round of INDCs should therefore be considered as the first step in building foundations for a successful global climate agreement. The social and political effects of the INDCs and the processes undertaken at national level transcend the aggregate effect they are estimated to have on total global GHG emission levels in 2025 and 2030. The preparation of the INDCs has in many countries incentivized exploration of linkages between development and climate, as well as development of new national climate polices, and can be seen as an important step in a transition towards low carbon economies.

The Paris Agreement can support these national transitions and provide the framework for mobilization of the enhanced mitigation effort that is required to align national efforts with the global mitigation ambition indicated by the 2°C pathways. Establishing a robust, effective and transparent follow-up and review framework as part of the Paris Agreement will be critical in this context.

The INDCs and options for enhanced mitigation action must be seen in the broader context of economic growth and sustainable development. The Sustainable Development Goals (SDGs) recently adopted in New York by Heads of State of all member states of the United Nations explicitly recognise the interdependence between the achievement of climate, development and sustainability goals and recommends prioritizing coherence, co-benefits, and complementarity between the SDGs and a climate change agreement under the UNFCCC.

The SDG Goal 13 "Take urgent action to combat climate change and its impacts" specifically acknowledges that the

Figure ES2: The emissions gap



United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change, and the targets associated with the goal are clearly aligned with the ambitions in the INDCs.

7. What are some of the options for closing the gap?

A number of recent global studies conclude that there is a significant potential to reduce global emissions in 2030 – beyond the reductions resulting from implementation of the INDCs. If this potential is fully exploited, it could bring global emissions to a level very close to bridge the emissions gap in 2030. Furthermore, the studies suggest that this can be done by relying on proven technologies and policies.

A number of recent studies and reports, including by the IPCC and leading international research institutions, identifies a significant emissions reduction potential by 2030. Acknowledging that the methodologies, assumptions, scope and coverage of measures considered vary across the assessed studies, they all show that tapping into unused emission reduction potential could narrow the emissions gap in 2030 considerably. Taken together, they indicate that global greenhouse gas emissions could be further reduced by between 5 to 12 $GtCO_2e$/yr (range: 3-13) relative to the emissions level resulting from implementation of the unconditional INDCs, and between 5 to 10 $GtCO_2e$/yr (range: 1-11) relative to the emissions level associated with implementation of the conditional INDCs. These reductions could contribute to the reductions needed to bridge the emissions gap in 2030, which as previously stated is estimated at 14 $GtCO_2e$ (range: 12-17) for the unconditional INDC case and at 12 $GtCO_2e$ (range: 10-15), if both unconditional and conditional INDCs are implemented.

There is considerable uncertainty associated with the possibilities for achieving the emission reduction opportunities put forward in some of these studies. At the same time, the studies assessed do not cover all relevant measures, thematic areas and sectors. In other words the total technical and economic emission reduction potential in 2030 could be larger than indicated in the studies assessed. In comparison the Fourth Assessment Report of the IPCC indicated a total emission reduction potential in 2030 of 23 $GtCO_2e$ (range: 16-31). No update of the total emission reduction potential in 2030 was provided in the Fifth Assessment Report of the IPCC, but sectoral updates in this report indicate emission reduction potentials in 2030 of the same order of magnitude.

The assessed recent studies emphasize the key importance of enhanced energy efficiency with a particular emphasis on industry, buildings and transport, and expanded use of renewable energy technologies for power production combined with increased efficiency of fossil fuel-based power production will all be critical for achievement of the desired large-scale emission reductions. Other key sectors for enhanced mitigation action emphasized in the studies include forestry, agriculture and waste.

These are all sectors that have been assessed in earlier UNEP Emissions Gap Reports and where significant opportunities for bridging the gap have been highlighted through possibilities for replication, acceleration and scaling up proven good practices and policies.

8. How can International Cooperative Initiatives contribute to implementation of INDCs and enhance ambitions?

The impact of actions by International Cooperative Initiatives can potentially be significant. Preliminary assessments indicate a contribution in the range of 2.5 to 4 $GtCO_2e$ in 2020, if fully implemented. Part of this contribution falls within the Cancun pledges while the additional contribution may be in the range of 0.75 to 2 $GtCO_2e$ in 2020.

Significant attention has been put on mitigation actions by ICIs including actors other than Parties to the UNFCCC.

ICIs include a wide variety of activities, which makes consistent and thorough assessment difficult. Nevertheless, an effort has been made to assess all available information and organize it under a simple catalogue of actions categorized by type of constituent engaged. This catalogue serves to focus on those ICIs that have the most impact potential and by disentangling the various initiatives the overlap and double-counting risks with the national pledges can be minimized.

The report examines initiatives in three broad categories:

- Cities and regions
- Companies
- Sectors

A few examples below illustrate the wide span of ICIs:

- C40 Cities Climate Leadership Group – is a network of the world's megacities committed to taking action that reduces global GHG emissions. It has 75 affiliated cities (as of July 2015) and a total of 80 total participants
- The Compact of Mayors - is an agreement by three city networks to undertake a transparent and supportive approach to reduce city-level emissions, and to reduce vulnerability from, and enhance resilience to, climate change, in a consistent and complementary manner to national level climate protection efforts. It builds on ongoing city-level efforts
- Cement Sustainability Initiative (CSI) - is an alliance of 25 leading companies in the global cement industry created under the auspices of the World Business Council for Sustainable Development (WBCSD). Participants commit to developing a climate change mitigation strategy, setting reduction targets for CO_2 and reporting annually on their progress.

A number of new studies have examined the major initiatives and this report presents an assessment of these studies and their estimates of the emission reduction potential for each category of initiative. The studies list a number of challenges related to the analyzed ICIs including elements of overlap between initiatives and comparability of transparent monitoring, reporting and verification (MRV) of results. It is therefore difficult to assess whether all the international initiatives actually deliver on promises, as most initiatives propose only voluntary commitments and hence make it difficult for accountability and compliance to be enforced and sometimes lack robust Monitoring, Reporting and Verification (MRV).

Many initiatives can, however, play important roles to advance climate action, as they:

- Encourage or facilitate emission reductions at the city and regional level, via knowledge sharing, capacity building and technical support for project planning and implementation
- Identify partnerships and support local communities to become climate resilient
- Represent common city-level interests to influence policymakers at other levels
- Help implement climate plans and low-carbon and climate-resilient economic development projects
- Achieve transparency and accountability by encouraging best practice in GHG emission reporting
- Help overcome financial barriers and attract investors and accelerate additional capital flows into cities for low carbon projects.

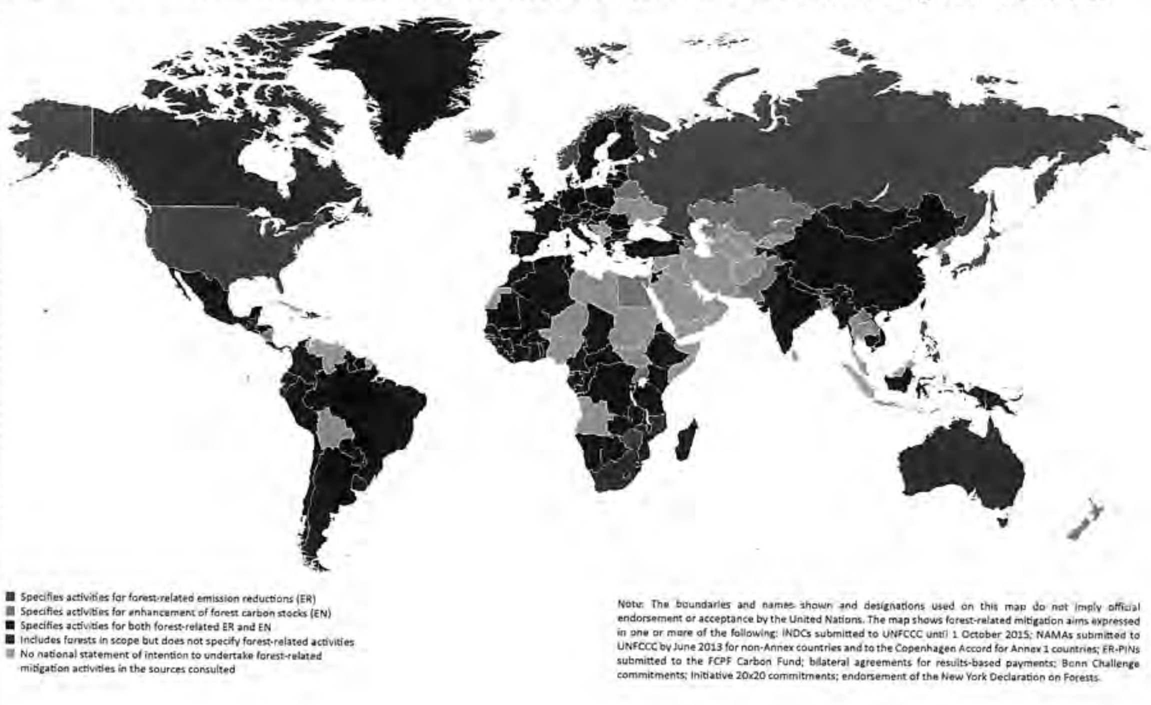
The studies compare the emissions reduction potential for the different categories of initiatives compared to a current trajectory baseline (noting that studies are not necessarily using same baseline approaches). Even if uncertainties are quite large, it is interesting that results are quite comparable at the aggregate level, even if the assessment of the different groups of initiatives varies significantly.

The assessment notes that the impact of non-state climate commitments can be significant, most likely in the range between 2.5 and 4 $GtCO_2e$ in 2020 (taking into account that not all initiatives are included in all assessments). These numbers include an estimate of overlaps between the various initiatives, in terms of actual actions, sectors, greenhouse gases and regions.

It is harder to estimate the overlap between these non-state initiatives and government emission reduction pledges for 2020. The recent studies examined in this assessment suggest that the overlap ranges between 33 and 70 per cent, resulting in possible additional net contributions of the order of 0.75 to 2 $GtCO_2e$ in 2020.

Even if ICIs are not necessarily additional to national 2020 pledges, they can be an important component of actually implementing these and at the same time facilitate or even drive increased national ambition. Only one study extrapolates the potential reductions to 2030, so it is not possible to present numbers here, but the study indicates that the mitigation contribution from existing ICIs would be substantial.

Figure ES3: National statements of intention to undertake forest-related mitigation activities



- Specifies activities for forest-related emission reductions (ER)
- Specifies activities for enhancement of forest carbon stocks (EN)
- Specifies activities for both forest-related ER and EN
- Includes forests in scope but does not specify forest-related activities
- No national statement of intention to undertake forest-related mitigation activities in the sources consulted

Note: The boundaries and names shown and designations used on this map do not imply official endorsement or acceptance by the United Nations. The map shows forest-related mitigation aims expressed in one or more of the following: INDCs submitted to UNFCCC until 1 October 2015; NAMAs submitted to UNFCCC by June 2013 for non-Annex countries and to the Copenhagen Accord for Annex 1 countries; ER-PINs submitted to the FCPF Carbon Fund; bilateral agreements for results-based payments; Bonn Challenge commitments; Initiative 20x20 commitments; endorsement of the New York Declaration on Forests.

9. What is the potential for greater forest-related mitigation, in particular through REDD+?

Forest-related mitigation activities in both developing and developed countries are attracting significant political attention, both in the negotiation process over the last years and in many of the submitted INDCs. Special focus is on policies and actions under REDD+ as the theoretical potential of forest-related mitigation activities in developing countries is estimated to be up to 9 $GtCO_2$ in 2030. The realization of this theoretical potential will be constrained by economic and land-use factors.

A rapid review[6] has been undertaken of forestry related mitigation actions in the submitted INDCs and these are together with other types of national engagement in forestry related mitigation illustrated in the global map below. The map clearly shows that many countries see potential mitigation opportunities in the forestry sector.

A special focus in the assessment has been devoted to the set of policy approaches and actions known as REDD+ as one option for facilitating cost-effective contributions to climate change mitigation, in developing countries. REDD+ (as defined under the UNFCCC) includes – reducing greenhouse gas emissions from deforestation and forest degradation, conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks.

REDD+ has seen marked progress under the UNFCCC negotiations over the last ten years, as a policy tool to reduce forest related emissions, including on measurement, safeguards and eligibility for results-based finance. In order for developing countries to access results-based finance for REDD+ emissions reductions or enhanced removals of carbon from the atmosphere, they need to have in place:

- A national strategy or action plan
- A national forest monitoring system
- A safeguards information system and a summary of information on how the REDD+ safeguards have been addressed and respected
- A forest reference emissions level or forest reference level
- Fully measured, reported and verified results, in terms of emission reductions/enhanced removals.

These requirements place some constraints on the potential for REDD+ implementation in the short term, for example the speed at which policies can be put in place and governance improvements can be implemented. The availability of finance, whether domestic or international, to cover the upfront costs of REDD+ measures will also be a determining factor. Results-based finance, by its nature, will be released only after success has been achieved. Many developing countries have expressed their interest in large-scale forest-related actions, both in their INDCs and a range of other statements.

The theoretical emissions reduction potential has been assessed for Africa, Asia-Pacific, and Latin America and the Caribbean and is broadly in the range 2.7-3.3 $GtCO_2$ in 2030 for each region. However, the realization of this theoretical potential will be significantly constrained by economic and land-use factors.

[6] Individual countries classified according to the actions specified in the documents reviewed.

Chapter 1

Scoping the 2015 report

Lead authors: John Christensen (UNEP DTU Partnership), Paul Burgon (independent consultant)

1.1 Moving towards a new international climate change agreement

The year 2015 has the potential to become a turning point in global efforts to transform the prevailing economic development paradigm into a more sustainable one.

All UN member countries reached agreement in September 2015 on a set of 17 sustainable development goals (SDGs) to be achieved by 2030. The main political instrument to address SDG 13 - "Take urgent action to combat climate change and its impacts" - is the United Nations Framework Convention on Climate Change (UNFCCC). Countries will meet again at the UNFCCC 21st Conference of the Parties (COP 21) in Paris with the aim of establishing a new international climate change agreement, hereafter the 'Paris Agreement', with the ambition of limiting changes in global temperatures to below 2°C or 1.5°C warming in 2100 compared to pre-industrial levels. The decision "[...] to adopt a protocol, another legal instrument or an agreed outcome with legal force under the Convention applicable to all Parties" originated at COP 17 in Durban (Decision 1/CP.17) and has been confirmed most recently at COP 20 in Lima (Decision 1/CP.20) (UNFCCC, 2014).

As the foundation for a new agreement, and reiterating decisions of COP 19 in Warsaw, the 'Lima Call for Climate Action' requested each Party "[...] to communicate to the secretariat its intended nationally determined contribution [INDC] towards achieving the objective of the Convention as set out in its Article 2" (UNFCCC, 1992)[1] ensuring that these are submitted "[...] well in advance of the twenty-first session of the Conference of the Parties [...] in a manner that facilitates the clarity, transparency and understanding of the intended nationally determined contributions" (UNFCCC, 2014).

The architecture of a new climate agreement has many facets relating to mitigation and adaptation, and the array of issues under negotiation has become significantly more complex since the Convention was established. The Paris Agreement will also aim to establish a framework to enhance capacity building and provide technological and financial support for developing countries to accelerate the transition towards low carbon and climate resilient development paths. A number of key decisions related to these issues will be required, while the core structure of the agreement will be based on the INDCs.

1.2 Key questions

Subsequent to COP 15, UNEP has produced an annual Emissions Gap Report presenting an up-to-date assessment of how actions, pledges and commitments by countries affect the global GHG emissions trend and how this compares to emissions trajectories consistent with the goal of keeping temperatures below 1.5°C or 2°C by 2100. The difference has become known as the emissions gap, calculated for specific target years.

This year, UNEP was requested by a number of countries to undertake an independent scientific assessment of the INDC submissions to inform the political process. The UNFCCC Secretariat has undertaken the formal compilation for COP 21.

The 2015 UNEP Emissions Gap Report asks four principal questions:

i) What are the latest estimates of 2025 and 2030 total global emissions levels consistent with the goal of holding the global average temperature rise below 2°C or 1.5°C above pre-industrial levels by 2100?
ii) What is the progress on implementation of the Cancun pledges for the period to 2020?
iii) Will the combined INDC commitments for 2030

1 Article 2 states "The ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner" (UNFCCC, 1992).

(if fully implemented) be sufficient to stay within the range consistent with the 2°C temperature goal?

iv) What are possible contributions in selected key areas, where action can be accelerated to enhance the ambition of national pledges both in the period before and after the expected entry into force in 2020 of the Paris Agreement? This year the detailed assessment is on possible mitigation contributions from International Cooperative Initiatives (ICIs) and enhanced forest-related mitigation activities with a focus on Reducing Emissions from Deforestation and Forest Degradation (REDD+).

1.3 Aim of the report and assessment principles

This is the sixth UNEP Emissions Gap Report and while the focus of the assessment has gradually shifted from initially examining the emissions gap in 2020 to focusing on 2030, the scientific basis has remained firmly based on the best available analysis worldwide.

The objective of the report remains the same, which is to assess the global progress towards the emissions reductions required to be on track towards the agreed target of limiting global average temperature increase to below 2°C by the end of the century compared to pre-industrial levels. In parallel, the report assesses the possible actions to be taken to achieve the necessary reductions and how these can be accelerated and scaled up to close the gap between the target and actual emissions trends – a constant feature of this series of reports.

1.4 INDC Assessment process

The INDC assessment team's approach has been to assess the impacts of the INDCs on future global GHG emissions. Global GHG emissions in 2025 and 2030 are compared under four scenarios – the baseline scenario (assuming no additional climate policies since 2010), the current policy trajectory scenario (includes currently adopted and implemented policies), the INDC scenario (how global GHG emissions might evolve with full implementation of the INDCs) and the 2°C scenario (representing an idealized global scenario consistent with limiting warming to below 2°C by 2100, keeping the option open to strengthen the global temperature target to 1.5°C). Each scenario is a composite in the sense that it draws on multiple individual scenarios from the published literature. The emissions gap is estimated as the difference between the INDC scenario and the 2°C scenario.

The approach to the assessment is characterized by the following principles:

i) For nationally-generated data, assessment is based on the figures directly available in the officially submitted INDCs

ii) For independently-generated data, assessment is based on peer-reviewed published analyses (or on related outputs) by independent modelling groups/ analysts based on the analysis of the information available in the INDCs

iii) Participation of a balanced team of experts in the INDC assessment (by gender, professional and sectoral background, institutional affiliation and geographical location).

In the process of preparing the Report and the INDC assessment, experts have frequently debated differences in understanding of assumptions (such as forms of mitigation contribution, conditional versus unconditional INDCs, use of international market mechanisms and treatment of the land use sector). By scrutinising assumptions (used by governments, independent modelling groups and international bodies), the team has been able to resolve many inconsistencies which, in turn, has led to increased confidence in the accuracy and validity of results.

1.5 Organization of the report

The report comprises six chapters – this first one scoping the outline, with subsequent ones falling under two main parts of the report.

Part I comprises Chapters 2 and 3. Chapter 2 focuses on the importance of enhanced pre-2020 mitigation action. It starts by presenting recent estimates for global emission levels and assesses pathways consistent with the 2°C and 1.5°C temperature goals, based on the latest available literature. It then explains why enhanced early action matters and outlines the implications of not enhancing action, followed by a review of progress with current 2020 pledges. Chapter 3 assesses the 119 INDCs, covering 146 countries, submitted by 1 October 2015, with a specific focus on the extent to which the INDCs in aggregate contribute to a reduction in global GHG emissions consistent with limiting average global temperature increase to below 2°C in 2100 with >66 per cent chance. The chapter quantifies an emissions gap – the gap in 2025 and 2030 between future emission levels with the INDCs fully implemented and the emission levels consistent with the temperature goals of 1.5°C and 2°C in 2100.

PART II explores some of the opportunities for narrowing and potentially bridging the estimated emissions gap in 2030. It starts with an overview of key issues and potentials for reducing GHG emissions by 2030, based on an assessment of a number of recent studies. This is followed by two focal chapters. Chapter 5 assesses the possible contribution to global mitigation efforts by key International Cooperative Initiatives (ICIs) led by actors other than the Parties to the UNFCCC. Finally, Chapter 6 reviews a range of forest-related mitigation activities and identifies the technical potential for both CO_2 emissions reductions and sequestration from these activities in developing countries, and with a special focus on REDD+.

As in previous editions, this year's Report has been put together by an international team of top scientists. This year 42 scientists from 24 scientific groups in 18 countries have contributed to the report.

Chapter 2

The importance of pre-2020 action

Section 2.2:
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2.1 Introduction

This Chapter first discusses recent global emission levels and trends, and reviews where global emissions would be heading in the absence of additional deliberate climate policies. It then presents assessment of global emission pathways that would keep global warming to below respectively 1.5°C or 2°C in 2100. This is followed by an elaboration of why enhanced early action matters and a discussion of the implications of not increasing short-term climate mitigation efforts.

Achievement of the Cancun 2020 pledges will be important for the transition to least-cost mitigation pathways from 2020. Section 2.3 therefore takes a closer look at progress towards achieving the 2020 pledges. The focus is on the Parties that are members of the G20, as these economies collectively generate around three quarters of global GHG emissions. However, it remains critical that all countries advance as far as possible towards achieving – and ideally exceeding – their Cancun pledges.

2.2 Global emission pathways and the importance of enhanced action

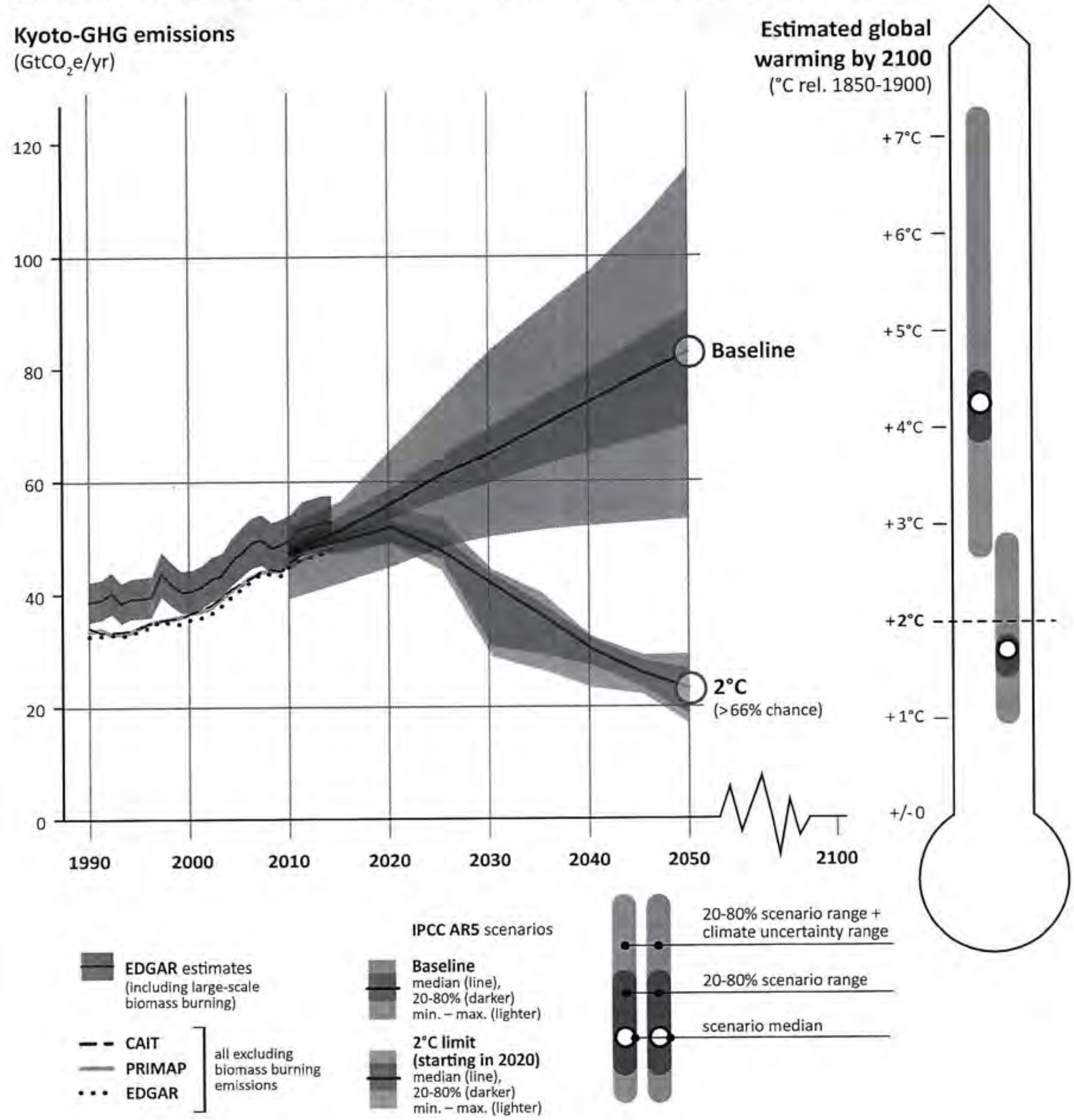
2.2.1 *Recent trends and baselines*

Over the past decades, global GHG emissions have increased steadily with small variations around a longer term trend. Moreover, during the first decade of the 21st century, emissions increased at a faster rate (2.2 per cent/yr) than during the last three decades of the 20th century (1.3 per cent/yr) (IPCC, 2014a). After the recovery from the economic crisis (with a 3.5 per cent increase in 2010-2011), the emissions growth slowed to 1.8 per cent on average over the subsequent two years[1]. The most recent global emission estimates[2] are for the year 2014. In that year, total global Kyoto-GHG emissions[3] amounted to about 52.7 $GtCO_2e/yr$ (range: 47.9-57.5[4], Figure 2.1). Global carbon dioxide (CO_2) emissions from fossil fuels and industry alone were estimated at 35.5 $GtCO_2/yr$[5] for 2014 (range: 32.5-38.5[6]).

In the absence of any further mitigation action compared to these trends, GHG emission projections are set to increase significantly over the 21st century. These projections are influenced by many factors. For example, economic and population growth will generally result in an increase in emissions, while energy intensity improvements in the global economy and reductions of carbon intensity in energy production will generally result in a decrease in emissions. These factors have characterized the last three decades of the 20th century. During the first decade of the 21st century, however, carbon intensity increased again, thus further contributing to rising global emissions.

1 Based on EC-JRC/PBL. EDGAR version 4.3. http://edgar.jrc.ec.europa.eu/, 2015 update (forthcoming).
2 Data for this year is available from EDGAR and PRIMAP.
Sources: EC-JRC/PBL. EDGAR version 4.3. http://e gar.jrc.ec.europa.eu/, 2015 update (forthcoming), PRIMAP4 baseline: PIK-Potsdam. https://www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/research/rd2-flagship-projects/primap/emissions-module
3 Here aggregated with 100-year Global Warming Potentials (GWPs) of the IPCC Second Assessment Report.
4 90 per cent confidence interval, based on the uncertainty range assessed in IPCC AR5 Working Group III.
5 Source: BP Statistical Review of World Energy June 2015, http://www.bp.com/statisticalreview
6 95 per cent uncertainty range, based on Andres *et al.* (2014).

Figure 2.1: Historical greenhouse gas (GHG) emissions and projections until 2050



Left hand panel: Historical GHG from CAIT* (dashed line), PRIMAP** (solid line), and EDGAR*** (dotted line) – all excluding biomass-burning emissions. The solid line surrounded by the brown-shaded area shows the EDGAR estimates when including large-scale biomass burning emission estimates as in IPCC AR5 WG3****, and their overall 90% uncertainty range. Projections are drawn from the IPCC AR5 Scenario Database and show baselines (grey) and scenarios limiting warming to below 2°C by 2100 with at least a likely (>66%) chance (blue). The 2°C scenarios start from 2020 levels and assume a global least-cost pathway afterwards. Data for these pathways can be found in Table 2.1 under label "2°C (>66% in 2100)", along with other temperature target definitions. For each subset the median (solid line), the 20-80% range (dark) and the min-max range (lighter) of Kyoto-GHG emissions are shown.

Right hand panel: Estimated global temperature increase in 2100 of both scenario subsets. The climate uncertainty represents the 90% range of carbon-cycle and climate response uncertainty, as used in the IPCC AR5 WGIII assessment. Kyoto-GHG emissions are aggregated using 100-year Global Warming Potentials reported in the IPCC Second Assessment Report.

SOURCES:
* CAIT: World Resource Institute (WRI). http://www.wri.org/resources/data-sets/cait-historical-emissions-data-countries-us-states-unfccc
** PRIMAP4 baseline: Potsdam Institute for Climate Impact Research (PIK). https://www.pik-potsdam.de/research/climate-impacts-and-vulnerabilities/research/rd2-flagship-projects/primap/emissions-module
*** EDGAR: European Commission, Joint Research Centre (JRC)/ Netherlands Environmental Assessment Agency (PBL). Emission Database for Global Atmospheric Research (EDGAR) version 4.3. http://edgar.jrc.ec.europa.eu/, 2015 update (forthcoming), (Olivier and Janssens-Maenhout, 2012).
**** based on updates of van der Werf *et al.* (2010).

A projection of GHG emissions and their driving factors in the absence of dedicated climate policies is often referred to as a 'baseline'. In the IPCC Fifth Assessment Report (Clarke *et al.*, 2014), baselines are defined as "not to include climate policy after 2010"[7]. In such baselines, GHG emissions are expected to increase to about 70-90 $GtCO_2e$/yr in 2050[8], and in most cases global warming would exceed 4°C by the end of the century, as indicated in Figure 2.1.

2.2.2 Pathways towards 1.5°C and 2°C

In 2014, the UNEP Emissions Gap Report described how global temperature levels are linked to so-called carbon dioxide emission budgets, and how these budgets, in line with holding warming to below 2°C, can be spread over time (UNEP, 2014). While these budgets remain useful and valid benchmarks, this year's analysis uses emission scenario data compiled for the IPCC AR5[9] to further explore the timing of reaching global net zero emissions and the evolution of annual GHG emissions over time. Data from a recent scientific study that described pathways that limit warming to below 1.5°C by 2100 were also included[10].

Pathway characteristics for both 1.5°C and 2°C scenarios are provided in Table 2.1. These show pathways with limited action until 2020 and global least-cost mitigation afterwards. These are in line with current policy trajectories (see Section 2.3 and Chapter 3), which suggest that the global community did not enhance its mitigation action from 2010 aligned with long-term least-cost 1.5°C or 2°C pathways from 2010 onward (UNEP, 2014). Therefore, the scenarios used in this year's report assume global emissions in 2020 that are roughly in line with the Cancun pledges for 2020 (that is, 49-56 $GtCO_2e$ in 2020 as indicated in Table 2.1). Furthermore, the pathways shown allow temperatures to 'overshoot' – that is, to temporarily exceed the 2°C limit before falling below it again by 2100[11]. These pathways do not represent the only possibilities of limiting warming to below 1.5°C and 2°C. Some level of flexibility is available for emissions falling outside the range. However, this flexibility is not infinite and enhanced pre-2020 action matters (as further discussed in Section 2.2.3).

As Table 2.1 shows all scenarios are characterized by net negative global total GHG emissions by 2100. Looking specifically at CO_2 emissions that play a dominant role in determining long-term warming as described in Box 2.1, 1.5°C- and 2°C-consistent scenarios reach net zero CO_2 emissions globally between 2045 and 2075 (Table 2.1). Scenarios in line with 1.5°C reach net zero CO_2 emissions around 2050. In scenarios that keep warming to below 2°C with >66 per cent chance, the timing is of the order of one or more decades later, more specifically around 2070 (range: 2060-2075)[12].

Achieving global net zero CO_2 emissions is a geophysical requirement. It follows directly from the fact that to limit warming to any level, total net CO_2 emissions need to be capped, and from the fact that, up to the present day, global CO_2 emissions are still rising[13]. In theory, a small set of scenarios is able to limit warming to below 2°C[14] without achieving net negative emissions by 2100 (UNEP, 2014). However, these scenarios all start stringent, global mitigation before 2020 (see also Section 2.2.3), which is no longer considered realistic. Without exception, all 1.5°C scenarios available in the literature reach net negative CO_2 emissions by mid-century, even with stringent mitigation action having started in 2010.

In most scenarios, global net zero and negative emissions are achieved by the use of so-called negative emission technologies that offset any residual positive emissions. Such negative emissions might be achieved on a large scale, for example, by massive afforestation or by combining bio-energy with capture and storage of CO_2. Bio-energy combined with capture and geological storage of CO_2 has been studied increasingly over the past decade, but uncertainties about its large-scale deployment remain (see Annex A for details).

Compared to 2°C pathways, significantly fewer studies have explored pathways that limit warming to 1.5°C (Clarke *et al.*, 2014). Findings for the very stringent 1.5°C limit are therefore less robust. However, one scientific review of 1.5°C scenarios (Rogelj *et al.*, 2015a) found that such scenarios are in many aspects similar to 2°C-consistent scenarios, but that they are characterized by faster emissions reductions in the near term (in 2020 and 2030). Compared to 2°C, the rapid and profound decarbonization of the energy system in 1.5°C scenarios is driven by earlier reductions in the power sector, important efforts to limit energy demand in the industry, buildings, and transport sector; and no delays in global mitigation action beyond 2020. This more rapid transformation translates into significantly higher costs. For example, carbon prices are about two or three times higher in 1.5°C scenarios than in scenarios that keep warming to below 2°C with >66 per cent chance (Rogelj *et al.*, 2015a).

2.2.3 Why enhanced early action matters

Enhanced early action facilitates the transition to the stringent, long-term emission reductions required for limiting warming to below 1.5°C and 2°C. It would enable countries i) to overachieve their current pledges by 2020,

7 They may or may not include Kyoto Protocol commitments until 2012.

8 Scenario-based ranges in this chapter refer to the 20th to 80th percentile range, unless stated otherwise.

9 In particular, the emission scenarios available in the IPCC AR5 Scenario Database were used. Temperature projections for the IPCC AR5 Scenario Database were computed with a probabilistic version of MAGICC. (Meinshausen *et al.*, 2009; Meinshausen *et al.*, 2011).

10 Rogelj *et al.* (2015a). These 1.5°C scenarios temporarily exceed the 1.5°C limit during the 21st century in order to fall below it again with >50 per cent chance in 2100. This is sometimes referred to as a temperature overshoot. Insufficient data are available for assessing pathways that return warming to below 1.5°C by 2100 with >66 per cent chance.

11 Pathways for 2°C scenarios that do not allow overshooting (that is, where temperatures stay below 2°C during the 21st century) are shown in the technical Annex A to Chapter 2, available online.

12 These numbers differ from the ones presented in the 2014 Emissions Gap Report (UNEP, 2014, Table 2.1), where the median year and range of annual net global CO_2 emissions including LULUCF becoming zero was indicated as 2065 (range: 2055-2070). The reason is that this year the final IPCC AR5 Scenario Database data are used, whereas the estimate last year was based on a preliminary release of the IPCC AR5 scenarios database data. In addition, this year the estimate is corrected for sampling bias by removing scenarios that do not represent a variation at the global level, but only represent a variation in the regional burden sharing scheme. See Annex A, available online, for technical details.

13 See Rogelj *et al.* (2015b) for a detailed discussion.

14 Both with a >66 per cent or >50 per cent chance, based on the IPCC AR5 Scenario Database.

Box 2.1: The global carbon dioxide (CO_2) budget, non-CO_2 GHGs and the link to global warming

Limiting warming to any desired level requires a cap on total, cumulative anthropogenic CO_2 emissions. Working Group I of the IPCC (IPCC, 2013) showed that global mean temperature increases are almost directly proportional to cumulative carbon dioxide emissions since the pre-industrial period. This leads to the important conclusion that there is a maximum amount of carbon dioxide emissions, or a CO_2 budget, that can be discharged to the atmosphere over time if society wishes to stay within a 2°C or other global warming limit. The IPCC indicated that to limit warming to below 2°C with a 'likely chance' (that is >66% chance) by the end of the century, about 1 000 $GtCO_2$ of CO_2 emissions remained 'in the budget' from 2011 onward* (IPCC, 2014b; Knutti and Rogelj, 2015). To keep CO_2 emissions within such a budget allowance, annual global CO_2 emissions have to become zero at some point during the 21st century. This is a geophysical requirement that applies regardless of the budget level chosen. For non-CO_2 GHGs with a shorter lifetime in the atmosphere, such as methane, the levels of emissions that are emitted per year are more important than the cumulative amount**. Reducing their annual emissions is also important to limit global mean temperature increase to low levels. Table 2.1 indicates the year of global annual emissions becoming net zero for each of the pathways considered.

* This number is accompanied by an uncertainty range, which depends on the concurrent mitigation of non-CO_2 GHGs.
** This is approximately true, as for non-CO_2 GHGs that stay in the atmosphere for quite a while (for example, N_2O has an atmospheric lifetime of 121 years) there is also a more limited cumulative effect. See, for example, Smith *et al.* (2012).

Table 2.1: Overview of pathway characteristics of 1.5°C and 2°C scenarios based on a re-analysis of the IPCC AR5 Scenario Database and a recent study on 1.5°C scenarios[15].
All scenarios have prescribed 2020 emissions consistent with the GHG pledges made by Parties in Cancun in 2010, and hence do not represent least-cost emission levels until then. All available scenarios with limited action until 2020 rely on net negative CO_2 emissions from energy and industry during the 21st century. Most scenarios with such specifications were contributed to the IPCC AR5 Scenario Database by the LIMITS intercomparison project[16]. Note that this table provides data for limiting warming below 1.5°C and 2°C in 2100. Further information is provided in the Tables of Annex A (available online)

Limiting warming in 2100 (allowing for overshoot)					
1.5°C (>50% in 2100)	Pathways limiting warming to below 1.5°C by 2100 with >50% chance Limited action until 2020 and least-cost mitigation afterwards				
Number of available scenarios: 6; Number of contributing modelling frameworks: 2 Year of global annual emissions becoming net zero† for: Kyoto-GHGs: **(2060-2080)**; total CO_2 (including LULUCF): **(2045-2050)**; CO_2 from energy and industry: **(2045-2055)**					
	Annual emissions of global total greenhouse gases [$GtCO_2e/yr$]				
Year	2020	2025	2030	2050	2100
median*	**56**	**47**	**39**	**8**	**-5**
range and spread**	53(-/-)56	46(-/-)48	37(-/-)40	4(-/-)14	-5(-/-)-3
2°C (>66% in 2100)	Pathways limiting warming to below 2°C by 2100 with >66% chance Limited action until 2020 and least-cost mitigation afterwards				
Number of available scenarios: 10; Number of contributing modelling frameworks: 4 Year of global annual emissions becoming net zero† for: Kyoto-GHGs: **2085 (2080-2090)**; total CO_2 (including LULUCF): **2070 (2060-2075)**; CO_2 from energy and industry: **2070 (2060-2075)**					
	Annual emissions of global total greenhouse gases [GtCO2e/yr]				
Year	2020	2025	2030	2050	2100
median*	**52**	**48**	**42**	**23**	**-3**
range and spread**	49(49/53)55	44(46/50)53	29(31/44)44	17(18/27)29	-11(-9/-1)0
2°C (50-66% in 2100)	Pathways limiting warming to below 2°C by 2100 with 50-66% chance Limited action until 2020 and least-cost mitigation afterwards				
Number of available scenarios: 4; Number of contributing modelling frameworks: 2 Year of global annual emissions becoming net zero† for: Kyoto-GHGs: **(2095-2095)**; total CO_2 (including LULUCF): **(2065-2070)**; CO_2 emissions from energy and industry: **(2070-2080)**					
	Annual emissions of global total greenhouse gases [$GtCO_2e/yr$]				
Year	2020	2025	2030	2050	2100
median*	**53**	**50**	**47**	**28**	**-1**
range and spread**	50(-/-)55	49(-/-)51	46(-/-)48	27(-/-)29	-2(-/-)-1

† Rounded to nearest 5 years. Explanation of format: 'median (20th percentile – 80th percentile)' – for example, '2085 (2080-2090)'; no median is provided if fewer than 10 scenarios are available '(minimum–maximum)' – for example, '(2060-2080)'.
* Rounded to the nearest 1 $GtCO_2e/yr$.
** Rounded to the nearest 1 $GtCO_2e/yr$. Explanation of format: 'minimum value (20th percentile/80th percentile) maximum value' – for example, '44(46/50)53'. No percentiles are provided if fewer than 10 scenarios are available – for example, '46(-/-)48'.

15 See Rogelj et al. (2015a).
16 See Kriegler et al. (2013).

and ii) to transition towards a pathway in line with a least-cost trajectory after 2020. By making the shift in emissions less abrupt, enhanced pre-2020 and pre-2030 action reduces the so-called transitional challenges (see below). Furthermore, to keep the door open for limiting warming to below 1.5°C by 2100, enhanced early action seems essential. Previous reports (UNEP, 2012, 2013, 2014) provided detailed discussion of the trade-offs between early and late action. Three main areas of importance with respect to enhanced early action were highlighted in particular:

1. *Economics and technology*, where enhanced early action will:
   - mediate the requirement for very steep emission reductions in the medium term
   - facilitate mitigation in the medium to long term by reducing lock-in of carbon and energy intensive infrastructure in the energy system and society as a whole
   - spur near-term learning and development of technologies that will be essential in the long term
   - provide early policy signals which are needed for action in the following decades
   - reduce the overall costs and economic challenges during the transitional period, for example, in terms of upscaling of energy investments
   - reduce the dependence on unproven technologies such as negative emissions technologies[17] and increase the options society can choose from to achieve stringent emission reductions.
2. *Climate outcomes:* Enhanced early action will reduce climate risks, for example, by influencing the rate of temperature increase (Schaeffer *et al.*, 2013; Ricke and Caldeira, 2014).
3. *Co-benefits:* Enhanced early action will enable the realisation of near-term co-benefits of climate change mitigation, such as improved public health as a result of lower air pollution, improved energy security, and reduced crop yield losses[18].

The issue of lock-in is very important in a number of ways. Even with enhanced early action, it is projected that carbon intensive infrastructure, such as unabated coal-fired power plants, will have to be shut down before the end of their lifetime in some stringent mitigation scenarios, and delay exacerbates this (Rogelj *et al.*, 2013; Johnson *et al.*, 2015). Furthermore, delay also locks in energy intensive practices. Limiting energy demand is critical to keep stringent mitigation targets within reach (Clarke *et al.*, 2014). Furthermore, the transition to a low energy-demand society is also inhibited by delays of action, as more energy intensive infrastructure continues to be built up. Infrastructure lock-in makes the transition to a low-carbon path harder.

17 Enhanced early action is important in reducing dependence on negative emissions in the long term for achieving stringent climate targets like 2°C. However, there are no scenarios available that return warming to below 1.5°C by 2100, without the use of bio-energy combined with capture and geological storage of CO_2.

18 Note that the IPCC AR5 also identified adverse side-effects of climate change mitigation, which will have to be considered simultaneously.

Enhanced early action is thus important. As described above, overachievement of the 2020 pledges will improve the chances for the stringent emission reductions that are required post-2020 (Rogelj *et al.*, 2013; Clarke *et al.*, 2014).

2.3 Progress towards the 2020 pledges: a closer look at major economies

Section 2.2 underlined the importance of pre-2020 mitigation action to achieving consistency with the below 2°C by 2100 scenarios. It is critical that all countries, and particularly the highest-emitting economies, advance as far as possible towards achieving – and ideally exceeding – their Cancun pledges. This section takes a closer look at progress towards achieving these 2020 pledges, focusing on the parties that are members of the G20[19]. These economies collectively generate around three quarters of global GHG emissions[20].

2.3.1 Assessment of G20 countries' 2020 emissions under three cases

The section compares current emissions trajectories of G20 members with the trajectories associated with the achievement of these Parties' 2020 pledges. It should be read with three important caveats in mind. First, not all pledges demand the same level of effort to achieve. In other words, a country currently on track to achieve its pledge has not necessarily made a greater effort to mitigate emissions than a country not yet on track[21]. Secondly, these projections are subject to the uncertainty associated with macroeconomic trends, such as changes in gross domestic product (GDP), as well as the impact of policies. Thirdly, the emission trajectories analysed here do not quantify the potential impact of using offsets to achieve pledges. If offsets are traded internationally, and are counted towards the pledges of both buying and selling parties, the global impact of the pledges will be weakened. Most countries have not clarified their intentions concerning use of offsets to meet their 2020 pledges. Australia, Brazil, Canada, the European Union, and the United States have explicitly not excluded the possibility; others have not formally commented (CAIT WRI, 2015).

Table 2.2 compares 2020 emissions under three cases: a pledge case, based on official data; a current policy trajectory case, based on official data; and a current policy trajectory case, based on independent analysis. These cases are described in Box 2.2.

19 The members of the G20 are Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the UK, the USA, and the EU. In our analysis, the EU including all its Member States (regardless of G20 status) is considered as a single Party, and EU Member States are not considered individually. In general, evaluating the pledges of other countries is limited by a lack of data.

20 In 2012, these parties accounted for 77 per cent of global emissions excluding LULUCF and 75 per cent of global GHG emissions including LULUCF (CAIT WRI, 2015).

21 See Appendix 2.D of the 2013 UNEP Emissions Gap Report (UNEP, 2013) for further discussion of this issue.

Box 2.2: Assumptions of analysis of progress towards pledges

For each country or Party, Table 2.2 compares estimates for 2020 emissions under three cases:

1. **Pledge case (official data):** Identifies the maximum level of GHG emissions that each country or Party could emit in 2020 and still meet its pledge – without considering the use of offsets. If a pledge is presented as a range (Brazil, China and India), the less ambitious end of the range is adopted as the official pledge estimate. If a country has both a conditional and unconditional pledge (Indonesia), only the unconditional pledge is used. If a country has only a conditional pledge (Mexico, South Africa), the conditional pledge is used. For countries whose pledges are framed relative to a baseline scenario, it is assumed that baselines are not adjusted in the future. For countries whose pledges are framed as GHG intensity targets, economic growth consistent with official projections is assumed[22]. Where available, the 2020 emission level described by the country or Party as the pledge level is used; alternatively, these levels are calculated working from official base-year or baseline data.

2. **Current policy trajectory case (official data):** Identifies official estimates of 2020 emissions considering projected economic trends and current policy approaches, including policies at least through 2012.

3. **Current policy trajectory case (independent analysis):** Similarly identifies estimates of 2020 emissions considering the best current estimates of projected economic trends and current policy approaches, but is based on independent analysis rather than official data. Figures are drawn from the Climate Action Tracker (CAT, 2015) and den Elzen *et al.* (2015) for all countries, as well as other, country-specific sources where noted. Current policy trajectory (independent analysis) supplements the official sources described in point two by providing data that aim for consistency across countries and political independence.

Projections only consider a limited subset of sectors and gases, for example, CO_2 emissions from fossil fuels are omitted, as they cannot be compared to projections and targets that include the full set of GHGs across the entire economy.

22 For China, GDP is assumed to reach 61.6 trillion yuan in 2020, consistent with China's National Communication (People's Republic of China, 2012). For India, GDP is assumed to reach 120.41 trillion rupees ('06–'07 rupee value) in 2020, consistent with the average of the scenarios presented in Planning Commission Government of India (2014).

Table 2.2: Emissions in 2020 under pledge case and current policy trajectory cases for G20 countries ($MtCO_2e$)[23]

Parties	2020 Pledge Case (based on official data)	Current Policy Trajectory (based on official data)	Current Policy Trajectory (based on independent estimates)[24]	Mitigation pledge and current policy trajectory details
Australia	530[a] (DoE, 2015)	655[a] (DoE, 2015)	575-580[b] (CAT, 2015) 650-665[a] (den Elzen *et al.*, 2015)	Base year pledge Current Policy Trajectory (official data) excludes impacts of Emissions Reduction Fund (ERF) (see discussion below)
Brazil	2 070[a] (Brazilian Government, 2010)	N/A	1 750-2 075[a] (CAT, 2015) 1 470-1 520[a] (den Elzen *et al.*, 2015)	Baseline scenario pledge
Canada	610[a] (Environment Canada, 2014)	730[a] (Environment Canada, 2014)	745[b] (CAT, 2015) 720-760[b] (den Elzen *et al.*, 2015)	Base year pledge
China*	14 500[a] (People's Republic of China, 2012)	N/A	12 200-12 600[a] (CAT, 2015) 12 535-13 420[a] (den Elzen *et al.*, 2015)	Intensity pledge 2020 Pledge Case assumes 40% reduction in GHG intensity and 2020 GDP of People's Republic of China (2012), adjusted for non-CO_2 projections from CAT (2015). The high end of this range is based in part on China's Second National Communication (People's Republic of China, 2012), which considers policies only through 2010, and is therefore likely to be higher than actual 2020 emissions
European Union	4 500[b] (EEA, 2014a)	4 230[b] (EEA, 2015)	4 115-4 375[b] (CAT, 2015) 4 105-4 370[b] (den Elzen *et al.*, 2015)	Base year pledge Current Policy Trajectory (official data) does not fully reflect all policies adopted past mid-2012
India*	3 815[b] (Planning Commission Government of India 2011, 2014)	N/A	3 500-3 600[b] (CAT, 2015) 3 535-3 960[a] (den Elzen *et al.*, 2015)	Intensity pledge 2020 Pledge Case assumes 20% reduction in GHG intensity per Planning Commission Government of India (2011), 2020 GDP per Planning Commission Government of India (2014), and exclusion of the emissions from agriculture and LULUCF per Planning Commission Government of India (2011)
Indonesia	1 335[a] (BAPPENAS, 2015) 2 185[a] (Ministry of Environment Indonesia, 2010)	N/A	2 540[a] (CAT, 2015) 1 910-1 950[a] (den Elzen *et al.*, 2015)	Baseline scenario pledge 2020 Pledge Case of 1 335[a] is calculated based on the baseline from BAPPENAS (2015)[25] 2020 Pledge Case of 2 185[a] is calculated based on the baseline from Ministry of Environment Indonesia (2010)
Japan	1 300[b] (UNFCCC, 2014)	1 320[b] (UNFCCC, 2014)	1 230-1 330[b] (CAT, 2015) 1 135-1 330[b] (den Elzen *et al.*, 2015) 1 350-1 400[b] (Kuramochi, 2014)	Base year pledge
Mexico	555[a] (Mexico, 2015) 670[a] (NCCS, 2013)	830[a] (Government of Mexico, 2012; SEMARNAT, 2013)	785-800[a] (CAT, 2015) 770-810[a] (den Elzen *et al.*, 2015)	Baseline scenario pledge 2020 Pledge Case of 555[a] is calculated from INDC (Mexico, 2015) baseline[26] of 792 Current Policy Trajectory (official data) is based on Government of Mexico (2012), adjusted per SEMARNAT (2013)

23 Figures do not consider the possible purchase or sale of offsets. Figures including LULUCF indicated with [a], excluding LULUCF indicated with [b].

24 References to den Elzen *et al.* (2015) in this column represent PBL estimates based on the method of den Elzen *et al.* (2015). Some numbers presented here have been updated per latest estimates available from http://infographics.pbl.nl/indc/.

25 The INDC baseline is based on a revised national inventory that shows significantly lower 2010 emissions than those shown in the National Communication and assumed by other studies cited here. See http://ranradgrk.bappenas.go.id/rangrk/beranda/92-bahasa/informasi-sektoral/193-hasil-indc for a comparison of 2010 emissions.

26 The INDC baseline is based on a new methodology with global warming potentials (GWPs) from the IPCC 5th Assessment Report; it is therefore not comparable to any other sources cited here. All other sources use GWPs from the IPCC 2nd Assessment Report; the NCCS (2013) also uses a previous methodology.

Parties	2020 Pledge Case (based on official data)	Current Policy Trajectory (based on official data)	Current Policy Trajectory (based on independent estimates)[24]	Mitigation pledge and current policy trajectory details
Republic of Korea	550[a] (Republic of Korea, 2015) 545[a] (Republic of Korea, 2014)	N/A	745-755[b] (CAT, 2015) 585-620[b] (den Elzen *et al.*, 2015)	Baseline scenario pledge 2020 Pledge Case of 550[a] is calculated from INDC (Republic of Korea, 2015) baseline of 783
Russian Federation	2 515[b] (Government of Russia, 2014)	2 410[b] (Government of Russia, 2014)	2 600[b] (CAT, 2015) 2 295-2 375[b] (den Elzen *et al.*, 2015)	Base year pledge 2020 Pledge Case reflects 25% reduction calculated based on national inventory data (Government of Russia, 2014)
South Africa	585[a] (Department of Environmental Affairs, 2011a, 2011b)	N/A	730[b] (CAT, 2015) 560-885[b] (PBL, 2015)	Baseline scenario pledge
United States of America	5 145[a] (Biennial Report, 2013)	5 920[a] (Biennial Report, 2013)	6 360-6 600[b] (CAT, 2015) 5 445-6 170[a] (den Elzen *et al.*, 2015)[27]	Base year pledge Current Policy Trajectory (official data) is from the 'with measures' scenario in the Biennial Report (2013). The USA considers that it has moved onto the 'with additional measures' trajectory, with a range of 4 893-5 591 $MtCO_2e$ for 2020
No 2020 pledge				
Argentina	No pledge	No pledge	380-480[b] (CAT, 2015)	
Saudi Arabia	No pledge	No pledge	645[b] (CAT, 2015)	
Turkey	No pledge	No pledge	655[b] (CAT, 2015) 485-690[b] (den Elzen *et al.*, 2015)	

Notes:
[a]Figures including LULUCF
[b]Figures excluding LULUCF
[*]China and India have GHG intensity targets based on the ratio of GHG emissions to GDP. For consistency, we have converted these to absolute emission numbers based on the official documentation cited above, but a determination of whether each country has achieved its pledge should be based on intensity rather than absolute emissions.

Estimates are rounded to the nearest 5 $MtCO_2e$.

27 A suite of additional studies (Rhodium Group, 2014; Belenky, 2015; Hausker *et al.*, 2015) finds that US emissions in 2020 could range from 5 087-5 844 $MtCO_2e$ incl. LULUCF if the Administration implements further regulations consistent with its Climate Action Plan.

2.3.2 Progress of G20 countries

Based on this analysis, three of the parties considered here – China, the EU28, and India – are on track to meet their pledges without purchasing offsets according to all available analyses. Three more – Brazil, Japan, and Russia – are on track according to most estimates and are within one per cent, one per cent, and three per cent of the pledge level, respectively, according to all estimates.

China's and India's pledges are framed in terms of GHG intensity reductions from 2005 levels, and several sources indicate that both countries are currently on track to achieve them. Studies indicate that China, which pledged a reduction of 40-45 per cent in emissions intensity, is on track to achieve a reduction of at least 42 per cent (IEA, 2014a, 2014b; CAT, 2015; PBL, 2015; Sha *et al.*, 2015). For India, Garg *et al.* (2014) show that by 2012, India had already reduced intensity by 17 per cent out of a pledged reduction of 20–25 per cent by 2020, and the CAT (2015) and PBL (2015) show India on track for a 36 per cent or 28 per cent reduction by 2020, respectively[28].

Japan announced an adjustment to its pledge in November 2013 from a 25 per cent reduction on 1990 levels to a 3.8 per cent reduction on 2005 levels (similar to an increase of about 3.1 per cent on 1990 levels). While this adjustment makes it much easier for Japan to achieve its pledge, current official projections still place Japan's 2020 emissions slightly above its pledge threshold (UNFCCC, 2014). Independent projections differ slightly – CAT (2015) shows Japan on track to meet its revised pledge, whereas den Elzen *et al.* (2015) estimates a range in 2020 from slightly below to slightly above the pledge level. Japan's actual trajectory, however, will depend significantly on the respective roles of nuclear power and coal-fired power to meet future needs[29].

Canada and Mexico are likely to require further action or purchased offsets, or both in order to meet their pledges, according to government and independent estimates. Mexico's 2020 pledge is conditional on the provision of adequate financial and technological support from developed countries as part of a global agreement (Mexico, 2015).

According to independent analysis, the Republic of Korea will also require further action to meet its pledge, but this cannot be verified based on publicly available official projections. Independent estimates of 2020 emissions range from well below to well above the pledge level (CAT, 2015; den Elzen *et al.*, 2015).

In the cases of Australia[30] and the USA, government and independent analyses reach differing conclusions regarding each country's progress towards its pledge. In the case of Australia, the government projects 2020 emissions of approximately 655 $MtCO_2e$, not including the impact of the Emission Reduction Fund (ERF). The Australian government states that it is "on track" to meet its target of 533 $MtCO_2e$, and that the ERF has contracted projects expected to deliver abatement of 47 $MtCO_2e$ (Commonwealth of Australia, 2015). Prior to the initial auction, CCA (2014) reviewed studies of the potential of the ERF and concluded, "In short, these studies suggest that the ERF's contribution to reducing emissions is likely to fall some way short of what is required to meet Australia's minimum 2020 target". Independent analyses (CAT, 2015; PBL 2015) project emissions above the pledge level.

The USA contends that the 'with additional measures' scenario from a 2014 addendum to its biennial report now represents its current policy trajectory. This trajectory shows the United States on track to achieve its pledge. Independent analyses, by contrast, find that further action is still necessary (see, for example, Rhodium Group, 2014; Belenky, 2015; CAT, 2015; Hausker *et al.*, 2015; PBL, 2015).

Insufficient information is currently available to determine whether Indonesia and South Africa are on track to meet their pledges. In the case of Indonesia, independent projections span a wide range, and official projections reflecting current policies are unavailable. In the case of South Africa, official projections to 2020 do not reflect recently adopted and implemented policies, and independent estimates vary widely, from well below the pledge level to well above it. South Africa's pledge is conditional.

Finally, Argentina, Saudi Arabia and Turkey have not proposed GHG reduction pledges for 2020 (as of 1 October 2015, Argentina and Turkey had submitted post-2020 pledges to the UNFCCC as part of their Intended Nationally Determined Contributions).

Despite progress towards implementing policies in line with pledges, work remains to be done to bring all G20 countries into pledge attainment. Additionally, better data are necessary to adequately track this progress in some countries. Ensuring continued progress towards 2020 pledges will reduce the mitigation burden associated with achieving the post-2020 pledges put forward in the INDCs.

This section has examined the extent to which G20 countries are proceeding towards the minimum level of their 2020 pledges, in light of the importance of pre-2020 GHG reductions for achieving consistency with 2°C scenarios, with implications beyond 2020. As described earlier in this chapter, this report does not address the global emissions gap in 2020, so the cumulative impact of the progress towards 2020 pledges is not calculated. UNEP (2014) found that emissions under the global current policy trajectory – taking into account progress by the G20 countries – roughly aligned with the higher-emissions end of the range associated with meeting the unconditional pledges.

It is important to recognise that these pledge levels do not align with the least-cost pathways to limit warming with stringent mitigation action starting in 2010 (UNEP, 2014). Ideally, all countries with 2020 pledges will recognise the need to exceed their undertakings while countries without 2020 pledges will strengthen their own mitigation ambition with appropriate polices and measures. This would allow a transition towards a pathway in line with a least-cost trajectory after 2020, with the associated economic, technology, societal co-benefits, and climate outcome benefits highlighted in Section 2.2.

28 Calculated for China based on an assumed GDP growth rate of 8.5 per cent (PBL, 2015) and 7.0 per cent (CAT, 2015), and for India based on an assumed GDP growth rate of 7.5 per cent (PBL, 2015) and 6.4 per cent (CAT, 2015).

29 A study commissioned by Japan's Ministry of Environment (MOE, 2015) projected that by 2030, the share of renewable energy in the electricity sector could reach around 25-30 per cent in a 'medium deployment' case and 30-35 per cent in a 'high deployment' case.

30 See CCA (2014) for further discussion.

Chapter 3

The emissions gap in 2025 and 2030

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3.1 Introduction

The Lima Call for Climate Action, adopted by Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in December 2014, noted the gap between Parties' mitigation pledges for 2020 and the emission pathways consistent with limiting the increase in global average temperature to below 2°C or 1.5°C (UNFCCC, 2014). It reiterated the invitation issued by the 2013 Warsaw decision for Parties to communicate their Intended Nationally Determined Contributions (INDCs) towards achieving the objective of the Convention (UNFCCC, 2013) (see Box 3.1).

This chapter explores the INDCs submitted by 1 October 2015 (UNFCCC, 2015a), with a specific focus on the extent to which the INDCs *in aggregate* are in accordance with the long-term objective of the Convention, which is "[...] to achieve [...] stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system". The chapter quantifies an 'emissions gap' – the gap between future emissions under full implementation of the INDCs and under the pathways consistent with limiting warming to below 2°C in 2100 – for the years 2025 and 2030. The Chapter first presents qualitative information about the

Box 3.1: INDCs in the Warsaw (2013) and Lima (2014) decisions under the UNFCCC

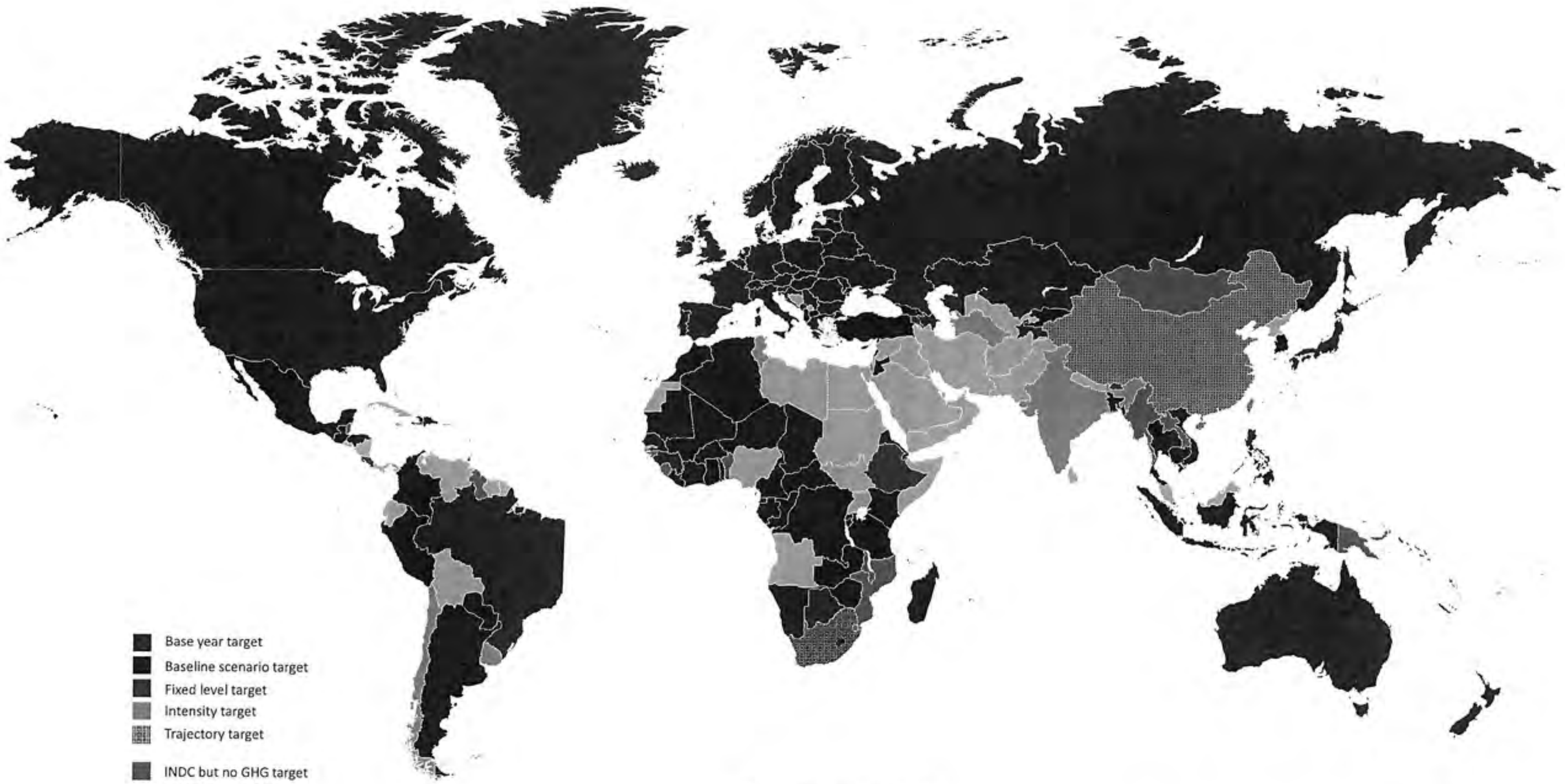
The Warsaw decision 1/CP19 (UNFCCC, 2013) introduced the concept of INDCs as follows:

- All Parties are invited to initiate or intensify preparations for their INDCs, without prejudice to the legal nature of the contributions
- All Parties are invited to communicate their INDCs well in advance of COP 21 "[...] (by the first quarter of 2015 by those Parties ready to do so) in a manner that facilitates the clarity, transparency and understanding of the intended contributions, without prejudice to the legal nature of the contributions".

The Lima decision 1/CP20 (UNFCCC, 2014) reiterated the points agreed in Warsaw, and also:

- Agreed that each Party's intended nationally determined contribution towards achieving the objective of the Convention as set out in its Article 2 will represent a progression beyond the current undertaking of that Party
- Invited all Parties to consider communicating their undertakings in adaptation planning or consider including an adaptation component in their INDCs
- Agreed that the information to be provided by Parties may include, as appropriate, inter alia, quantifiable information on the reference point (including, as appropriate, a base year), time frames and/or periods for implementation, scope and coverage, planning processes, assumptions and methodological approaches including those for estimating and accounting for anthropogenic greenhouse gas emissions and, as appropriate, removals, and how the Party considers that its INDC is fair and ambitious, in light of its national circumstances, and how it contributes towards achieving the objective of the Convention as set out in its Article 2 (UNFCCC, 1992).

Figure 3.1: Map showing countries that submitted INDCs by 1 October 2015



Adapted from WRI CAIT Climate Data Explorer

Note: The boundaries and names shown and designations used on this map do not imply official endorsement or acceptance by the United Nations

Source: WRI CAIT Climate Data Explorer (WRI, 2015)

INDCs submitted, concerning – for example, the treatment of adaptation, equity, and various GHG accounting issues. It then quantifies future global GHG emission pathways with full implementation of INDCs out to 2030, and compares them to the pathways for limiting warming to below 2°C that were described in Chapter 2.2. INDCs that countries intend to achieve unconditionally, as well as INDCs that are subject to conditions (such as the provision of international climate finance), are evaluated separately. A final update of the assessment including later submissions will be presented on the UNEP Live website before the start of COP 21.

3.2 Broad characteristics of submitted INDCs

By 1 October 2015, a total of 119 INDCs, covering 146 countries and 85-88 per cent of global GHG emissions in 2012 (JRC/PBL, 2012; WRI, 2015), had been submitted to the UNFCCC[1,2]. Every INDC includes a mitigation component and just over 85 per cent cover both mitigation and adaptation. Fifteen INDCs cover mitigation only.

Mitigation INDCs were submitted by countries from all regions (see Figure 3.1), and the 10 largest emitters had all submitted their INDCs by 1 October. These are, in descending order of emission levels, China, the USA, EU, India, Russia, Indonesia, Brazil, Japan, Canada and Mexico. The review of the INDCs submitted by 1 October 2015 identified broad mitigation-related groupings as follows:

Coverage: 38 INDCs explicitly state that they are economy-wide. Many of these cover 100 per cent of national GHG emissions, while another specifies 98.5 per cent coverage.

Sectors: 50 INDCs include all major IPCC sector categories (energy, industrial processes and product use, agriculture, waste, and Land Use, Land-Use Change and Forestry (LULUCF)), while 61 INDCs are sector-specific. Eight INDCs do not explicitly state which sectors are covered.

Nitrogen trifluoride: 19 INDCs cover nitrogen trifluoride (NF_3, also a Kyoto gas from 2013 onward) in addition to all Kyoto GHGs of the first commitment period. With respect to NF_3, two countries (Gabon and Republic of Congo) indicate the gas is to be included in future.

Selective GHGs: 50 INDCs cover only CO_2, N_2O and CH_4 (and another INDC includes SF_6 in addition to these). Eleven INDCs include only CO_2 emissions, while two (Mauritius and Mexico), besides first-commitment-period Kyoto Protocol gases, also include Short Lived Climate Forcers (SLCF)[3].

100-year Global Warming Potential (GWP): The common metric of 100-year GWP values is indicated in some, but not all, INDCs, referring to different IPCC Assessment Reports (ARs). GWP values used in INDCs are not all the same. 38 INDCs indicate the use of 100-year GWP values from the IPCC Second Assessment Report (AR2), while 29 INDCs use values from the IPCC AR4. Mexico, Brazil and Ecuador use 100-year GWP values from the IPCC AR5. Brazil further indicated 100-year Global Temperature Potential (GTP) values from the IPCC AR5.

3.2.1 *Forms of mitigation contributions*

Figure 3.1 illustrates that Parties' mitigation contributions take several forms. Below, the various forms of targets included by Parties in their INDCs are summarized.

Base year target: 32 INDCs report on an absolute reduction from historical base year emissions. The base year chosen varies, with 1990, 2005 and 2010 being the most common. Most Parties chose 2030 as the target year for their INDCs. However, 11 countries chose 2025.

Baseline scenario target: The form of emissions reduction relative to a baseline projection has been chosen in 63 INDCs, mainly for countries located in South and Central America, Africa and South Asia. Two countries using a baseline scenario target are Guyana and Mozambique. They quantify the $MtCO_2e$ they intend to reduce, but do not specify relative baseline emissions projections.

Trajectory target: South Africa has a trajectory target stating the emission range in 2025 and 2030 and adds an emission range in absolute Mt to its trajectory target. Specifying a peaking year is part of China's and Singapore's INDCs. In these cases, the timing of the maximum CO_2 emissions has been communicated, but not the level, while adding intensity targets.

Intensity target: China also specifies the carbon intensity of GDP, indicating percentages by which CO_2 emissions per unit of GDP will be reduced by 2030, compared to the 2005 intensity. Singapore adopts the same approach, but for all GHG emissions, giving an emission intensity of GDP. A further four countries (Chile, India, Tunisia and Uruguay) indicate reductions in emission intensity of GDP as the main form of their mitigation INDC.

Fixed level target: Seven countries put forward a fixed level target; that is, they specify the $MtCO_2e$ that they intend not to exceed in a given year (Armenia, Bhutan, Costa Rica, Eritrea, Ethiopia, Israel and Sierra Leone). Kenya's INDC, though framed as percentage emission reduction relative to a baseline projection, adds the Mt in the same sentence; the calculation of absolute emissions in 2030 is simple multiplication.

Actions and non-GHG metrics only: Six countries (Gambia, Guinea Bissau, Malawi, Myanmar, Rwanda and Swaziland) include only actions and another four countries only non-GHG metrics (Cape Verde, Papua New Guinea, Samoa and Vanuatu).

Additional non-GHG metrics: Some INDCs include additional non-GHG metrics, for example, in the form of a target for non-fossil-fuel primary energy share, in the case of China, and a reduction from baseline projections of Short Lived Climate Pollutants, in the case of Mexico.

1 This total of 119 recognizes that the EU submitted collectively as 1 INDC. Counting the 28 EU member states separately, the country total covered by the INDCs is 146.

2 Covering all sectors including land use, land-use change and forestry (LULUCF), and all six Kyoto gases of the first commitment period [carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6)].

3 Mexico's unconditional INDC is equivalent to a reduction of 51 per cent of black carbon (BC); with conditional reductions extending up to 70 per cent of BC emissions, both below BAU by 2030. Mauritius does not provide further information about their SLCF emissions.

Renewable energy (RE) target: 42 INDCs include quantified renewable energy (RE) targets as a form of non-GHG metric or actions consistent with their GHG target, in addition to other forms. For example, Brazil targets 45 per cent of renewables in its energy mix by 2030, including expanding the use of renewable energy sources other than hydropower to between 28-33 per cent and increasing the share of renewables (other than hydropower) in the power supply to at least 23 per cent. Furthermore, eight INDCs (Cape Verde, Gabon, Indonesia, Jordan, Lebanon, Papua New Guinea, Samoa and Vanuatu) made RE targets part of their headline mitigation contribution. As an example, Gabon's RE target is expressed as 80 per cent of electricity supply from hydropower by 2025, and as a summary component of its mitigation INDC in addition to an emission reduction target, while Samoa's contribution is a "[...] 100% renewable energy target for electricity generation through to the year 2025".

From the above review, it is evident that, in the absence of agreed forms of mitigation contribution and the units in which those might be expressed, countries have selected a wide variety of forms. Over 50 per cent of the mitigation INDCs have taken the form of emission reduction relative to a baseline projection. Within single forms, different units have been chosen; forms are not mutually exclusive; and several countries have chosen more than one form of mitigation contribution. This has increased the analytical challenge of comparing INDC elements and ensuring consistency when aggregating the different contributions.

3.2.2 Treatment of Agriculture, Forestry and Other Land Use

The vast majority of INDCs includes the land-use sector or a component of it. Only a few countries (including Albania, Andorra, Djibouti, Georgia, Marshall Islands, Republic of Macedonia and Trinidad and Tobago) explicitly exclude it. Some countries (for example, Republic of Korea) indicate that a decision on whether to include LULUCF will be made later. Few countries explicitly include a separate forest goal (for example, Benin, China and India).

Most Parties referring to LULUCF include it (or at least the forest component of it) as any other sector within the INDC. In some cases it is not clear if LULUCF is included in the base year. Among those Parties referring to LULUCF accounting rules (most developed or Annex I country Parties), in several cases there is some uncertainty on which rule will be applied. Canada, United States and Australia intend to use a net-net approach[4]. Japan and Switzerland declare the use of an equivalent methodology to those under the Kyoto Protocol. New Zealand will confirm details of the accounting approach prior to or upon ratification of the Paris Agreement. The EU indicates that policy on how to include LULUCF will be established as soon as technical conditions allow. In addition, Switzerland, Australia, New Zealand, United States and Canada declared also that emissions from natural disturbances may or will be excluded, consistent with available IPCC guidance.

Almost all developing countries have mitigation actions both in agriculture and LULUCF. In many cases, LULUCF represents the most relevant current source of emissions and the main area for future mitigation. Often REDD+ is mentioned, but sometimes the relationship between INDC and REDD+ is not fully clear.

Several developing countries include specific LULUCF information within the unconditional and the conditional targets (for example the expected LULUCF mitigation and the related cost of implementation).

In terms of methodology for estimating GHG emissions and removals, the IPCC 2006 Guidelines are mentioned as the primary guidance by most countries (including all developed country Parties). The 2003 Good Practice Guidance for LULUCF is mentioned by few countries (for example, Kenya, Madagascar, Peru, Jordan and Benin). Some countries also refer to the 1996 IPCC guidelines (for example, Argentina, Democratic Republic of Congo, Macedonia and Republic of Korea).

3.2.3 Adaptation components in INDCs and undertakings in adaptation planning

The Lima decision invited all Parties to consider including an adaptation component in their INDCs or to consider communicating their undertakings in adaptation planning. Components on adaptation have been included in just over 85 per cent of INDCs submitted by 1 October (102/119). Of these, three (Australia, Israel and Monaco) indicate in their INDCs that they are working to build their adaptation strategies during 2015, while Brazil's INDC states that it is "[...] working on the design of new public policies, through its National Adaptation Plan (NAP), in its final elaboration phase", and Macedonia's INDC states that "[...] climate change adaptation shall be the subject of more detailed analysis in the future" (UNFCCC, 2015a).

Four undertakings in adaptation planning were submitted or referred to in the INDCs submitted to the UNFCCC. Undertakings in adaptation planning were submitted by both the EU and the USA. These are available on the UNFCCC website (UNFCCC, 2015b) as distinct from the INDC portal (UNFCCC, 2015a). Furthermore, New Zealand and Norway refer in their INDCs (UNFCCC, 2015a) to undertakings in adaptation planning by referring to chapters in their national communications.

3.2.4 Specifying support required or offered

Several countries have stated requirements for support for their INDCs in the form of finance, technology transfer, and investment in capacity building, and through international support or the use of international market mechanisms or both.

Conditional versus unconditional INDCs: 42 INDCs have both unconditional and conditional components to their GHG emission reduction targets while 39 include only conditional contributions. 37 INDCs do not make a clear distinction between conditional and unconditional provisions in their INDCs.

4 Net-net is a term used to describe a method for LULUCF accounting under the Kyoto Protocol, where credits and debits are obtained by comparing the accounting period to the base year. However, under the Kyoto Protocol, LULUCF forestry activities were often without reference to the base year, or were with reference to a projected reference level. If an INDC explicitly includes LULUCF in the base year, then net-net is assumed to be treating LULUCF is the same way as any other GHG inventory sector. It is also possible for countries to use a net-net accounting approach where the base year does not include LULUCF, but the LULUCF contribution is added or subtracted from total national emissions in the target year.

Use of international market mechanisms: 22 INDCs indicate they will mainly achieve their emission reductions domestically, although only seven of these specifically state international market mechanisms will not be used. An explicit intention to use these mechanisms is stated by 11 countries, while 20 INDCs express support for their use and a further 23 are considering their potential use. Norway and Iceland indicate in their INDCs that they will likely continue their participation in the EU Emissions Trading System (ETS). Liechtenstein's INDC indicates "[...] supplemental emission reductions abroad", while Albania, Chad, Ethiopia, Montenegro and Rwanda intend to "[...] sell carbon credits". In formulating their mitigation INDCs, four countries (Ghana, Guyana, Japan and New Zealand) have assumed that international mechanisms will be used.

Requests for international support, including finance: 91 countries have indicated requirements for international support, with 71 INDCs quantifying these requirements in monetary terms. Examples include India's INDC, which notes that "[...] a preliminary estimate suggests that at least US$2.5 trillion will be required [...]" as a total cost, for its intended contributions, and Morocco's INDC, which communicates that meeting its target will require US$45 billion of investment, of which US$35 billion is conditional on international support (UNFCCC, 2015a). Ethiopia notes that "[...] full implementation of Ethiopia's INDC requires support in the form of finance, capacity building and technology transfer", and estimates that implementing its Green Economy Strategy requires expenditure which exceeds US$150 billion (UNFCCC, 2015a). Another example comes from Kenya's INDC, which states that "Kenya will require support in form of finance, investment, technology development, and capacity building", estimating that "[...] over US$40 billion is required for mitigation and adaptation actions across sectors up to 2030". For further detail on these examples, see UNFCCC (2015a).

Offers of international support (including finance): No Annex II country has specified finance, technology or capacity-building support that might be offered or provided in the future. China has offered support for other developing countries, "[...] including the small island developing countries, the least developed countries and African countries", and plans to establish the "Fund for South-South Cooperation on Climate Change". Finally, the Republic of Belarus stated that it has supported, and will support, developing nations, mainly in the area of awareness-raising, education, capacity building, and in the area of research and development relating to climate change issues. For further detail on these examples, see UNFCCC (2015a).

3.2.5 How countries address equity, ambition and Article 2 of the Convention

The Lima decision invited information on fairness and ambition, and how the INDC contributes towards achieving the objective of the Convention as set out in its Article 2 (UNFCCC, 1992).

In relation to the objective of the Convention, 52 of the INDCs make reference to Article 2 (verbatim or indirectly), while 62 INDCs refer to the 2°C goal; 36 INDCs make no reference to either Article 2 or 2°C.

Most INDCs have addressed equity (or fairness) and ambition in some way. However, 80 INDCs do not offer specific metrics to support their claims to relative fairness in relation to their INDCs, instead providing only general statements or reference to principles. A further 31 INDCs draw on analyses conducted by modelling teams or experts from within the country. Only eight INDCs – Andorra, Brazil, Macedonia, Monaco, Norway, Republic of Moldova, South Africa and Switzerland – refer to external, independent analyses.

On equity, a range of arguments and indicators is referred to in the INDCs. The most common indicator chosen is per capita emission levels, described in 57 INDCs. Specifically, 68 INDCs refer to their countries representing a small share of global emissions. Additionally nine INDCs (Andorra, Armenia, Bangladesh, EU, Japan, Jordan, Monaco, Norway and Switzerland) reference ranges in IPCC reports for consistency with 2°C.

Further details are available in Annex B of this report (available online), presenting a summary of key characteristics of all INDCs submitted by 1 October 2015 in table form.

3.3 Methodology for quantifying the effect of INDCs on global GHG emissions

3.3.1 Overview of scenarios

To assess the impact of the INDCs on future global GHG emissions, global GHG emissions in 2025 and 2030 are compared under four scenarios. Each scenario is composite. It draws on multiple individual scenarios from the published literature in line with the characteristics described below.

- **The baseline scenario** assumes that no additional climate policies have been put in place since 2010 (see also Chapter 2). It is sourced from the scenario database that accompanied the Fifth Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC) (Clarke *et al.*, 2014).
- **The current policy trajectory scenario** takes into account currently adopted and implemented policies. It is based on (i) the current policies scenarios from three[5] out of the eight global INDC analyses[6] that provide such current policy trajectory scenarios, (ii) official country-specific data sources, and (iii) independent country-specific data sources, as detailed in Table 3.1.

5 These three groups with current policy scenarios are: (i) the Climate Action Tracker by Climate Analytics, NewClimate Institute, Ecofys and Potsdam Institute for Climate Impact Research–PIK (CAT, 2015); (ii) International Energy Agency (IEA, 2014); and iii) PBL Netherlands Environmental Assessment Agency (den Elzen *et al.*, 2015). The groups from LSE and DEA (see footnote 6) also have current policies scenarios that are calibrated at the IEA current policies scenario.

6 These eight global groups with INDC scenarios are: (i) the Climate Action Tracker by Climate Analytics, NewClimate Institute, Ecofys and PIK (CAT, 2015); (ii) PBL Netherlands Environmental Assessment Agency (PBL, 2015) (iii) International Energy Agency (IEA, 2014, 2015); (iv) London School of Economics and Political Science (LSE) (Boyd *et al.*, 2015); (v) Climate and Energy College / University of Melbourne dataset (Meinshausen, 2015); (vi) Danish Energy Agency (DEA, 2015); (vii) Climate Interactive (Climate Interactive, 2015); and (viii) NIES (Masui, 2015).

- **The INDC scenario** portrays how global GHG emissions might evolve with full implementation of INDCs. It is sourced from (i) the official estimates included in the INDCs (UNFCCC, 2015a), (ii) calculations based on the INDCs and on other documents submitted by countries to the UNFCCC (such as national GHG inventories, national communications, biennial reports, and biennial update reports), (iii) estimates published in country-specific studies, and (iv) eight global analyses, described further below.

- **The 2°C scenario** represents an idealized global scenario consistent with limiting warming to below 2°C, keeping the option open to strengthen the global temperature target to 1.5°C. It comprises the subset of scenarios from the IPCC AR5 scenario database that (i) have a greater than 66 per cent chance of keeping global temperature increase to below 2°C in 2100 compared pre-industrial levels, (ii) are consistent with full implementation of 2020 pledges that are anchored in the Cancun Agreements, and

Table 3.1: Overview of INDC studies included in the assessment by type of source (in alphabetical order)

Reference	Geographic coverage	Sector and gas coverage	Scenario coverage
Global INDC analyses			
Climate Action Tracker (CAT, 2015; Gütschow *et al.*, 2015)	Global	All	Current policy trajectory, INDC
Climate and Energy College / University of Melbourne dataset (Meinshausen, 2015)	Global	All	INDC
Climate Interactive (Climate Interactive, 2015)	Global	All	INDC
Danish Energy Agency (DEA, 2015)	Global	All	INDC
London School of Economics and Political Science (LSE) (Boyd *et al.*, 2015)	Global	All	INDC
International Energy Agency - World Energy Outlook (IEA, 2014; IEA, 2015)	Global	CO_2 from energy use[a]	Current policy trajectory, INDC
National Institute for Environmental Studies (NIES) (Masui, 2015)	Global	All	INDC
PBL Netherlands Environmental Assessment Agency (den Elzen *et al.*, 2015; PBL, 2015)	Global	All	Current policy trajectory, INDC
Official country-specific data sources			
Australian Government (2015)	Australia	All	Current policy trajectory
Biennial Report/Biennial Update Report (UNFCCC National Reports, 2015)[a]	Brazil, Japan, Norway, Korea, Republic of, Russia and Switzerland	Varies	Current policy trajectory
Department of Environmental Affairs (2014)	South Africa	All	Current policy trajectory, INDC
EEA (2014)	EU	All	Current policy trajectory
Government of Canada (2014)	Canada	All	Current policy trajectory
INDCs (UNFCCC, 2015a)	Brazil, Japan, Korea, Republic of, Mexico, Morocco, South Africa and the USA	Varies	INDC
National Climate Change Strategy (2013)	Mexico	All	Current policy trajectory
National Communications (UNFCCC National Reports, 2015)	Indonesia, USA	Varies	INDC
Independent country-specific data sources			
Centre for Policy Research (Dubash *et al.*, 2015)	India	CO_2	Current policy trajectory
Climate Advisers (Belenky, 2015)	United States	All	Current policy trajectory, INDC
Energy Research Institute Low carbon scenarios (based on Jiang *et al.*, 2013)	China	CO_2[b]	Current policy trajectory, INDC
Indian Institute of Management, Ahmedabad (Garg *et al.*, 2014)	India	All	Current policy trajectory
Institut du Développement Durables et des Relations Internationales (IDDRI, 2015)	Japan	All	INDC
National Center for Climate Strategy and International Cooperation (Sha *et al.*, 2015)	China	CO_2[b]	INDC
World Resources Institute (Kuramochi, 2014)	Japan	All	INDC
World Resources Institute (Hausker *et al.*, 2015)	United States	All	Current policy trajectory, INDC

[a] Augmented with US Environmental Protection Agency (2012), JRC/PBL (2012) and den Elzen *et al.* (2015) to produce economy-wide figures.
[b] Augmented with Tavoni *et al.* (2015) and Government of China (2012) to produce economy-wide figures.

(iii) distribute emission reductions across regions, gases and sectors after 2020 in such a way that that global mitigation costs of necessary reductions are minimized.

3.3.2 Methodology for current policy trajectory and INDC scenarios

While the baseline and 2°C scenarios are drawn entirely from the IPCC AR5 database and have not been adjusted, the data sources and methodologies for the current policy trajectory and INDC scenarios are more complex, as indicated above and in Table 3.1. The methodology in the assessment of these scenarios is therefore described in more detail in the following.

As mentioned, the **current policy trajectory scenario** draws from the current policy scenarios of three of the eight global analyses, in addition to current policy scenarios from official and independent country-specific sources. Where no data are available from official or independent country-specific sources, the assessment uses the median current policy scenario estimate from the three global studies.

Current policy trajectory scenarios assume that no additional mitigation action is taken beyond current policies – even if it results in 2020 pledges not being achieved or being overachieved. Current policy trajectories reflect all adopted and implemented policies, which for the purpose of this report are defined as legislative decisions, executive orders, or their equivalent. This implies that publicly announced plans or strategies alone would not qualify, while individual executive orders to implement such plans or strategies would qualify. Ultimately, however, these definitions may be interpreted differently in the different underlying studies. This assessment is bound by the definitions that the individual research groups use.

The **INDC scenario** draws on individual INDC scenarios from the same eight global analyses. It furthermore draws on official and independent country-specific sources, as indicated in Table 3.1. These are converted to two global estimates in the same manner as for the current policy trajectory scenario. Finally, it considers five additional scenarios that are created by combining emission growth rates of the non-INDC countries from five modelling groups (Tavoni *et al.*, 2015)[7] with the median emission values for INDC-countries taken from the INDC scenarios of the eight global INDC analyses, and the two additional analyses based on the aggregated official and independent country-specific data sources[8]. The resulting composite INDC scenario comprises the median, 10th percentile, and 90th percentile global estimates for 2025 and 2030 from all of these sources.

7 *The Low climate IMpact scenarios and the Implications of required Tight emission control Strategies* (LIMITS) study modelled reference scenarios consistent with achieving the Cancun pledges, assuming constant climate policies thereafter. The LIMITS modelling groups are: Energy Research Centre of the Netherlands (ECN), Fondazione Eni Enrico Mattei (FEEM), International Institute for Applied Systems Analysis (IIASA), Pacific Northwest National Laboratory (PNNL), and Potsdam Institute for Climate Impact Research (PIK).

8 These five scenarios represent the sum of the median value for 2025 and 2030 emissions for countries with INDCs from the ten INDC analyses (eight global studies, one official and one national global estimate) and estimated values for future emissions in non-INDC countries. The latter are calculated by applying the 2010-2030 emission growth rates from each of the five LIMITS studies to the median 2010 emissions of the non-INDC countries from the ten INDC analyses. This results in five additional global INDC scenarios considered in the composite INDC scenario.

3.3.3 Unconditional and conditional INDC cases

As discussed in Section 3.2, some countries place conditions on all or part of their INDCs. Consequently, two cases are explored in this assessment: unconditional INDCs and conditional INDCs. In the unconditional INDC case, Parties with INDCs are assumed to implement targets without conditions only. Parties that solely have a conditional target, or have not submitted an INDC, are assumed to follow a current policy trajectory. In the conditional INDC case all Parties with INDCs are assumed to implement their conditional targets. Parties that only have an unconditional target are assumed to implement that target, and Parties with no INDCs are assumed to follow a current policy trajectory, or if that is not available, a baseline scenario. In both the unconditional and the conditional INDC cases, it is assumed that for any traded international offsets, each unit is counted towards the INDC of a single country only – either the buyer or the seller.

The studies from which the current policy trajectory scenario and the INDC scenario are drawn differ in a number of respects, such as: conditional versus unconditional INDCs; assumptions regarding non-covered sectors and gases; treatment of LULUCF and surplus emission units; and different bases for calculating Global Warming Potentials (GWPs).

The methodological differences between the groups cannot be fully harmonized, which leads to some uncertainty as indicated in the results presented in Section 3.4, where the implications of the differences between studies are also further explored.

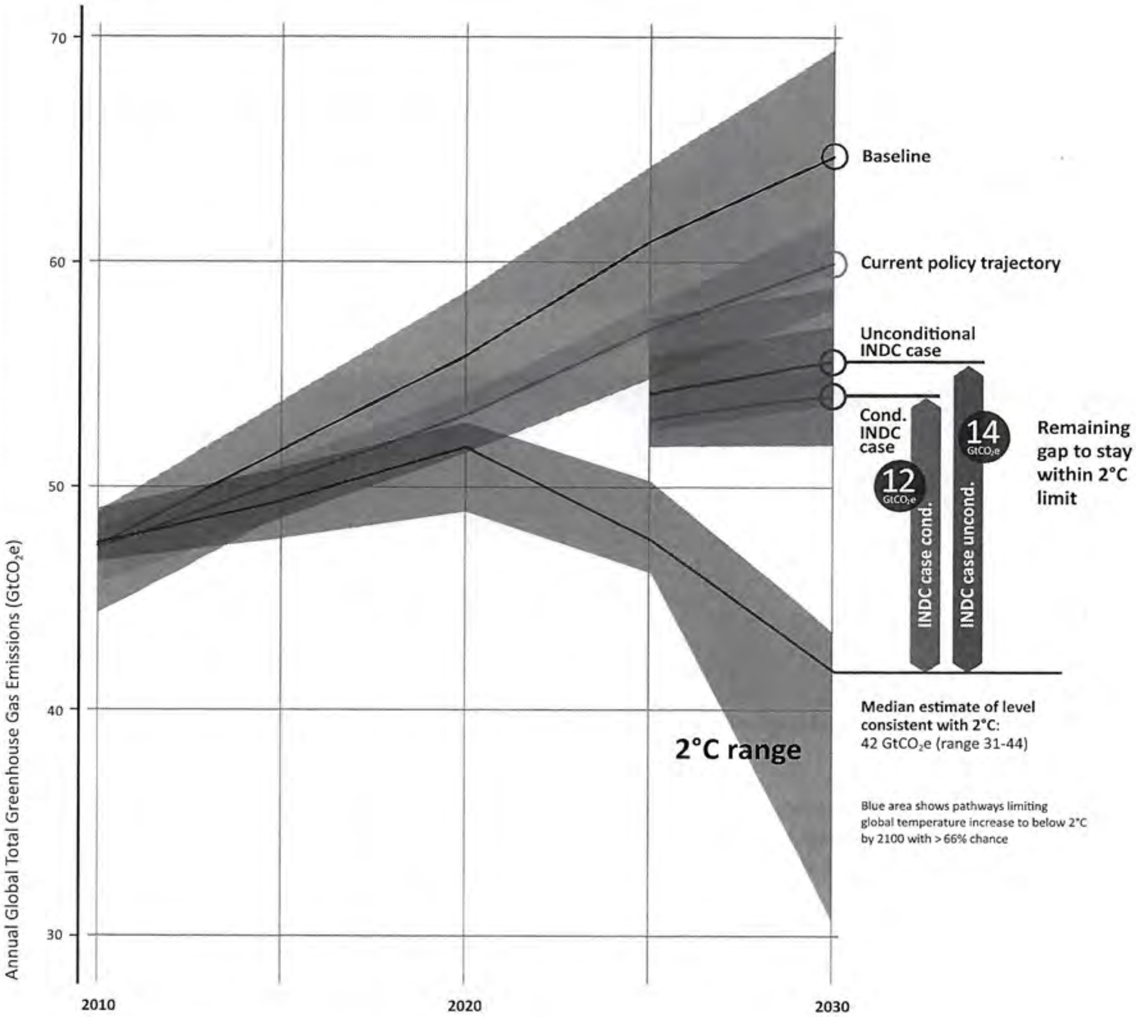
3.4 The effect of INDCs on global GHG emissions

This section presents the findings regarding the aggregate effect on global total GHG emissions of full implementation of the INDCs in 2025 and 2030, compared to the emissions implied by baseline, current policy trajectory and 2°C scenarios. The results are shown in Figure 3.2, with details on medians and ranges provided in Table 3.2. It should be noted that the baseline emission projection is about 2.5 $GtCO_2e$ lower in 2030 compared to the projection in last year's Emissions Gap Report (UNEP, 2014). The reason is that this year baseline emission projections are not harmonized to the global GHG emissions of 49.5 $GtCO_2e$ in 2010.

Taken together, Figure 3.2 and Table 3.2 show that full implementation of the **unconditional INDCs** will reduce global GHG emissions in 2025 by 7 $GtCO_2e$ (range: 3-8) relative to the baseline, and by 3 $GtCO_2e$ (range: 0-4) relative to the current policy trajectory. This leaves a gap in 2025 of 7 $GtCO_2e$ (range: 5-10) between the unconditional INDC scenario and the 2 °C scenario.

In 2030, the reduction from the unconditional INDCs is 9 $GtCO_2e$ (range: 6-11) relative to the baseline and 4 $GtCO_2e$

Figure 3.2: Global greenhouse gas emissions under different scenarios and the emissions gap in 2030



Sources:

Baseline and 2°C ranges: 20th to 80th percentile of the scenarios in IPCC database

INDC case: 10th to 90th percentile of the global estimates for 2025 and 2030 from all global analyses and official and independent country-specific sources

Table 3.2: Global total GHG emissions, emission reductions and distance to the 2°C range in 2025 and 2030 under different scenarios (median and range)

2025 emissions gap assessment estimates				
Scenario	Global total emissions (range)	Emission reduction compared to baseline (range)	Emission reduction compared to current policy trajectory (range)	Remaining emission reduction to stay within 2°C limit (range)
	$GtCO_2e$	$GtCO_2e$	$GtCO_2e$	$GtCO_2e$
Baseline	61 (57-64)	n/a	n/a	13 (9-17)
Current policy trajectory	57 (55-58)	4 (3-6)	n/a	9 (7-10)
Unconditional INDCs	54 (53-58)	7 (3-8)	3 (0-4)	7 (5-10)
Conditional INDCs [a]	53 (52-56)	8 (5-9)	4 (1-5)	5 (4-8)
2°C pathways	48 (46-50)	13 (11-15)	9 (7-11)	0 (0)

2030 emissions gap assessment estimates				
Scenario	Global total emissions (range)	Emission reduction compared to baseline (range)	Emission reduction compared to current policy trajectory (range)	Remaining emission reduction to stay within 2°C limit (range)
	$GtCO_2e$	$GtCO_2e$	$GtCO_2e$	$GtCO_2e$
Baseline	65 (60-70)	n/a	n/a	23 (18-28)
Current policy trajectory	60 (58-62)	5 (3-7)	n/a	18 (16-20)
Unconditional INDCs	56 (54-59)	9 (6-11)	4 (1-6)	14 (12-17)
Conditional INDCs [a]	54 (52-57)	11 (8-13)	6 (3-8)	12 (10-15)
2°C pathways	42 (31-44)	23 (21-34)	18 (16-29)	0 (0)

[a] Assumes full implementation of both unconditional and conditional INDCs.

(range: 1-6) relative to the current policy scenario, leaving a gap of 14 $GtCO_2e$ (range: 12-17) between the INDC scenario and the 2°C scenario (See Figure 3.2 and Table 3.2)[9].

In comparison, if countries were to **also fully implement the conditional INDCs,** global GHG emissions in 2025 would be reduced by 8 $GtCO_2e$ (range: 5-9) relative to the baseline, and by 4 $GtCO_2e$ (range: 1-5) relative to the current policy trajectory. This leaves a gap in 2025 of 5 $GtCO_2e$ (range: 4-8) between the combined implementation of unconditional and conditional INDCs and the 2°C scenario.

In 2030, the emission reduction from the combined implementation of unconditional and conditional INDCs is 11 $GtCO_2e$ (range: 8-13) relative to the baseline, and 6 $GtCO_2e$ (range: 3-8) relative to the current policy scenario, leaving a gap of 12 $GtCO_2e$ (range: 10-15) between the INDC scenario and the 2°C scenario in 2030.

Excluding the potential impact of surplus emission units (for countries where achieving the INDC generates higher emissions than their current policy trajectory), would further reduce this gap by 0.5 $GtCO_2e$ (range: 0-1) by 2030, to a final level of 12 $GtCO_2e$ (range: 9-15).

If countries that have not yet submitted an INDC were to reduce their emissions by the same average percentage below current trajectories as those that have already submitted their INDCs (as of 1 October 2015), the gap for the full implementation of both unconditional and conditional INDCs could be narrowed by an additional 0.5 $GtCO_2e$ in 2025 and 1 $GtCO_2e$ in 2030, to 11 $GtCO_2e$[10].

3.4.1 *Temperature implications of the emission levels resulting from the INDCs*

The temperature implications of the emission levels implied by the INDCs are illustrated in Figure 3.3, which compares the emission levels estimated for the unconditional and conditional INDCs with emission pathways over the 21st century[11,12].

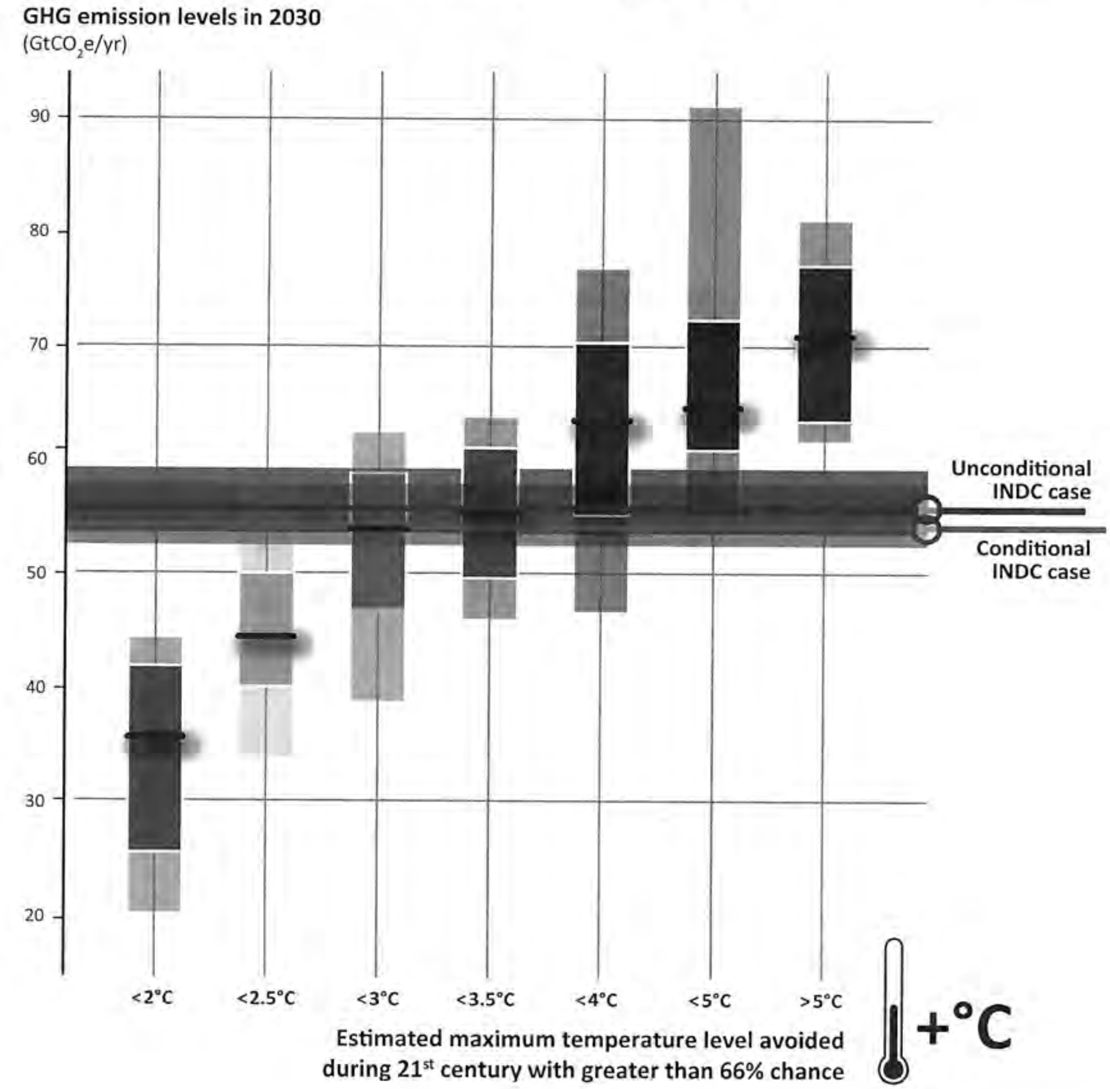
9 UNEP (2014) estimated a 2030 emissions gap of about 14–17 $GtCO_2e$, based on the extrapolation of the four pledge cases in 2020 (52–54 $GtCO_2e$). This study, however, estimates 2020 emissions at 54-55 $GtCO_2e$. Therefore, the lower end of the previous gap estimate (14 $GtCO_2e$) is no longer relevant, and the gap assessed in this report under the INDC scenario is more appropriately compared with the higher end of the previous gap estimate (17 $GtCO_2e$).

10 Countries covering 85 per cent of global emissions reduce emissions for the conditional INDCs about 6 $GtCO_2e$ below the current trajectories in 2030. The remaining 15 per cent are assumed to reduce emissions by about 1 $GtCO_2e$ ((6)/85×15=1.05).

11 Based on Rogelj *et al.* (2011) to warrant a sufficient coverage of scenarios in the range of interest. These scenarios assume a constant level of climate mitigation from 2000 or 2005 and until 2100.

12 Note that the scenarios underlying Figure 3.3 assume a constant level of mitigation ambition over the 21st century, from 2000 or 2005 onward. This is different from what is assumed for the 2°C – consistent scenarios in Chapter 2, where scenarios achieve the Cancun pledges in 2020 and then start a global mitigation path towards 2°C. As a result, the 2030 emission levels in line with limiting warming to below 2°C with greater than 66 per cent chance in Figure 3.3 are lower than the levels reported in Chapter 2.

Figure 3.3: Greenhouse gas emissions levels in the year 2030 from long-term scenarios that assume a constant level of climate action over time starting before 2010, compared to the estimated conditional and unconditional INDC emission levels for 2030



Scenarios are grouped based on the level of warming they avoid during the 21st century with at least 66% chance, and show median (black line), 15-85th percentile range (dark coloured boxes), and the minimum maximum range (ligher shaded boxes). The 10-90th percentile range for the INDC cases is shown.

The Figure illustrates that compared to the levels of 4°C and above that would be expected under baseline projections (see also Chapter 2) current policies and full implementation of the INDCs would reduce the long-term temperature projections. More specifically, Figure 3.3 illustrates that full implementation of unconditional INDC results in estimated 2030 emission levels that are most consistent with scenarios that limit global average temperature increase to below 3.5°C by the end of the century 2100 with >66 per cent chance.

Figure 3.3 furthermore illustrates that a move from implementation of the unconditional to combined implementation of both conditional and unconditional INDCs would have an effect on long-term temperature projections. Combined implementation of unconditional and conditional INDCs, results in projections becoming more consistent with long-term scenarios that limit global average temperature increase to below 3°C by the end of the century with a greater than 66 per cent chance[13].

There is significant overlap between the ranges of the unconditional and conditional INDC emission levels, as well as between the scenario bins. Taking uncertainty ranges into account, the 3.5°C value for implementation of unconditional INDCs could decrease to 3°C or increase towards 4°C for the low and high unconditional INDC estimates respectively. When including the full implementation also of conditional INDCs, the emission level estimates taking uncertainty ranges

13 Given the uncertainties in both projections and climate response, the resolution of the bins is limited and therefore the above-mentioned estimates are to be interpreted as indications of the broad order of magnitude of the expected avoided warming.

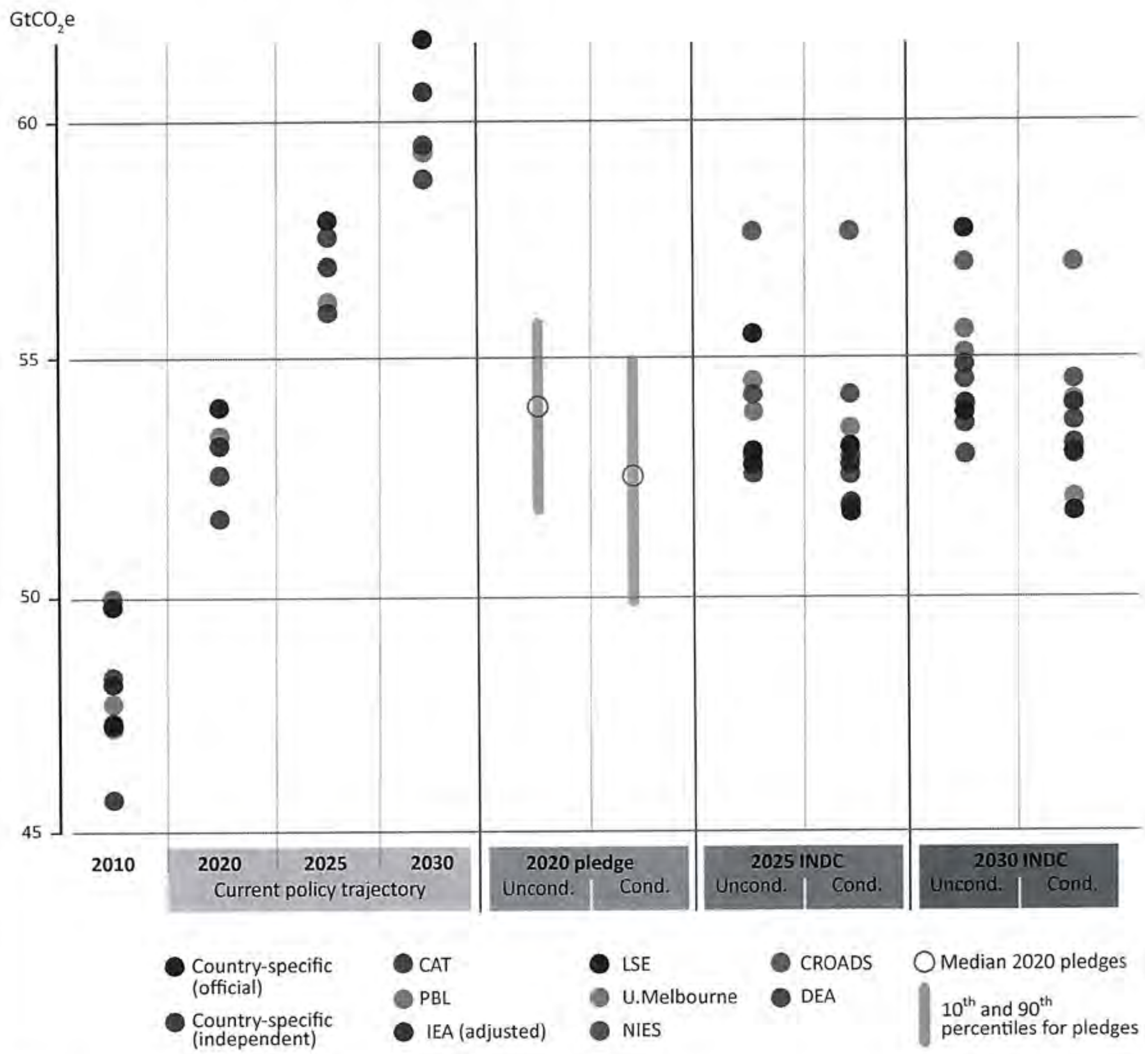
into account become most consistent with long-term scenarios that limit global average temperature increase to below 3-3.5°C by the end of the century with >66 per cent chance.

3.4.2 Overview of differences between studies and their implications

A number of methodological factors can contribute to differences in findings between studies. To illustrate the range of estimates from the studies considered for this assessment, Figure 3.4 provides an overview of historical emissions (2010), current policy trajectories (2020, 2025, and 2030), Cancun pledges (2020), and unconditional and conditional INDCs (2025 and 2030) by the different studies considered.

The figure illustrates that differences can be significant. However, it is noteworthy that, amongst all the global modelling and country-specific scenarios, there is unanimity that full INDC implementation would indeed reduce global emission levels in 2025 and 2030 relative to the current policy trajectory.

Figure 3.4: Global greenhouse gas emissions as implied by submitted INDCs (original data from different modelling groups, including LULUCF)



Notes:

Uncertainty ranges for baseline and 2°C scenarios are the 20th and 80th percentile of the full scenario dataset, the uncertainty range for current policy trajectories is assumed to be the same as for the baseline, the uncertainty ranges of the INDC scenario is 10th to 90th percentile of the data points.

Subsequent to the finalization of this gap assessment, the IEA has updated their unconditional INDC emission estimate for 2030 to 52 $GtCO_2e$. This is approximately 2 $GtCO_2e$ lower than the estimate shown in the figure and based on IEA (2015).

The main factors that contribute to the discrepancies and consequently the approximate ranges in the 2030 emission estimates are described below. Where possible, the uncertainty that each discrepancy implies for 2030 global emissions, is also indicated.

- **Non-covered sectors and countries**: There is often a significant range in the emission estimates for sectors not included under INDC pledges, such as emissions from international aviation and maritime transport (bunkers) and for countries which have not submitted an INDC. For example, the uncertainty range across the model groups for the emission projections from international bunker emissions are 1.7 $GtCO_2e$ (range: 1.3-2.1), which is consistent with the uncertainty ranges of the projections from international shipping and aviation organisations (ICAO, 2013; IMO, 2014). The results from different studies will vary, since some have explored the impact of mitigation policies of only a subset of countries.
- **Uncertainties surrounding the emission projections of the countries with INDCs**: Modelling groups have used different assumptions regarding the implementation of INDCs. Many INDCs put forward absolute GHG emission goals, which can be represented easily. There are also many INDCs that referenced a business-as-usual emission projection. However, for most INDCs an estimate of target-year or target-period emissions is given. The quantification of these INDCs is not surrounded with moderate uncertainties (see Section 3.5). The few countries putting forward GDP emission intensity targets (measured as the improvement in emissions per unit of GDP), did not provide target-year GDP estimates or indicate the data source for GDP absolute level, BAU, or reference level if given. The quantification of these INDCs with intensity targets poses additional uncertainties.
- **Land use, land-use change and forestry (LULUCF):** LULUCF plays a relevant role in the mitigation target of most INDCs. Quantification of the LULUCF contribution depends on the availability of adequate official information from each country on: (i) the modality of inclusion of LULUCF in the INDC (for example, LULUCF treated as any other sector or through special accounting rules); (ii) historical data and projections (for example, from INDC, GHG inventories, National Communications, Biennial Update Reports). Using information available in 32 INDCs[14] and based entirely on countries' information, the unconditional LULUCF mitigation contribution is estimated at around 1.6 $GtCO_2$ (of which 0.5 $GtCO_2$ comes from Annex I countries). In addition 0.3 $GtCO_2$ is explicitly indicated as conditional (from non-Annex I countries). Taking into account uncertainties due to accounting rules of ±0.3 $GtCO_2$ for Annex I countries, and due to countries' projections, the total range of LULUCF contribution ranges from negative contributions of 0.1 $GtCO_2$ to positive contributions of 4.3 $GtCO_2$. This range does not consider possible future natural disturbances in Annex I countries explicitly, the impact of which is assumed to be excluded according to UNFCCC Kyoto Protocol provisions. Another source of uncertainty for Annex I countries is the modality of inclusion of LULUCF in the base year, whose impact on GHG allowances is estimated as ±0.2 $GtCO_2$[15]. For non-Annex I countries, uncertainty stems from the range of country projections available and from the availability of adequate support to achieve the conditional targets.
- **Impact of harmonization of global 2010 emissions** (no impact on emissions gap): The median estimate of all model teams shows global emissions of 47.5 $GtCO_2e$ in 2010, which is lower than the independent global emission estimates of the IPCC AR5 of about 49.5 $GtCO_2e$ (range: 45-54). In Chapter 2, the global emission pathways consistent with meeting the below 2°C target also have global emissions with a median estimate of 47.5 $GtCO_2e$ by 2010, so the discrepancy between the historical emissions and the emission projections resulting from the INDCs of the model teams has not been corrected. If we were to resolve the discrepancy in historical emissions (that is, harmonization), this would also increase the emission projections resulting from the INDCs by about 2 $GtCO_2e$ (under a constant harmonization) or about 1 $GtCO_2e$ (under a decreasing harmonization, towards zero by 2050, for example). However, as the global emission pathways consistent with meeting the 2°C target also need to be harmonized, and thus would increase by the same amount, harmonization has no impact on the global emissions gap.
- **Conditional versus unconditional INDCs**: Some studies report separate figures for conditional and unconditional INDCs, while others combine this aspect with other uncertainties in a maximum/minimum range or leave out the conditional targets completely.
- **Surplus emission units**: For countries where the emission level resulting from the INDC is higher than the current policy trajectory, some studies use the current policies trajectory as the value for the INDC emission level, implying that they do not allow the use of surplus emissions, whereas the other studies assume INDC emission levels.
- **Global Warming Potential**: About 25 per cent of all countries have submitted their INDC based on GWP from the Fourth Assessment Report of the IPCC. Many of the models, however, still work based on GWP from the Second IPCC Assessment Report. It is not always possible to convert from one GWP to another in the context of a particular study without making assumptions that may differ by modelling group.
- **Differences between data sources for historic data and projections**: Assumptions differ on baselines and reference years.

14 11 Annex I Parties and 21 non-Annex I Parties accounting for about 41 per cent of global GHG emissions in 2012.

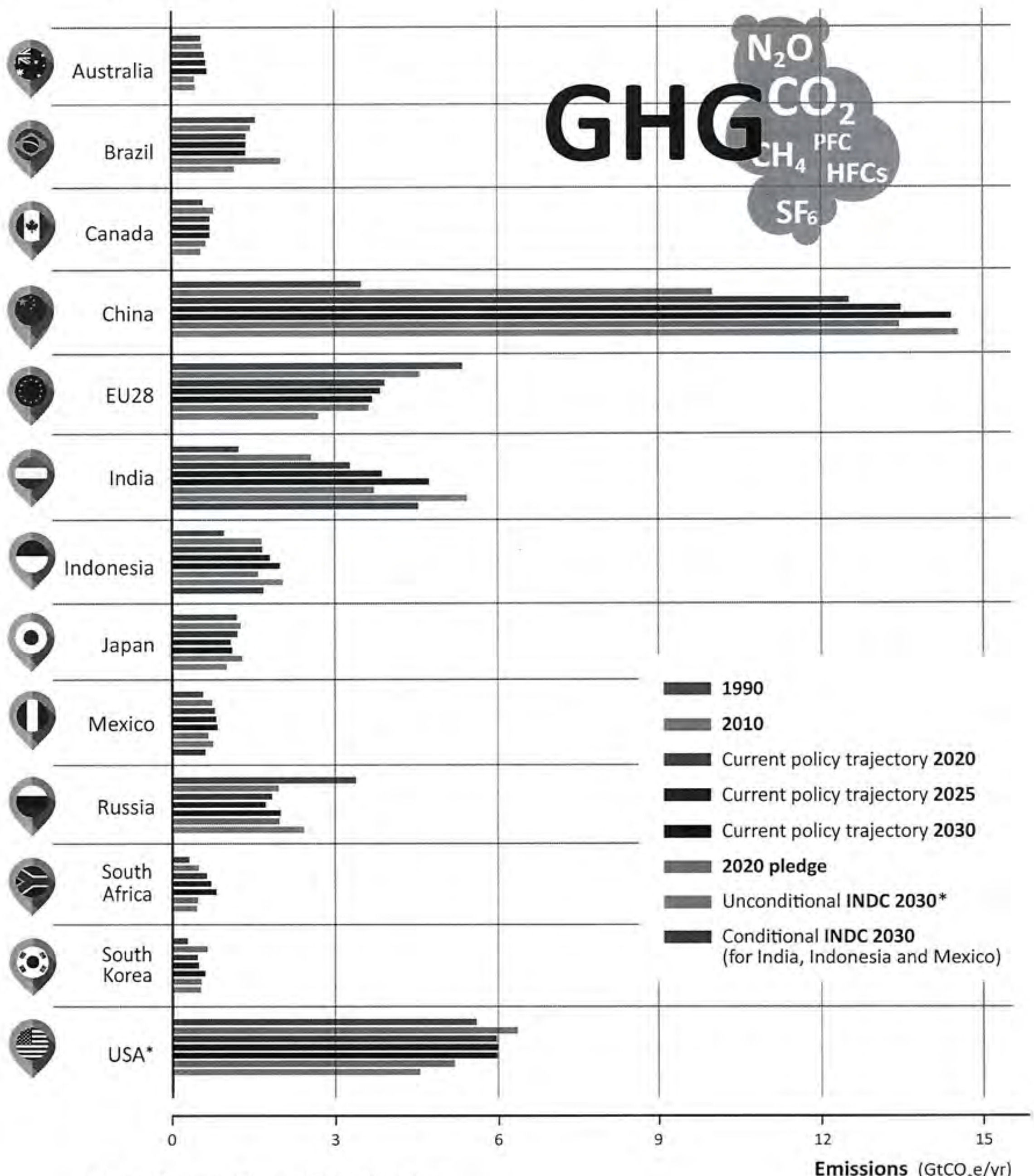
15 Here, natural disturbances are taken into account, if they are explicitly mentioned in the INDC, because if LULUCF is included in the base year natural disturbances are expected to be excluded in the base year.

3.5 INDCs of G20 countries

This section presents additional findings concerning the emissions of some of the highest-emitting countries – namely 13 of the G20 countries (counting the EU as one) that had submitted their INDCs by 1 October 2015. Their emission levels and INDCs have the largest impact on the aggregate, global findings of this assessment.

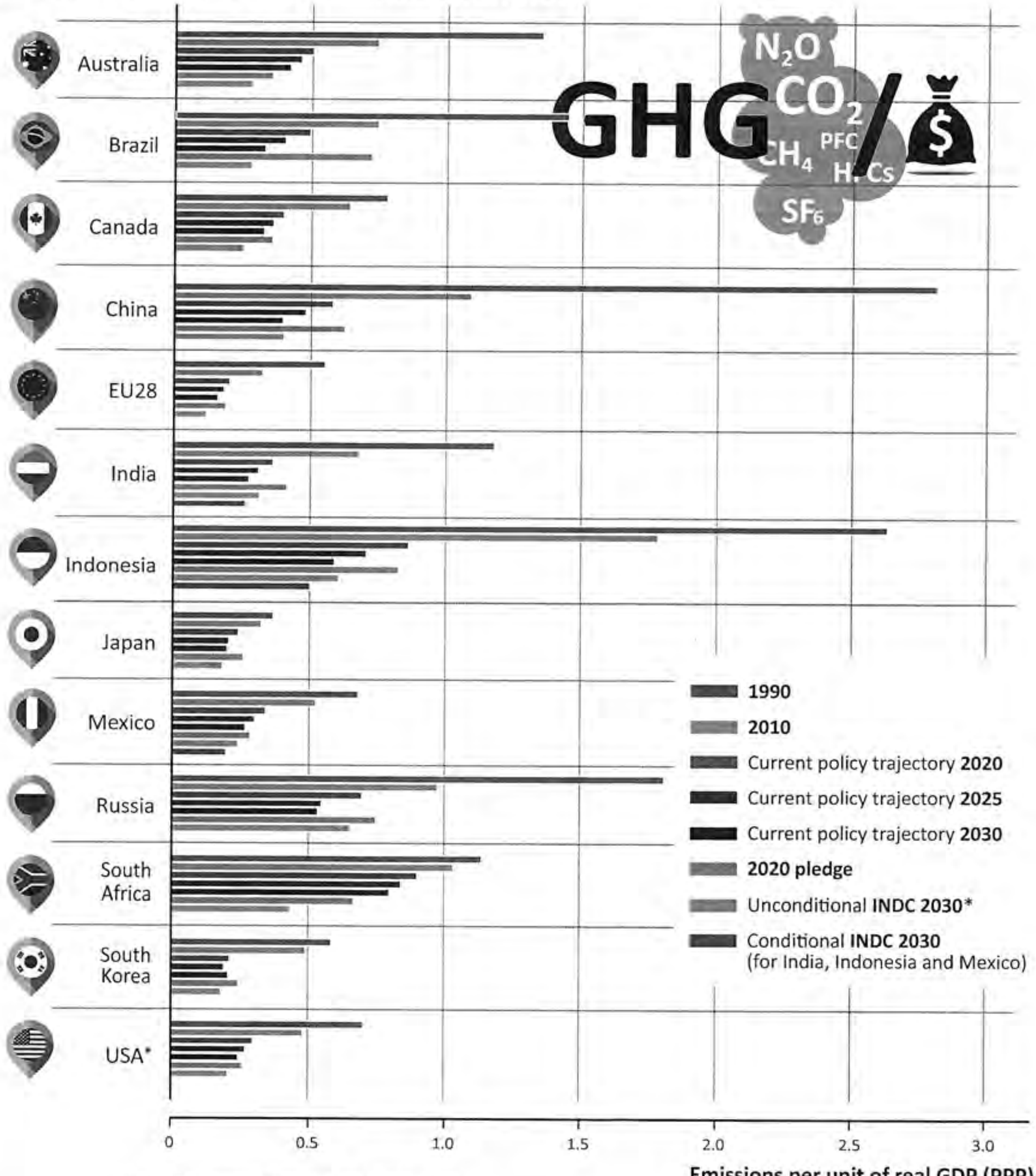
Cross-cutting information regarding national emissions, emissions per GDP and emissions per capita for these countries is summarized in Figure 3.5, Figure 3.6, and Figure 3.7 respectively. The figures present this cross-cutting information for historic emissions (for 1990 and 2010), current policy trajectories (for 2020, 2025, and

Figure 3.5: Greenhouse gas emissions for G20 countries with INDCs submitted by 1 October for historic emissions (1990, 2010), current policy trajectory emissions (2020, 2025, 2030), and INDC emissions (2025, 2030)



* For USA unconditional INDC is for 2025

Figure 3.6: Greenhouse gas emissions *per unit of real GDP (US$ 2005)* G20 countries with INDCs submitted by 1 October for historic emissions (1990, 2010), current policy trajectory emissions (2020, 2025, 2030), and INDC emissions (2025, 2030)



* For USA unconditional INDC is for 2025

2030)[16], Cancun pledges (for 2020)[17], and unconditional and conditional (in the case of India, Indonesia and Mexico) INDC cases (for 2030, noting that for USA, the 2025 unconditional INDC is shown).

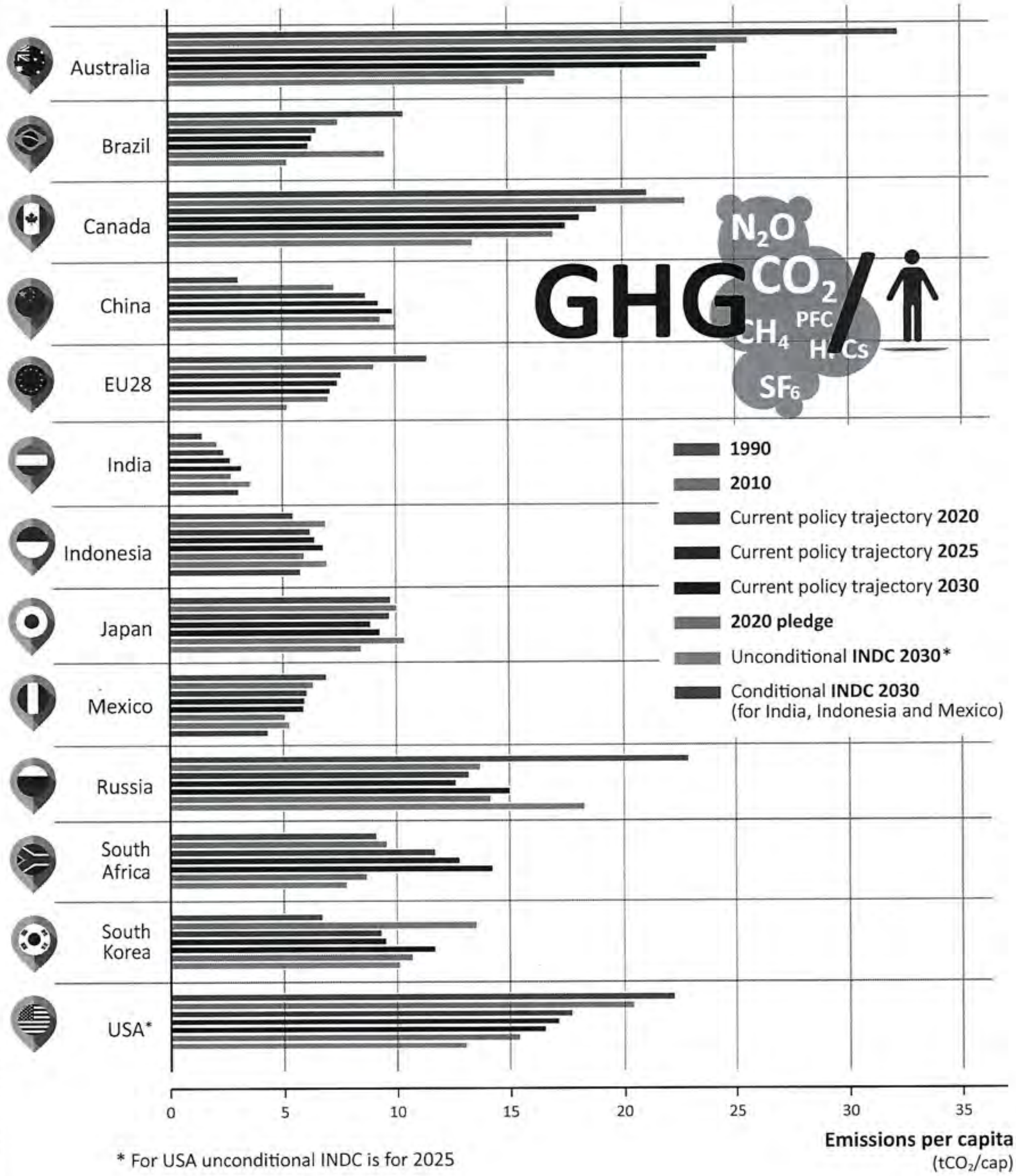
By comparing the current policy trajectory scenarios and the INDC scenarios, the figures indicate whether or not a country is on track to meet its 2020 pledge (as discussed in Chapter 2.3) and its INDC target. The figures do not attempt to comment on the ambition of either the 2020 pledges or the INDC targets. It is also important to note that the current policy trajectory scenarios, which attempt to reflect the most recent mitigation policies, differ from the baseline or "business as usual" scenarios employed by some countries, which typically assume that no new policies are adopted or implemented after a given cut-off year.

Figure 3.5 shows that the emissions from middle-income countries such as Mexico, Indonesia (only for conditional INDC), Brazil and South Korea are expected to peak before 2025. Emissions of China and India are expected to peak by

16 The current trajectories draw only from those studies that explicitly account for currently adopted and implemented policies. These include Climate Action Tracker, IEA adjusted, and PBL and relevant country-specific studies where available.

17 The estimates for 2020 pledges are based on the UNEP 2014 report (UNEP, 2014) and as these estimates are based on a different set of model studies from current year, only the median emission level are shown in the country graphs.

Figure 3.7: Greenhouse gas emissions *per capita* of G20 countries with INDCs submitted by 1 October for historic emissions (1990, 2010), current policy trajectory emissions (2020, 2025, 2030), and INDC emissions (2025, 2030)



* For USA unconditional INDC is for 2025

2030 or later. These countries have relatively high emission intensities due to carbon intensive economies. Emissions from most high-income countries have already peaked. The EU28 peaked around 1980, the Russian Federation around 1990, and in Canada, Japan, and the USA around 2005.

The emission levels as a result of INDCs show a decline in per capita emissions between 2010 and 2030, except for China, India and the Russian Federation (Figure 3.6)

All countries show a substantive reduction and convergence in emission intensity (emissions per GDP) by 2030 as a result of their INDCs (Figure 3.7). The largest reductions take place in countries with the highest emission intensities in 2010, such as Indonesia and China.

In addition, detailed findings for each of the above-mentioned countries are provided in Annex 1 to this report. For each of these countries, Annex 1 includes a brief description of the elements of the INDC that have been considered by the modelling groups. A discussion of the reasons for discrepancies between different data sources is included. Data is sourced from the global studies, the national studies and official government sources.

3.6 Concluding remarks

A number of important policy implications can be drawn based on the assessment presented above. First, due to the steep rate at which global emissions must decline after 2020 to be consistent with the 2°C scenario, the emissions gap grows rapidly over time. This underscores the importance of enhanced early action to reduce emissions. Secondly, bearing in mind the emissions gap that remains even under the most optimistic assumptions about the INDCs, countries should not assume that these proposed contributions will be sufficient to meet agreed global objectives. While an appropriate level of additional ambition would depend on equity considerations, in general, countries should expect that additional ambition will be necessary. Failure to anticipate this could result in technological lock-in and stranded assets. Third, the INDC process has proven to elicit greater ambition from countries relative to a current policy trajectory. Future calls for INDCs may therefore be successful in eliciting even greater ambition. Early calls to enhance ambition for the 2020 to 2030 timeframe can best address the need for enhanced early action.

In this context the IPCC AR5 (IPCC, 2014) highlighted that if GHG emissions are above 55 $GtCO_2e$ in 2030, challenges of transitioning to low emission levels in line with 2°C in the longer term will become particularly daunting (Figure 6.32 in Clarke *et al.*, 2014). The challenges are much reduced if 2030 Kyoto-GHG emissions are kept below 50 $GtCO_2e$ (Clarke *et al.*, 2014), or even more so, to 42 $GtCO_2e$ in line with a least-cost 2°C pathway after 2020.

To sum up, this assessment of the aggregate effect of the INDCs on global total GHG emissions in 2025 and 2030 essentially tells two stories. First, the INDCs do present a real increase in the levels of ambition compared to a projection of current policies; all global modelling analyses and scenarios based on country-specific data sources assessed, reached this conclusion. Secondly, however, the ambitions are far from sufficient, and the emissions gap in 2030 is very significant. Unless ambition is raised rapidly, the projected emission levels resulting from the INDCs are likely to lead to a path that at best will be consistent with an increase in global average temperature of below 3°C in 2100. If considering unconditional INDC levels only, the projected temperature increase is closer to below 3.5°C. Taking uncertainty ranges into account, the emission level estimates under full implementation of both unconditional and conditional INDCs become most consistent with long-term scenarios that limit global average temperature increase to below 3-3.5°C by the end of the century with >66 per cent chance.

Chapter 4

Opportunities for bridging the gap

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4.1 Introduction

The INDCs represent a real increase in the level of mitigation ambition compared to a continuation of current policies. However, as Chapter 3 illustrates, even with combined implementation of unconditional and conditional INDCs, the emissions gap in 2030 is estimated to be in the order of 12 $GtCO_2e$.

The central question is then if and how this emissions gap can be narrowed and potentially bridged?

This second part of the Emissions Gap Report explores some of the answers to this question. Assessing the most recent literature, it sets off by providing an overview of key issues and opportunities for narrowing and potentially bridging the emissions gap in 2030 in this chapter. These opportunities include:

- Establishing a dynamic framework under the Paris Agreement to drive continuous strengthening of mitigation ambition and ensure efficient implementation of the agreement
- Boosting pre-2020 mitigation action to reduce mitigation costs, avoid lock-in and maintain a possibility of staying below 1.5°C by 2100
- Introducing, replicating and scaling up good practice mitigation action, enabling countries to overachieve on their INDCs and bring about a transition to a low carbon economy
- Full integration of development and climate co-benefits in policies, planning and action.

This is followed by 2 chapters providing in-depth assessment of opportunities to further tap into emission reduction potentials in one cross-cutting area, International Cooperative Initiatives (Chapter 5), and for one sector, forestry (Chapter 6).

4.2 Ensuring coherence, synergy and complementarity between climate change, economic growth and sustainable development

A deeper understanding and recognition of the interdependency between climate change, economic growth and sustainable development has emerged over the past decade. The Sustainable Development Goals (SDGs) recently adopted in New York by Heads of State of all member states of the United Nations (UN, 2015a) (see also Chapter 1) are an exemplification of this recognition. The SDG process explicitly recommends prioritizing coherence, co-benefits, and complementarity between a climate change agreement under the UNFCCC and the SDGs.

The interrelationships between climate and development are demonstrated in the SDGs and the Fifth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC, 2014a, 2014b). Similarly linkages between economic growth, sustainable development and climate change are echoed across the recent literature (GGBP, 2014; Ansuategi *et al.*, 2015; GCEC 2015a, 2015b; IEA, 2015a, 2015b). A briefing paper prepared for the United Nations Sustainable Development Summit in New York earlier this year states that "Progress towards many SDGs will be affected, overwhelmingly negatively, by climate change (for example food security, water scarcity and water related disasters, poverty and livelihoods, health, and the well-being of ocean and terrestrial ecosystems)" (UN, 2015a, p.2). At the same time, "[...] significant progress on many SDGs can contribute to tackling climate change (including sustainable energy, infrastructure and industrialization, sustainable consumption and production, sustainable agriculture and sustainable cities)" (UN, 2015a, p.2).

Box 4.1: Preparation of the INDC in Chile

The preparation of the INDC has involved high level political responsibility starting with a political mandate from the President implemented by the Council of Ministers for Sustainability and Climate Change. In order to get both political engagement and input for consideration, the draft INDC was submitted for public consultation over a period of 4 months with public briefings throughout the country. Proposals received went into a revision process for the draft INDC and final decision rested with the Council. Mitigation discussion was focused around two possible emission intensity targets for the country with different implications but neither of them was seen as damaging to the economy. So climate change policies were treated, in effect, as an integral part of overall national development.

Box 4.2: Preparation of the INDC in the Gambia

The INDC of the Gambia comprehensively addresses mitigation and adaptation and relevant means for implementation like finance, technology and capacity building. The INDC process has been founded in the context of the regular national development planning process. The national INDC preparation process has a strong focus on stakeholder engagement with sensitization workshops in each of the eight districts of the country and broad cross ministerial and institutional engagement in the actual preparation of the national submission. As a small LDC the Gambia has limited mitigation potential but has identified a number of areas like renewable energy, forestry and agriculture where actions can be implemented - some domestically, others requiring international financial and technological support.

Similarly, the recent IPCC AR5 Synthesis Report states with high confidence that climate change poses a threat to equitable and sustainable development (IPCC, 2014a). However, the report also finds that it is possible to pursue strategies and actions that will move towards climate-resilient pathways for sustainable development, while simultaneously facilitating improved livelihoods, social and economic well-being and effective environmental management (IPCC, 2014a).

The SDG Goal 13 "Take urgent action to combat climate change and its impacts" specifically acknowledges that the United Nations Framework Convention on Climate Change is the primary international, intergovernmental forum for negotiating the global response to climate change (UN, 2015b), and the targets associated with the Goal are clearly aligned with the ambitions in the INDCs. From the assessment of the submitted INDCs it is evident that many countries have established national processes that are explicitly anchored in an understanding of climate change mitigation and adaptation in the broader context of sustainable development planning at the national level (see Box 4.1 and 4.2).

4.3 A robust, effective and transparent follow-up and review framework under the Paris Agreement is vital to narrow the emissions gap

A robust, effective and transparent follow-up and review framework is critical to ensure the implementation of an ambitious global agreement on climate change. The SDG process has emphasized the importance of establishing a framework for periodic follow-up and review of progress towards implementation of the SDGs and mobilization of further action to accelerate implementation with a four-year interval (UN, 2015c).

A similar approach seems likely to feature in the Paris Agreement. As of 23 October 2015, the UNFCCC draft negotiating text includes mention of periodical global stocktakes of the implementation of the Paris Agreement guided by modalities to be adopted by a body under the new agreement at its first session[1].

A dynamic approach of the Paris Agreement that enables countries to regularly review and strengthen their INDCs is consistently highlighted as essential to enhance mitigation ambition and narrow the emissions gap (GCEC, 2015a; IDDRI, 2015; IEA, 2015a; INDC Forum, 2015; Spencer *et al.*, 2015). In this way it has been stressed that the first round of INDCs should be seen as the basis for a 'virtuous circle' of rising ambition (IEA, 2015a), and as representing 'floors rather than ceilings' to national ambition over the coming years (GCEC, 2015a).

In this context it is important to note that the social and political effects of the INDCs and the processes undertaken at national level transcend the aggregate effect they are estimated to have on total global GHG emission levels in 2025 and 2030. The preparation of the INDCs, has in many countries incentivized exploration of linkages between development and climate outcomes, and can be seen as a step towards a transition to a low carbon economy. As Figures 3.6 and 3.7 in Chapter 3 illustrate, in many cases the INDCs support a decoupling of economic growth and emissions growth, and reduce per capita emissions.

The Paris Agreement can support these national transitions and provide the framework for mobilization of the enhanced mitigation effort that is required to align national efforts with the global mitigation ambition indicated by the 2°C pathways.

1 Draft text available at http://unfccc.int/files/meetings/bonn_oct_2015/application/pdf/ws_1_and_2.pdf [Accessed 6 November 2015].

Establishing a robust, effective and transparent follow-up and review framework as part of the Paris Agreement will be critical in this context.

The following sections look into the opportunities for further enhancing mitigation action to narrow and potentially bridge the emissions gap, which would support the transition towards a low carbon economy and facilitate overachievement of the emission reductions put forward in the INDCs.

4.4 Bridging the gap – realizing emission reduction potentials by 2020 and 2030

4.4.1 The critical role of boosting pre-2020 mitigation action

The importance of increasing pre-2020 mitigation action was underscored in Chapter 2. Reducing emissions compared to the current policy trajectories before 2020 will not only improve the chances for achieving the stringent emission reductions that are required after 2020 to limit warming to below 2°C by 2100. It will also reduce the costs of emission reductions, avoid lock-in of carbon and energy intensive infrastructure, and lower the risk associated with substantial dependence on negative emissions beyond 2050 to limit global warming to 2°C. In addition, as shown in Chapter 2, enhanced early action that goes beyond current policies would facilitate maintaining the option of limiting warming to below 1.5°C in 2100 (with a greater than 50 per cent chance).

Previous Emissions Gap Reports (UNEP, 2011, 2012, 2013) showed estimates of the aggregate emission reduction potential by sector by 2020[2]. This potential was based on studies that assumed earlier and more stringent mitigation action than indicated by the current policy trajectory. As we get closer to 2020, it is no longer possible to realize the full 2020 emission reduction potential referred to in previous Emissions Gap Reports. One reason is that often there is a considerable time lag between the adoption of emission reducing policies and options, their implementation and the reaping of the associated emission reductions. In addition, failure to invest in best available technologies and options as early as possible constrains our ability, in the near-future, to reduce emissions in some sectors and cross-cutting areas, because of lock-in of higher-energy use and emission investments with long timeframes.

The size of the remaining emission reduction potential by 2020 is difficult to assess, as few comprehensive updated studies are available. However, three recent technical reports by the UNFCCC (2014a, 2014b, 2015) highlight that significant emission reduction potential by 2020 remains. These reports focus on the thematic areas of renewable energy; energy efficiency; land use; urban environments; carbon dioxide capture, use and storage; and non-carbon dioxide GHG emissions. Another recent study finds that scaling up and replicating current good practices could, reduce global emissions by around 4.6 $GtCO_2e$ in 2020, if wide-spread and urgent action is undertaken (Fekete *et al.*, 2015).

2 Assessed in previous Emissions Gap Reports to be in the order of 17 ± 3 $GtCO_2e$, adopting a sectoral bottom-up approach, with marginal costs of up to US\$50–100/tCO_2e.

4.4.2 Reaping emission reduction potentials by 2030 to narrow and potentially bridge the gap

Extensive emission reduction potential by 2030

Looking beyond 2020, a number of recent studies and reports, including by the IPCC and leading international institutions, identify a significant emissions reduction potential by 2030 (IPCC, 2014b; IRENA, 2014; Fekete *et al.*, 2015; GCEC, 2015a; IDDRI, 2015; IEA, 2015a; JRC, 2015; OECD/IEA/NEA/ITF, 2015). Acknowledging that the methodologies, assumptions, scope and coverage of measures vary across these studies, they all document that tapping into unused emission reduction potential could narrow the emissions gap in 2030 considerably.

Specific examples are presented in Table 4.1 showing emission reduction opportunities by 2030 estimated by different studies, and how this potential relates to the gap assessment findings presented in Chapter 3. Only studies that allow comparison of emission reductions relative to the INDC case levels are included in the table. Several other recent studies show sizeable emission reduction potential in specific sectors or thematic areas, but cannot be directly compared to the 2030 baseline, current policy trajectory and INDC emission levels from Chapter 3 and are therefore not included in the table.

Taken together, the studies shown in Table 4.1 indicate that global GHG emissions could be further reduced in 2030 by between 5-12 $GtCO_2e$ (range: 3-13) relative to the emissions level resulting from implementation of the unconditional INDCs, and between 5-10 $GtCO_2e$ (range: 1-11) relative to the emissions level associated with implementation of the conditional INDCs. Such reductions would significantly narrow the emissions gap in 2030, which as previously stated is estimated at 14 $GtCO_2e$ (range: 12-17) for the unconditional INDC case, and at 12 $GtCO_2e$ (range: 10-15), if both unconditional and conditional INDCs are implemented. Furthermore, the studies rely exclusively on implementation of proven technologies and policies.

There is considerable uncertainty associated with the emission reduction potential estimated in the studies included in Table 4.1. On the other hand, the studies do not cover all possible measures, thematic areas or sectors. The study by NCI, PBL and IIASA (Fekete *et al.*, 2015), for example, excludes potential emission reductions in agriculture, parts of the transport and industrial sector, waste, and bunkers. Similarly, the IEA study only considers options for reducing energy-related CO_2 emissions.

In other words the total technical and economic emission reduction potential in 2030 could very well be larger than indicated in the table. Other sources like the Fourth Assessment Report, AR4, of the IPCC (2007) provided an estimate of total emission reduction potential in 2030 of

Table 4.1: Illustration of estimated emission reduction potentials by 2030 from various studies

Study	Emission reduction compared to baseline	Emission reduction compared to current policy trajectory	Emission reduction compared to INDCs unconditional / conditional
	$GtCO_2e$ by 2030 Median (range)[a]		
Emission reduction required to transition to 2°C pathways	*23 (18-28)*	*18 (16-20)*	*14 (12-17) / 12 (10-15)*
"Global mitigation scenario" (JRC, 2015)	19.5	14.5	11 / 8.5
Assumes a rapid intensification of policies across several world countries from 2015, leading to a peak in emissions as early as 2020. A progressive convergence of underlying carbon prices after 2030, depending on their per capita income, leads to an emissions profile by 2050 that is compatible with the below 2°C target.			
NewClimate Institute (NCI), PBL Netherlands, and International Institute for Applied Systems Analysis (IIASA) (Fekete *et al.*, 2015)	18-20	13-15	9-12 / 7-10
Considers the global implications of scaling up and replicating current good practice across nine policy areas and actions: 1) Increase renewable share in electricity through country dependent policy mix; 2) Emission reductions from production of fossil fuels; 3) Promotion of industrial energy efficiency through country specific policy instruments; 4) HFC and other F-gas emission reductions; 5) Standards for efficiency of appliances and lighting; 6) Energy efficiency of the building envelope (heating/cooling); 7) Fuel efficiency/emission standards light duty vehicles; 8) Support Electric cars driven by renewable electricity; and 9) Emission reduction from deforestation. The following sectors are not included: agriculture, parts of the transport and industrial sector, waste, and bunkers.			
New Climate Economy (GCEC, 2015a)	17 (12-22)[b]	12 (7-17)	8 (3-13) / 6 (1-11)
Identifies 10 key areas of opportunity for stronger climate action: 1) Accelerate low-carbon development in the world's cities; 2) Restore and protect agricultural and forest landscapes and increase agricultural productivity; 3) Invest at least US$1 trillion a year in clean energy by 2030; 4) Raise energy efficiency standards to the global best; 5) Implement effective carbon pricing; 6) Ensure new infrastructure is climate-smart; 7) Galvanize low-carbon innovation; 8) Drive low-carbon action through business and investor action; 9) Raise ambition to reduce international aviation and maritime emissions; and 10) Phase down the use of hydrofluorocarbons.			
"Bridge Scenario" (IEA, 2015a, 2015b)[c]	16	11	5
Medium coverage. Includes five energy-related measures: 1) Increasing energy efficiency in the industry, buildings and transport sectors; 2) Progressively reducing the use of the least-efficient coal-fired power plants and banning their construction; 3) Increasing investment in renewable energy technologies in the power sector from US$270 billion in 2014 to US$400 billion in 2030; 4) Gradual phasing out of fossil-fuel subsidies to end-users by 2030; and 5)Reducing methane emissions in oil and gas production.			

Notes: It is not possible to indicate technical and economic potential for specific levels of marginal cost based on the information provided in the studies.

[a] Median and range is indicated where possible. JRC (2015) and IEA (2015a, 2015b) do not provide uncertainty ranges. NCI, PBL, and IIASA (Fekete *et al.*, 2015) provide a range indicating medians of two analyses, but no uncertainty ranges.

[b] The New Climate Economy study (GCEC, 2015a) has baseline emissions in 2030 of 69 $GtCO_2e$ and indicate a total emission reduction potential of 21 (range: 16-26) $GtCO_2e$ compared to this baseline level. In the Table, the 2030 baseline emissions of 65 $GtCO_2e$ estimated in Chapter 3 are used. Therefore, the total emission reduction potential of the New Climate Economy study has been adjusted by -4 $GtCO_2e$ to be comparable to the Emissions Gap Assessment.

[c] IEA (2015a, 2015b) only considers CO_2 emissions. As the studies do not indicate the projected energy-related CO_2 emission share of global GHG emissions in 2030, the emission reduction calculations in the table are approximate, based on the assumption that global energy-related CO_2 emissions will also account for roughly two-thirds of global GHG emissions in 2030. This study does not distinguish between unconditional and conditional INDCs. Therefore, only one estimate for the emission reduction compared to INDC is included in the Table.

23 $GtCO_2e$ (range: 16-31)[3], which is in the order of magnitude required to bridge the gap in 2030. An update of the total emission reduction potential in 2030 is not available in the Fifth Assessment Report, AR5, of the IPCC (2014a, 2014b). However, updates for key sectors in AR5 indicate that emission reduction potentials in 2030 remain in the same order of magnitude as in the AR4 (IPCC, 2007).

For the industry sector overall, global mitigation potentials in 2030 of up to 8 $GtCO_2e$ are referenced in AR5 (IPCC, 2014b). For the transport sector, the emission reduction potential is assessed to be higher than reported in the AR4, with projected energy efficiency and vehicle performance improvements ranging from 30-50 per cent in 2030 relative to 2010 (IPCC, 2014a). Similarly, for the building sector, the AR5 reports that mitigation or energy saving potentials often go beyond 30 per cent up to even 60 per cent of the baseline (IPCC, 2014b)[4]. Analyses have furthermore shown that "[...] technological improvement keeps replenishing the potential for efficiency improvement, so that the potential for cost-effective energy efficiency improvement has not been diminishing in spite of continuously improving standards" (IPCC, 2014b).

Finally, for Agriculture, Forestry and Other Land Use (AFOLU), emission reduction potential of supply-side measures is estimated to be 7.2-11 $GtCO_2e$ in 2030 (IPCC, 2014b)[5].

The studies assessed all emphasize the key importance of enhanced energy efficiency, with a particular emphasis on industry, buildings and transport. Expanded use of renewable energy technologies for power production combined with increased efficiency of fossil fuel-based power production is also considered key. Other key areas and sectors for enhanced mitigation action emphasized in the studies include forestry, agriculture and waste. These are all areas that have been

3 The IPCC (2007) estimated sectoral emission reduction potentials in $GtCO_2e$ by 2030 with marginal costs in the range of US$50–100/$tCO_2e$ as follows: Power sector [2.4–4.7]; Manufacturing industry [2.5–5.5]; Transportation [1.6–2.5]; Buildings [5.4–6.7]; Forestry [1.3–4.2]; Agriculture [2.3–6.4]; and Waste [0.4–1.0].

4 Base years for the studies considered are generally between 2000 and 2010.

5 For mitigation efforts consistent with carbon prices up to US$100/$tCO_2e$, of which about a third can be achieved at below US$20/$tCO_2e$.

assessed in earlier UNEP Emissions Gap Reports and where significant opportunities for bridging the gap have been highlighted through possibilities for replication, acceleration and scaling up proven good practices and policies.

The importance of scaling up good practices and policies

There is immense potential for reducing emissions through world-wide replication and scaling up of good practices and policies as illustrated above. However, the emission reduction potentials shown in the previous sections can only be realized if strong, long-term and sector-specific policies are put in place at the global and national levels without delay.

Previous editions of the Emissions Gap Report (UNEP 2012, 2013, 2014) have demonstrated how proven policies can be scaled up (both in ambition and geographical reach) across countries and regions taking national differences and circumstances into account. Box 4.3 summarizes key proven policies in different areas considered in earlier Emissions Gap Reports.

Box 4.3: Summary of proven policies for reducing GHG emissions and achieving development goals highlighted in previous UNEP emissions gap reports (source: UNEP 2012, 2013, 2014)

The 2012, 2013 and 2014 UNEP Emission Gap Reports identify policies in key areas that have proven successful in reducing greenhouse gas emissions in many different countries, while contributing to national development goals. Such policies have the potential to make a significant contribution to bridging the gap, if scaled up in terms of ambition and geographical coverage.

Energy

These policies are related to improvements in energy efficiency in various sectors:

- Building sector – Regulations for building energy performance or codes for new construction: especially with regards to energy efficiency in heating, cooling appliances and lighting. Most developed countries also need to pay attention to renovating existing buildings in an energy efficient manner
- Industry sector – Country- and subsector-specific approaches rather than standardized policies: due to the diverse nature of the industry sector target policies have proven most effective
- Transport sector – Mandatory fuel economy standards for road vehicles: principal means for slowing down the growing fossil fuel consumption. Often supplemented with measure such as labelling, taxes and incentives, while promoting more efficient transportation modes
- Appliance standards – Regulations that prescribe the energy performance of manufactured products
- Appliance labels – Energy-efficiency labels that are fixed to manufactured products to describe the products' energy performance.

Agriculture

- Promotion of no-tillage practices
- Improved nutrient and water management in rice production
- Agroforestry: different agricultural management practices that all deliberately include woody perennials on farms and the landscape, and which promote a greater uptake of carbon dioxide from the atmosphere by biomass and soils.

Buildings

Policies that lower energy use and therefore reduce carbon-dioxide and other emissions (see also under Energy):

- Building codes: regulatory instruments that set standards for specific technologies or energy performance levels and that can be applied to both new buildings and retrofits of existing buildings.

Transport

These policies reduce energy use and therefore reduce carbon dioxide and other emissions (see also under Energy):

- Transit-oriented development: the practice of mixing residential, commercial and recreational land uses to promote high-density neighbourhoods around public transit stations
- Bus Rapid Transit (BRT): key elements of bus rapid transit include frequent, high-capacity service; higher operating speeds than conventional buses; separated lanes; distinct stations with level boarding; and fare prepayment and unique branding
- Vehicle performance standards: establish minimum requirements based on fuel consumption or greenhouse gas emissions per unit of distance travelled by certain vehicle classes.

The policies included above do not represent a comprehensive list. Moreover, some policies will be more appropriate and successful in reducing emissions in some countries than in others. Their success also depends on how stringently they are implemented.

Consideration of multiple benefits essential

Previous editions of the Emissions Gap Report have emphasized that in many, if not most, cases climate change mitigation is not the primary driver for action, but rather a significant co-benefit of sound sectoral and national development planning and policies. The previous Emissions Gap Reports offer examples of how ambitious policy instruments that lead to significant emission reductions can foster innovation and economic growth, bolster national energy security, improve public health and address other key developmental priorities.

The feasibility of introducing, replicating or expanding ambitious regulatory measures, market- and price-based instruments, and command-and-control measures varies across thematic areas, sectors and countries (UNEP, 2012; IPCC, 2014b). In order to build a strong case for enhanced action by policy makers and other stakeholders, it will be important to provide clear and convincing documentation of the wide range of benefits associated with the implementation of the policies and actions that can bring about the needed reductions of GHG emissions (UNEP, 2012).

Numerous studies confirm that many actions that reduce GHG emissions are associated with considerable co-benefits (IPCC, 2014a; Parry, *et al.*, 2014; WB, 2014; Fekete *et al.*, 2015; GCEC, 2015b; Höhne *et al.*, 2015; UNFCCC, 2014a, 2014b, 2015). Accounting for co-benefits reduces the average cost of emission reduction options and increases the total emission reduction potential associated with a net benefit. For energy efficiency options, inclusion of multiple benefits in some cases triples the overall benefit of these options, notably where they heavily reduce coal use (GCEC, 2015b). Options associated with net costs, may also swing to net benefits when co-benefits are taken into account. This is, for example, the case for reduced deforestation, recycling of new waste, and offshore wind (GCEC, 2015b).

Full integration of co-benefits in planning and decision-making can thus have profound implications for climate and development action.

Chapter 5

International Cooperative Initiatives

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5.1 Introduction

The objective of this chapter is to provide an assessment based on published or readily available information of the possible contribution to global mitigation efforts especially by key International Cooperative Initiatives (ICIs). In addition, the chapter looks into the role of other groups of non-state actors. In the context of climate mitigation, ICIs are considered to be cooperative efforts led by actors other than Parties to the UNFCCC, but many are undertaken in partnership with national governments whose agencies are very often critical to the realization of the ICIs' emission reduction potential. Many ICIs have strong international partners – catalyzing both national and international actions and often providing opportunity for enhancing national ambition.

Across this spectrum, ICIs cover a wide range of activities, and although it is a challenge to cover them comprehensively, an effort has been made to assess available information and prioritize initiatives according to their potential mitigation significance. The chapter starts by presenting the results of a number of recent studies regarding the potential emission reduction contribution of ICIs together with an assessment as to what extent ICI contributions can be considered as *additional* to those anticipated from the Cancun pledges. This is followed by an examination of the links between national level cooperative initiatives and the UNFCCC process, with examples from selected INDCs submitted during 2015. The chapter then presents a detailed overview of ICIs grouped into three categories, cities and regions, companies and sectors, which helps illustrate the innovative approaches adopted by many non-state actors and facilitate opportunities for identifying new types of partnerships that could contribute to addressing the mitigation challenge.

A particular effort has been made to examine south-south initiatives that may have been under-represented in past reviews. The chapter focuses on actions on the ground rather than enabling measures, as the former are more quantifiable. Particular attention is given to private sector activities which, under favourable policy and legislative frameworks, strengthen technological innovation.

5.2 Quantitative impact of ICIs on emission reductions

An earlier estimate of the possible emissions reduction impact of ICIs was reported in the Emissions Gap Report 2013 (UNEP, 2013). This report stated a total expected impact of about 10 $GtCO_2e$ in 2020, based on a number of underlying studies (Blok *et al.*, 2012; IEA, 2013; UNFCCC, 2013).

A number of recent studies have estimated both the gross emission reduction potential of ICIs for 2020 and 2030, and, for 2020, attempted to calculate net impacts additional to what will be included in the 2020 pledge achievement. These include a study carried out for UNEP by Ecofys (UNEP, 2015), a study by Yale University (Hsu *et al.*, 2015) and a study by the Netherlands' Environmental Assessment Agency (Roelfsema *et al.*, 2015). An overview of the results, broken down by sector is given in Table 5.4.

Although all studies have comparable methodologies (Mosteller and Hsu, 2015) and consider similar categories, there are marked differences in scope between the studies. UNEP (2015) started from all initiatives gathered on the Climate Initiatives Platform (CIP, 2015), and then selected the most significant ones for quantitative analysis. Commitments made at the New York Climate Summit in 2014 were not included because of their early stage of development. This summit sparked significant new engagement on climate action and a number of new ICI type commitments were presented (Climate Change Summary, 2014). Hsu *et al.* (2015) explicitly focus on these new commitments from the Climate Summit. Roelfsema *et al.* (2015) took a similar approach as the UNEP report, but the authors used a different baseline scenario. They also included major initiatives outside the UNFCCC framework (for example, those of national governments under the Montreal Protocol). This is also the only study to project possible emission reduction contributions to 2030, partly through extrapolation. Findings from a further study (CISL/Ecofys, 2015) have been also been included in the assessment, even if the coverage was more restricted. These differences in scope and coverage indicate that the total impact of non-state climate action could be larger than reported by each individual study, as they do not fully overlap.

An overall conclusion of the assessment is that the impact of non-state climate commitments can be very significant, most likely in the range of 2.5-4 $GtCO_2e$ in 2020 (taking into account that not all initiatives are included in all assessments). This already accounts for an estimate of overlap between the various initiatives, in terms of actual actions, sectors, greenhouse gases and regions.

It is difficult to estimate the overlap between these non-state initiatives and national government pledges for 2020. Overlap between these varies from full overlap, for example for the Global Fuel Efficiency Initiative, to virtually no overlap, for example for the international marine and aviation sector (Roelfsema *et al.,* 2015). For countries with economy-wide reduction pledges the overlap is hard to estimate, but likely to be larger, compared to the overlap for countries with very narrowly defined pledges limited to one or two particular sectors. Roelfsema *et al.* (2015) estimated the overlap for individual initiatives and country pledges and, by aggregating this to the global level, found a total of 70 per cent overlap between initiatives included and government pledges for the year 2020. In contrast, UNEP (2015) found a lower overlap of just 33 per cent at the maximum for the initiatives and country pledges included in their study. As shown in Table 5.1 below, these two key studies would suggest that the estimated range of emission reductions from ICIs net of the 2020 pledges is currently in the order of 0.75-2.2 $GtCO_2e$ in 2020.

Table 5.1: Quantitative emission reduction impact of initiatives in 2020, according to different studies (in $MtCO_2e$). All emission reductions are compared to a business-as-usual or current policies scenario

Actors or sectors		UNEP, 2015	University of Yale (Hsu *et al.,* 2015)	University of Cambridge (CISL/ Ecofys, 2015)	PBL (Roelfsema *et al.,* 2015)	
Target year		**2020**	**2020**	**2020**	**2020**	**2030**
Sub-national	Cities and municipalities	1 080	454[1]		600[2]	700
	Regions	760				
Companies		630		51-100[3] 10-30[4]	800[5]	1 400
Sectors	Energy efficiency	60[6]	1 750[7]	60		
	Efficient cook stoves	120				
	Renewable energy		0.2[8]			
	Transport				200[9]	500
	Methane and other SLCP	90			500[10]	1 300
	Fluorinated GHG			0.0-0.7[11]	0	700[12]
	Reduce deforestation	100[13]	331[14]	20-200	300[15]	700
	Agriculture	300				
	Shipping and aviation				200[16]	500
Overlap between initiatives		200			200	300
Total expected impact	**Midpoint**	**2 900**	**2 540**	***No total*** [17]	**2 500**	**5 500**
	Range	**2 500-3 300**				
% overlap with national pledges		**33**			**70**	
Impact of ICIs net of national pledges		**1 700-2 200**			**750**	

1 Compact of Mayors.
2 CDP – Top 500 Companies and Cement Sustainability Initiatives.
3 Cement Sustainability Initiative (WBCSD).
4 WWF Climate Savers programme.
5 C40 and Covenant of Mayors.
6 En.lighten initiative.
7 Energy Efficiency Accelerator.
8 Small Island Developing States (SIDS) Lighthouse Initiative.
9 Global Fuel Economy Initiative (GFEI).
10 Global Methane Initiative and Zero Routine Flaring by 2030.
11 Refrigerants Naturally!
12 North American 2013 HFC Submission to the Montreal Protocol.
13 Tropical Forestry Alliance.
14 New York Declaration on Forests.
15 New York Declaration on Forests.
16 International Maritime Organization and International Civil Aviation Organization.
17 No total given as study was not intended to be exhaustive.

It is important to recognize that the emission reduction impact of the initiatives assessed here assumes that the actors live up to their commitments. It is currently difficult to assess whether international initiatives actually deliver. Most initiatives put forward voluntary commitments which makes it difficult to enforce accountability and compliance. For some initiatives this leads to a lack of robust Monitoring, Reporting and Verification (MRV) (IVM, 2015). In practice, actors may over- or under-deliver compared to their commitments (see section 5.4.2 on delivery by companies). Although the 2013 Emissions Gap Report (UNEP, 2013) quoted a non-state contribution of just under 10 $GtCO_2e$/yr by 2020, this represented an acknowledged overlap with national pledges that was not quantified.

Beyond the possible direct mitigation contribution either as part of fulfilling government pledges or providing additional reductions, it is important to stress the possibilities for growth and acceleration of initiatives. A recent study (CISL/Ecofys, 2015) illustrates in several areas that there is significant potential for scaling up initiatives. The development and engagement of ICIs are rapidly evolving within all the different categories, therefore the results presented in this section must be seen as a snapshot of where ICIs stand today.

It would have been very interesting to assess the possible contribution from ICIs for 2030 and similarly, as with pledges, to examine how much of this contribution would be additional to the new INDCs. However, although PBL (Roelfsema *et al.,* 2015) does offer an extrapolation of the total expected impact of ICIs in 2030 (midpoint estimate 5.5 $GtCO_2e$), it is not feasible at this point to consider questions of 2030 additionality in any meaningful way.

5.3 Non-state actors and the UNFCCC process

In view of the importance of cooperative initiatives (often led by non-state actors) in low carbon development, some UNFCCC Parties and observers have called for better representation of their role in the UNFCCC process (Chan and Paux, 2014).

In December 2014 at the COP 20 in Lima, a new platform was launched to showcase climate mitigation initiatives as distinct from national pledges (NAZCA, 2015). The Non-State Actor Zone for Climate Action (NAZCA) signifies a "[...] symbolic step towards considering subnational and non-state actors within the political sphere of the UNFCCC" (Hsu *et al.,* 2015). The platform mainly promotes voluntary action and does not apply a standardised set of compliance, monitoring, reporting and verification rules. Although administered by the UNFCCC, data are primarily contributed by partner organisations and not collected by the UNFCCC itself.

The role of non-state actors has recently expanded due to the need to assist with INDC submissions of the UNFCCC Parties prior to COP 21 in Paris in December 2015. As pointed out by Edwards *et al.* (2015) "[...] the INDC design process offers an unprecedented opportunity to improve civil society and business participation in climate change policymaking".

Where some developing countries have lacked capacity, non-state actors have been able to assist. Both national and international NGOs have provided know how in connection with preparation of INDCs for different countries (for example, climateanalytics.org, energies2050.org).

Domestic non-state actors have also contributed to the national debate on INDCs. In Brazil, Observatório do Clima, a Brazilian coalition comprising more than 30 NGOs, has estimated annual GHG emissions estimates for Brazil since 2013. Even before the INDC process, the organization had already participated in domestic consultations led by the Ministry of Foreign Affairs. In Senegal, a non-governmental organization, Enda Energie, participated in the sectoral and national reports validation workshops and contributed to the preparation of scenarios used as the basis for the INDC[18].

The contribution of non-state actors to climate mitigation actions will continue following the submission of INDCs. They can be instrumental not only in facilitating the achievement of the emission reduction targets, but also in monitoring, reporting and verification of actions at national level (Dodwell *et al.,* 2015).

Some INDCs acknowledge the contribution of non-state actors. Mexico states that multiple stakeholders have been consulted during the INDC preparation, including NGOs specializing in adaptation. Interestingly, few INDCs have highlighted the role of non-state initiatives in mitigation. An exception is China, which plans to "[...] conduct low-carbon cities (towns) pilots as well as low-carbon industrial parks, low-carbon communities, low-carbon business and low-carbon transport pilots" (UNFCCC, 2015). Indonesia mentions "[...] active participation of the private sector, small and medium enterprises, civil society organizations, local communities and the most vulnerable groups [...]" in sustainable forest management (UNFCCC, 2015).

5.4 Summary of Initiatives

This section presents a review of the recent literature on ICIs with a main focus on initiatives that have substantial mitigation potential. Various reports (Hale and Roger, 2014; Hsu *et al.,* 2015; Roelfsema *et al.,* 2015; Roger *et al.,* 2015; UNEP, 2015) provide an overview of what has been announced or implemented by subnational governments, such as cities, municipalities and regions, company initiatives and initiatives with a specific sectoral focus. Descriptions of initiatives can be found on the Climate Initiatives Platform (CIP, 2015) and the NAZCA portal (NAZCA, 2015). Monitoring, reporting and verification (MRV) arrangements for the various initiatives is also assessed, as this is a key element in providing transparency and ensuring credibility. The ICIs considered are grouped into three categories, cities and regions, companies and sectors.

5.4.1 Cities and regions initiatives

Subnational governments can act on climate change mitigation in many ways. Sub-national jurisdictions, such as state or regional governments, have even attempted to

18 Direct communication with the NGO's representative.

compensate for the lack of political will at the national level (Somanathan *et al.*, 2014).

There are many ICIs in which several cities and regions cooperate; for example, UNEP's recent report on subnational actors lists twenty one initiatives of this type (UNEP, 2015). A few started in the 1990s[19], while the majority started in the period 2005-2012[20] and some were announced during the UN Secretary-General's Climate Summit in September 2014[21]. Initiatives focus on the following roles:

- Encouraging or facilitating emission reductions at the city and regional level, via knowledge sharing, capacity building and technical support for project planning and implementation
- Identifying partnerships and supporting local communities to become climate resilient
- Representing common city-level interests to influence policymakers at other levels
- Helping implement climate plans and low-carbon and climate-resilient economic development projects
- Achieving transparency and accountability by encouraging best practice in GHG emission reporting
- Helping overcome financial barriers and attract investors and accelerate additional capital flows into cities for low carbon projects.

The overview identifies those cities and regions initiatives with members who have committed to GHG emission reductions. In most cases they have (or plan to have) inventories or registries to report both their goals and their past and current GHG emissions, with the aim of promoting transparency and accountability. The following initiatives fall into this category: C40, carbon*n* (including Mexico City Pact and WWF Earth Hour City Challenge), Covenant of Mayors, Climate Group's States and Regions, Compact of Mayors and Compact of States and Regions (see Table 5.2). There is an overlap in membership between some of these various initiatives.

Monitoring, reporting and verification

The Covenant of Mayors provides European local governments with guidance on how to develop a Sustainable Energy Action Plan (SEAP). Once this is adopted, implementation towards the goal is monitored. As of July 2015, about 460 monitoring reports were available from 2 882 adopted SEAPs. C40 cities reporting via the CDP[22] are asked to report using the primary protocol standard or methodology to calculate GHG emissions (for example, 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories (GPC) (WRI, C40 and ICLEI, 2014)).

Cities participating in the Compact of Mayors are requested to use the Global Protocol for Community-scale GHG emissions (GPC) and they are also required within 3 years to submit a climate action plan which includes an implementation and monitoring plan.

The cities and regions initiatives generally have designated registries (see Table 5.2). In the case of the newer initiatives such as the Compact of Cities and Compact of States and Regions, signatories have the choice of reporting to the carbon*n* Climate Registry or CDP. In addition to reporting on GHG emissions, signatories are requested to advise which GHG protocol and emissions factors were applied. The Compact of Mayors requires a complete updated inventory every three years[23]. Annual reports or summaries are published by the initiatives or the reporting platform. These include the total planned emission reductions and often the base year of emissions, without specifying the current progress towards the emission reduction targets. Such information is currently only publicly available for a limited number of cities such as those under the Covenant of Mayors.

The cities that disclose their information to CDP also provide information on whether or not their GHG emissions inventory has been verified by a third party. While the SEAPs that are submitted to the Covenant of Mayor are subject to verification by the European Commission's Joint Research Centre, the monitoring progress reports available for certain cities on the website do not indicate that they are third party verified. Participating authorities to the CDP States and Regions platform will be asked to report whether data sources have been verified.

It is evident from the assessment of cities and regions initiatives that there are a number of different approaches to especially monitoring and reporting and generally limited independent verification. Recent development indicates that the initiatives are gradually building the necessary processes and moving towards more uniform approaches.

19 Including Climate Alliance, Energy Cities, ICLEI - Local Governments for Sustainability.

20 Including C40 Cities Climate Leadership Group (C40), U.S. Conference of Mayors' Climate Protection Agreement (MCPA), World Mayors Council on Climate Change (WMCCC), Connected Urban Development, Transition Network, The Climate Registry, Covenant of Mayors, EUROCITIES Declaration on Climate Change, carbon*n* Climate Registry (cCR), Mexico City Pact, R20, WWF Earth Hour City Challenge (EHCC), The Clean Revolution.

21 Including City Creditworthiness Partnership, Compact of Mayors, Compact of States and Regions, District Energy Accelerator, The Cities Climate Finance Leadership Alliance.

22 CDP (formerly Carbon Disclosure Project) is an organization focussed on monitoring GHG emission performance and climate action engagement for companies and other actors.

23 The year of the inventory should not be more than three years prior to the reporting year – that is, in 2017 inventories must be dated between 2014 and 2016. Over time, the Compact would like cities to update their inventories on a more frequent / annual basis.

Table 5.2: Overview of cities and regions initiatives[24]

Initiative/date of establishment	Description	Members	Registry and public access	Reporting	Partnerships/Collaboration
C40 Cities Climate Leadership Group (2005)	C40 cities leadership group is a network of the world's megacities committed to taking action that reduces global GHG emissions.	80 affiliated cities (as of October 2015)[25]	CDP database (registered access) C40 open data portal – (open access since early 2015)	Annual reporting to Carbon Disclosure Project (CDP) (concerning GHG emissions, plus risk and adaptation, policies/plans and goals, latest emissions from local government operations and community emissions, water supply) states whether data is externally verified or not. Publishes annual cities report that summarizes climate risks and adaptation and specific C40 research. In December 2014, C40, WRI and ICLEI launched the Global Protocol for Community-scale Greenhouse Gas Emission Inventories (GPC) to support cities to develop robust, comprehensive and consistent inventories.	In partnership with: Clinton Climate Initiative Cities Programme, ICLEI, World Bank, Bloomberg Philanthropies, CDP, and Arup.
carbon*n* Climate Registry (cCR) (2010)	cCR is not only an initiative itself, but also the reporting platform for two other initiatives: The Global Cities Covenant on Climate – The Mexico City Pact and WWF Earth Hour City Challenge. It is designated as the central repository of the Compact of Mayors and the Compact of States and Regions. Led by ICLEI.	461 reporting cities and city-regions (as of October 2015)	Own website (open access)	Annual reports/updates on the registry. Jurisdictions report mitigation and adaptation actions and their committed emission reduction targets. Current progress is not reported.	Led by ICLEI. In partnership with: World Mayors Council on Climate Change, Club of Madrid, UCLG, Ciudad de Mexico. C40 Cities, R20, Michael R. Bloomberg, UN SG Special Envoy for Cities and Climate Change, UN Habitat, WWF, Eco Mobility Alliance, cCCR Japan Project, PACMUN Plan de Accion Climatica Municipal, and Urban LEDS.
Covenant of Mayors (CoM) (2008)	The CoM is a group of city mayors, mostly from the EU, who commit to meet and exceed the EU CO_2 emission reduction target of 20% by 2020 (from a 1990 baseline).	5 515 signatories (as of October 2015)	Own website (open access)	Signatories make available their local sustainable energy action plans (SEAPs) and baseline inventory. Depending on the status, progress will be monitored and verified. Current progress is not reported.	In partnership with: Joint Research Centre of the European Commission, and many other supporting partners.
Mexico City Pact (The Global Cities Covenant on Climate) (2010)	Participating cities commit to 10 voluntary action points, including reduction of their local GHG emissions, adoption of mitigation measures to achieve their targets and reporting of their emissions and targets. Established by the World Mayors Council on Climate Change.	338 signatories (as of July 2015)	Via carbon*n* (open access)	118 of the 338 signatories report to the carbon*n* registry.	Led by the World Mayors Council on Climate Change. In partnership with: ICLEI, Club of Madrid, UCLG, and Ciudad de Mexico.
WWF Earth Hour City Challenge (EHCC)(2011)	The EHCC aims to showcase diverse solutions and challenges for cities in different parts of the world and to identify options for collaboration between these cities. Established by WWF.	163 (as of May 2015)	Via carbon*n* (open access)	n/a	Led by WWF. In partnership with: ICLEI.

24 Initiatives can be found at www.climateinitiativesdatabase.org
25 Africa, East Asia, Europe, Latin America, South and West Asia, Southeast Asia and Oceania.

Initiative/date of establishment	Description	Members	Registry and public access	Reporting	Partnerships/Collaboration
The Climate Group States and Regions Alliance (2005)	The Alliance brings together 27 subnational government leaders to share expertise, demonstrate impact and influence the international climate dialogue. In 2005 representatives of the local governments signed the Montreal Declaration of Federated States and Regions, in which they commit to setting targets and implementing climate action in their own jurisdictions. Led by the Climate Group.	119 (as of October 2015)	Own website	Website on alliance and its regions, infographic on emissions in 2008 and emission reduction goals until 2050, as well as commitments and declarations.	Led by The Climate Group. Affiliated network: The China Regional Low Carbon Alliance.
The Compact of Mayors (2014)	The Compact is an agreement by 3 city networks, including ICLEI, and then by their members, to undertake a transparent and supportive approach to reduce city-level emissions, and to reduce vulnerability from, and enhance resilience to, climate change, in a consistent and complementary manner to national level climate protection efforts. It builds on the ongoing city-level efforts.	85 (as of July 2015)	Report to either carbon*n* or CDP (in planning). 50 cities/ towns currently reporting to carbon*n* intend to comply with the Compact	Annual report, use Global Protocol for Community-Scale Greenhouse Gas Inventories. City Action for Urban Sustainability (CURB) Tool with inputs specifically for transportation, buildings, waste management sector where cities have greatest control under development.	In partnership with: C40 Cities, ICLEI, UCLG and other partners for reporting, funding and city networks.
Compact of States and Regions (2014)	The Compact represents a commitment by global state and regional government networks to provide an annual assessment of commitments (that is, GHG reduction targets), and progress towards those commitments (that is, GHG inventory data).	At least 18 (as of July 2015)	CDP's states and regions platform and/ or via carbon (public access) (carbon*n*, 2015)	Signatories will be required to provide their data annually using a recognized online reporting platform. It will be reported whether data has been verified. Data will be aggregated and published in a public report each year, showing reported GHG emissions arising in reporting regions, reported GHG reduction targets to quantify impact of commitments made to date.	Led by The Climate Group. Partnership with: The Climate Group States and Regions, NRG4SD, R20, CDP, and supported by the UN, Climate-KIC, Center for the New Energy Economy (CNEE), ICLEI and ENCORE.

5.4.2 *Companies initiatives*

Another set of ICIs engage private sector companies in mitigation activities. A total of 30 such initiatives are currently listed on the Climate Initiatives Platform (CIP, 2015). Many of these initiatives act more as convening platforms for exchange of best practice and advocacy than engaging in direct commitments. But some have objectives that indirectly lead to emission reduction, for example, those aiming to re-direct investment to clean energy.

An overview of companies' initiatives that focus on direct GHG emission reduction is provided in Table 5.3. One common characteristic, of the initiatives with considerable potential for emission reductions (UNEP, 2015), is the requirement for participating companies to set their own emission reduction commitments. The most recent climate initiative assessed in this chapter, the Science Based Target Initiative which was launched in 2014, requests participating companies to set targets that are compatible with a global 2°C goal (CDP, WRI and WWF, 2014).

There is a trend towards more collaboration between different kinds of partners. Most private sector companies' initiatives have up to 50 member companies, while others like the Caring for Climate Initiative has over 380 signatories.

Monitoring, reporting and verification

Among companies initiatives, members of the Cement Sustainability Initiative (CSI) use the Cement CO_2 and Energy Protocol, while others reporting via CDP routinely use The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard. The Caring for Climate companies are recommended to use CDP's reporting process on an annual basis. Other alternatives are the Global Reporting Initiative (GRI) guidelines and the Global Compact Advanced Communication on Progress (COP).

Almost all companies of the Business Environmental Leadership Council (BELC), the majority of WWF Climate Savers and CSI[26] companies, and half of the participating companies of Ultra-Low CO_2 Steelmaking (ULCOS) initiative self-report to CDP by means of a questionnaire. The information related to supply chain or climate change reported to CDP as part of their corporate disclosure can be viewed by registered users. The company can choose via the CDP Platform, whether their disclosure is available to registered users and whether their submission is scored. The Caring for Climate companies should annually report by means of a Communication on Progress-Climate (COP-Climate), which is available via the initiative's website[27].

Annual reports or summaries are published by the various initiatives or reporting platforms, covering total planned emission reductions and often the base year of emissions, without specifying the current progress towards the emission reduction targets.

The companies that disclose their information to the CDP, report whether their information on GHG emissions has been verified, whether assurance is still underway or whether no third party verification took place. The annual reports of Caring for Climate are self-assessed. The overall picture on MRV for company initiatives is, therefore, quite similar to that for cities and regions though with variation in approach and limited evidence of verification at present.

Progress towards goals

An important question is to what extent companies are on track to reach their goals. According to their Progress Report (Caring for Climate, 2014), which lists both large companies and SMEs, a subsample of 33 large companies with high quality data for 2012 and 2013 demonstrated a decrease in GHG emission levels of around 13 per cent against 2007 levels. However, the CDP Carbon Action Report 2014 (CDP, 2014) suggests that more than half of the companies in its sample did not set absolute targets and a quarter of absolute targets ended in the reporting year. The report notes that 70 per cent of the correctly set absolute targets by companies "[...] will not be achieved in a business-as-usual scenario and further action will be required" (CDP, 2014, p.12).

26 CSI companies can also report their information to a voluntary and independently-managed database of CO_2 and energy performance information of the global cement industry called Getting the Numbers Right (GNR). Annual summary information is published. The database covers over 930 individual facilities including non-CSI.

27 Failure to prepare a publicly available COP-Climate report will result in a change of status (to "non-communicating") and eventually in the delisting of a signatory from Caring for Climate.

Table 5.3: Overview of Companies initiatives

Initiative/Date of establishment	Description	Members	Partnership/collaboration
Business Environmental Leadership Council (BELC) (1998)	BELC is the largest US-based group of corporations. Companies adopt voluntary emission reduction targets and innovative programs in energy, carbon sequestration and waste management.	39 participants (global) (as of October 2015)	Led by Centre for Climate and Energy Solutions (C2ES)
Cement Sustainability Initiative (CSI) (1999)	CSI is an alliance of 25 leading companies in the global cement industry created under the auspices of the World Business Council for Sustainable Development (WBCSD). Participants commit to developing a climate change mitigation strategy, setting reduction targets for CO_2 and reporting annually on their progress.	25 participants (global) (as of October 2015)	Led by WBCSD
WWF Climate Savers (1999)	WWF Climate Savers is for companies seeking to substantially reduce their carbon footprints. Each participant sets a reduction target in absolute terms and within a defined timeframe.	28 participants (global) (as of October 2015)	Led by WWF
Ultra-Low CO_2 Steelmaking (ULCOS) (2004)	ULCOS is a consortium of 48 European companies and organisations from 15 European countries. The aim of the ULCOS programme is to reduce the CO_2 emissions of today's leading steel production routes by at least 50%.	10 participants (Europe-based) (as of October 2015)	Led by Arcelor Mittal
Caring for Climate Initiative (2007)	Caring for Climate is an initiative aimed at advancing the role of business in addressing climate change. Participants commit to set voluntary targets to improve energy efficiency and to reduce their carbon footprint.	385 participants (including investors) (global) (as of October 2015)	Led by UN Global Compact, UNFCCC secretariat and UNEP
Science Based Targets (SBT) (2014)	A joint initiative by CDP, the UN Global Compact, the World Resources Institute and WWF launched in 2014, aiming to increase corporate ambition on climate action consistent with limiting global warming to less than 2°C compared to pre-industrial temperatures.	44 companies (global) (as of October 2015)	CDP, UN Global Compact, World Resources Institute, WWF
RE100 (2014)	Aim of the initiative is for at least 100 companies to make a global 100% renewable commitment with a clear timeframe for reaching their goal. RE100 considers as 'renewable' the electricity generated from biomass (including biogas), geothermal, solar, water and wind energy sources (see RE100 criteria).	29 companies (global) (as of October 2015)	Led by The Climate Group, in partnership with CDP. Supported by IRENA and an action of We Mean Business. Corporate founding partners: IKEA and Swiss Re
Global Fuel Economy Initiative GFEI (2009)	A partnership between 6 organizations that promotes further research and action to improve fuel economy worldwide. GFEI's core activities are data development and analysis of fuel economy potentials, support for national and regional policy-making efforts and outreach and awareness raising to stakeholders (for example, vehicle manufacturers).	6 participants (global) (as of October 2015)	FIA Foundation, UNEP, IEA, International Council on Clean Transportation, International Transport Forum and University of California - Davis

5.4.3 *Sector initiatives*

Sector initiatives are grouped around renewable energy, energy efficiency, industrial processes, low carbon transport, land restoration and reforestation, and marine energy. There is a clear likelihood of overlap between the sector initiatives and the other categories (cities and regions, and companies), but recent estimates indicate this overlap to be relatively small – less than 10 per cent – in the region of 0.21 $GtCO_2e$/yr by 2020 on a total impact range of 2.5-3.3 $GtCO_2e$/yr by 2020 (UNEP, 2015). Table 5.4 identifies principal sector-led initiatives.

5.5 The private sector and innovation in mitigation

Looking beyond ICIs, the private sector is engaged in a wide range of climate activities that have the potential to reduce carbon intensity in many economies (Vergara *et al.*, 2015). Acknowledging the critical role of favourable policy and regulatory frameworks, the private sector is instrumental for innovation, as innovation stems from technology advances, often through new economic and financial opportunities, and market-based risk-taking undertaken by the private sector. Selected examples include:

- Renewable energy, which has seen annual investments grow between 2004-2014 by 500 per cent from US$45 billion to US$270 billion (FS UNEP Centre, 2015) partially as a result of significant reductions in capital and operation and maintenance costs. For example, PV utility-size costs have been consistently falling at 22 per cent per year since 1976 (Seba, 2014). Capital costs for wind energy have also seen substantial decreases (IRENA, 2015). This pace of change is already affecting how new capacity is being planned and has the potential to bring substantive additional changes in the power generation market in the near future
- Deployment of distributed power, which has the ability to shift modes of generation and transmission from

Table 5.4: Overview of sector initiatives

Sector	Sector initiative	Objectives and targets
Renewable energy	RE 100	Ambition to attain 100% renewable energy by 100 leading businesses.
	European Industrial Renewable Energy Initiative	Initiative for European businesses – PV to supply 12% of EU power by 2020; wind to provide 34% of EU power by 2030.
	Africa Clean Energy Initiative	Investment in renewable energy through Overseas Private Investment Corporation (OPIC) – US$250 million in loans and guarantees in Africa by 2020.
	CSP Alliance: USA	The CSP Alliance comprises solar thermal electric power developers and suppliers who advocate for the increasing acceptance, adoption and implementation of solar thermal electric technology and thermal energy storage.
Energy efficiency	Sustainable Energy for All - Global Energy Efficiency Accelerator	By 2030, aiming to contribute to the target of doubling the global rate of improvement in energy efficiency – driving action by public and private leaders at all levels.
	Zero Routine Flaring by 2030	Major oil companies and governments of oil-producing countries have committed to end routine gas flaring at oil production sites by 2030.
	Climate and Clean Air Coalition	Partnership engaging both countries and non-state actors to reduce short-lived climate pollutants including methane, black carbon and hydrofluorocarbons (HFCs).
	Coalition for Energy Savings	Coalition representing 400 associations, 150 companies in 30 countries in Europe (aiming for 40% energy savings in 2030 compared to 1990 levels).
Industrial processes	Carbon Disclosure Project	Improving the management of environmental risk by putting information on climate change, water and forest-risk at the core of business, investment and policy decision making.
	Cement Sustainability Initiative	Global effort by 25 leading cement producers (accounting for over 30% of global production) to pursue sustainable operations in over 100 countries.
	Global Methane Initiative	A multilateral partnership (14 countries) aiming to reduce global methane emissions and to advance the abatement, recovery and use of methane as a valuable clean energy source.
	Industrial Energy Efficiency Coalition	Alliance of private sector companies seeking to promote continuous energy efficiency improvements in industrial processes in the USA.
Low carbon transport	International Civil Aviation Organisation	Targeting 1.5% fuel use efficiency per year until 2020 and 2% thereafter.
	Bus Rapid Transit systems (BRTs)	Informal coalition of 64 BRTs in over 40 countries.
Land restoration and reforestation	Bonn Challenge	Targeting restoration of 150 million ha of forests by 2020.
	20x20 Initiative	Targeting restoration of over 20 million ha of degraded land in Latin America by 2020. Eight private impact investors have pledged US$670 million.
Marine energy	Marine Energy Council	Unites technology developers, academia, consultants, suppliers and service providers representing the wave, tidal, ocean current and riverine sectors focussing attention on opportunities in marine energy.

centralized solutions with large grids to local systems with only distribution grids, resulting in lower overall costs in many developing countries, in particular for rural and isolated communities

- Electric power storage, which has seen an average reduction in production costs of 14 per cent per year during the period 2007-2014 and may be at a tipping point for mass production (Nykvist and Nilsson, 2015)
- Electric vehicle technologies, which are projected to potentially disrupt the use of fossil fuels in transport and may represent one of the largest available energy efficiency measures (Vergara *et al.*, 2015), and
- The application of land restoration practices, which can significantly impact accumulation of carbon sinks.

Most, if not all, of these measures are also associated with significant co-benefits, for example through improvements in energy security, reductions in emissions of harmful airborne pollutants, increased food security, and recovery of soil and water quality (IPCC, 2014; Vergara *et al.*, 2015).

Together these developments improve the outlook for substantial reductions in global carbon emissions, in some cases at an unexpected pace, bringing new market solutions into play – working hand in hand with enabling policy from government and behaviour change initiatives in civil society. In the broader picture of raising ambition and closing the gap, these recent developments indicate that acceleration is possible with the right incentives, and action on the ground may eventually surpass formal commitments.

Chapter 6

Mitigation potential from forest-related activities and incentives for enhanced action in developing countries

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6.1 Introduction

Forest-related mitigation activities in both developing and developed countries represent important opportunities for climate change mitigation, and enhanced action on these activities could contribute significantly to narrowing the emissions gap. The IPCC AR5 (Smith *et al.*, 2014) highlights that 12 per cent of global greenhouse gas (GHG) emissions (in the period 2000-2009) come from forests and other land use change. Forests hold large carbon stores within their living biomass (above and below ground), in dead organic matter (litter/dead wood) and in soil. Enhanced mitigation action could involve enhancing carbon stocks in new or existing forests, changes to forest management, and increased reforestation and afforestation.

This chapter starts by providing a global overview of existing statements regarding intended forest-related mitigation actions by countries, including in their INDCs. This is followed by a review of the range of available forest-related mitigation options. International multi-stakeholder partnerships such as the New York Declaration on Forests and the Bonn Challenge on forest landscape restoration have focused on ambitious global objectives for the sector. Over the last ten years, there has also been considerable effort and progress under the UNFCCC in negotiating the set of policy approaches and interventions known as REDD+ (reducing GHG emissions from deforestation and forest degradation, 'plus' conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks), which is considered a key option under the UNFCCC for facilitating specific cost-effective contribution to climate change mitigation in developing countries (Eliasch, 2008; UNFCCC, 2009).

Reflecting the political interest in REDD+, the chapter has a special focus on assessing the potential contribution of carbon dioxide emissions reductions and sequestration from forest-related activities in developing countries to bridging the emissions gap in 2030; and the role REDD+ can play as a key instrument to realize these reductions.

6.2 Global overview of forest-related mitigation engagement

Countries are already committing to substantial efforts towards forest-related mitigation. To date a total of 109 countries (counting the EU as one), including 94 developing countries[1], have made statements regarding their willingness to reduce emissions from deforestation and forest degradation, or to enhance forest carbon stocks. Figure 6.1 provides a global overview of these national statements[2] that are made in a range of different texts and fora including:

- *Contributions under UNFCCC:*
    - Intended Nationally Determined Contributions (INDCs), conditional or unconditional (see Box 6.1): Several countries include quantitative information on anticipated forest-related activities and LULUCF. Of the 82 developing countries that submitted their INDC by 1 October 2015 and included forest-related contributions, the majority aim to undertake actions to reduce forest-related emissions and to enhance forest carbon stocks. Fifteen Annex I countries included forest-related contributions in their INDC of which eight specify these activities, which include reducing forest-related emissions, enhancing forest carbon stock or both

1 For analytical purposes, this chapter requires a list of developing countries. There is no standard UN list, but the UNFCCC states that most of the Convention's 'non-Annex I' Parties are developing, so this set is here used as an approximation (as in the former REDD+ Partnership's Voluntary REDD+ Database). In contrast, Annex I Parties are all industrialized or have economies in transition. http://unfccc.int/parties_and_observers/items/2704.php, see also http://unfccc.int/parties_and_observers/parties/negotiating_groups/items/1031.php

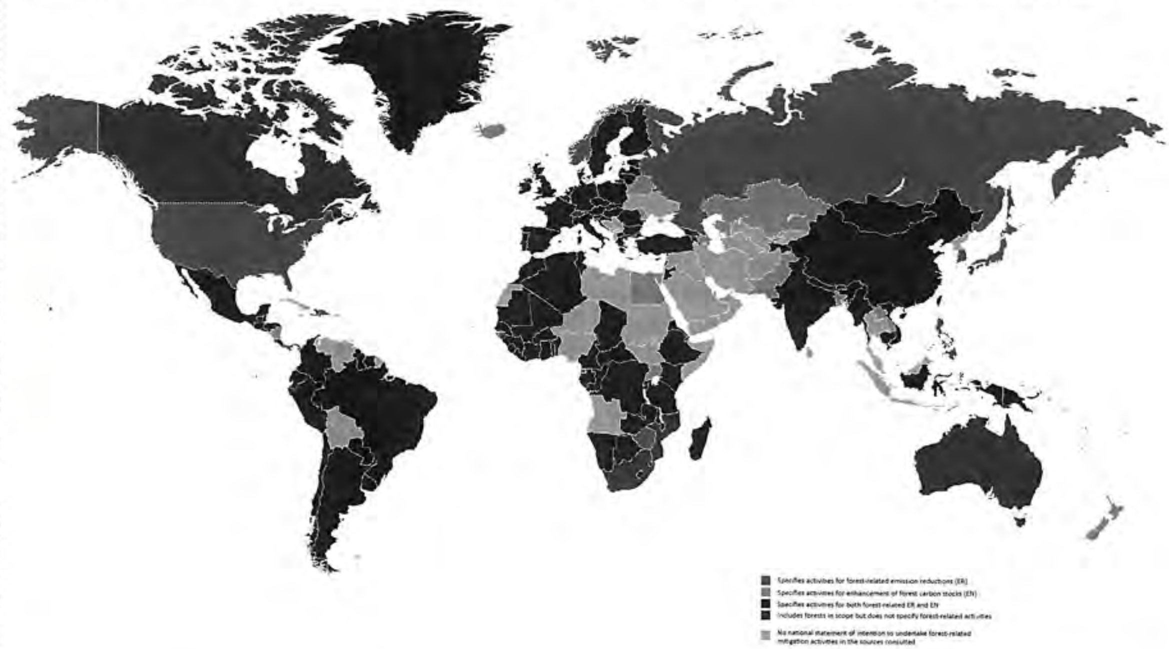
2 Underlying data can be found in Annex C, which is available online.

- Nationally Appropriate Mitigation Actions (NAMAs): Several countries include quantitative information on anticipated forest-related mitigation activities, in hectares or in carbon terms (UNFCCC, 2014a, 2014b, 2014c)
- *Bilateral arrangements:* Donors (including Germany and Norway) have agreements with Brazil, Ecuador, Ethiopia, Guyana, Indonesia, Liberia and Peru to provide funding conditional upon demonstrated success in contributing to mitigation through REDD+ ('results-based payments'). Other donors have made or are negotiating similar bilateral agreements
- *Carbon Fund:* Proposals for reductions as documented in ER-PINs (FCPF, 2015)
- *International multi-stakeholder partnerships*: The New York Declaration on Forests and Bonn Challenge commitments on forest landscape restoration (Bonn Challenge, 2015).

Of the 79 developing country Parties and five Annex I countries that have declared their intention to enhance forest carbon stocks in any of the sources listed above, 36 have quantified the area intended for restoration/afforestation/reforestation, amounting to a total of over 141 million hectares (ha).

As indicated in Chapter 3, analysis of the emission reduction contribution of LULUCF in INDCs estimates an approximate contribution of 1.6 $GtCO_2$ (of which 0.5 $GtCO_2$ comes from Annex I countries) from full implementation of unconditional INDCs, increasing to 1.9 $GtCO_2$ (range: -0.1-4.3) under full implementation of both unconditional and conditional

Figure 6.1: National statements of intention to undertake forest-related mitigation activities



Box 6.1: Forest-related mitigation in INDCs

Countries that have submitted INDCs describe their forest-related activities in a variety of different ways (see also Chapter 3). Some countries mention that the forest sector is relevant, but do not provide any quantification. Some specify conditional and unconditional contributions without indicating how these are attributed to forests. Some examples of the types of statements in the INDCs are:

- Democratic Republic of Congo: the INDC presents a 17 per cent emissions reduction contribution entirely conditional on finance, and achieved through agriculture, forestry and energy sectors. Forestry activities will focus mainly on afforestation and reforestation
- Ethiopia: the INDC presents a quantified target for mitigation in the forestry sector of 130 $MtCO_2$ through protecting and re-establishing forests and increasing carbon stocks, fully conditional on international support
- Brazil: the INDC presents an unconditional economy-wide emissions reduction for 2025. Specifically in the forest sector, implementation and permanence of REDD+ activities require the provision, on a continuous basis, of adequate and predictable results-based payments in accordance with the relevant COP decisions.

INDCs. The forest-related mitigation potential under the INDCs will be less than this, as forestry comprises a subset of LULUCF activities described in the INDCs. The following sections put these numbers into a broader context of forest-related mitigation opportunities and potentials.

6.3 Forest-related mitigation opportunities

Forest-related mitigation opportunities include maintaining or increasing forest areas and carbon density through reducing deforestation and degradation, afforestation or reforestation, or forest management to increase stand- and landscape-level carbon density (Nabuurs *et al.*, 2007).

Best practice policies to curb deforestation were reviewed in the 2012 Emissions Gap Report (UNEP, 2012). This report highlighted four distinct policy categories, including:

- Establishing new protected areas
- Using command-and-control measures (enacting, enforcing and monitoring of regulations on conversion of forest, may include investment in existing protected areas to prevent incursion (Scharlemann *et al.*, 2010))
- Using economic instruments (taxes, subsidies, payments for ecosystem services), and
- Creating policies affecting drivers and contexts that currently promote deforestation (sectoral policies, institutional frameworks, governance structures and agricultural subsidy reform).

Addressing the drivers of deforestation is critical. On-the-ground measures to reduce pressure on forests include sustainable intensification of agriculture to improve yields on existing land, and alternative livelihoods development for communities dependent on deforestation. Designating new protected areas, indigenous lands and community-managed forests can be effective in preventing deforestation *in situ*[3] and avoiding its displacement to other areas. However, forest-related mitigation approaches are generally found to be more effective if they also address the direct and indirect drivers of land-use change (Ewers and Rodrigues, 2008). Combinations of policies and measures that work at the landscape scale to reduce the drivers of deforestation, whilst identifying and protecting the most valued forests, are most likely to yield multiple benefits (New Climate Economy, 2015).

Reducing degradation and promoting enhancement of forest carbon stocks can also benefit from policies ranging from incentives for best practice to actions to address drivers (for example, fire and unsustainable harvesting). Sustainable forest management can reduce emissions from forest degradation through specific policies and measures, including adoption of reduced-impact logging in areas designated as production forest; prevention of illegal logging; planting of woodlots for poles or charcoal; promotion of more sustainable extraction and efficient use of fuelwood and charcoal; and support to community forestry and development of systems to limit the spread of anthropogenic fires such as those used in agriculture.

Enhancing carbon stocks may involve afforestation or reforestation, with approaches ranging from assisted natural regeneration to tree planting. In areas of disturbed forest, carbon stocks may be enhanced by controlling the degradation drivers covered above and by direct interventions, for example, through enrichment planting (Paquette *et al.*, 2009) or rewetting of drained peatland forest (Jaenicke *et al.*, 2010). Enhancing carbon stocks is one goal among many in the process known as forest landscape restoration, which aims to regain ecological integrity and enhance human well-being in deforested or degraded forest landscapes to meet present and future needs, whilst accommodating multiple uses over time (Maginnis *et al.*, 2012). Forest landscape restoration may involve planting trees on farms, woodlots or agroforestry systems, or establishing new areas of forests to restore and recreate the structure, function and composition of an original forest ecosystem, or both (Lamb and Gilmour, 2003).

Conserving, restoring and sustainably managing forests offers numerous benefits other than carbon storage, strengthening the case for prioritizing forest-related mitigation options. Forests provide essential ecosystem goods and services, such as water quality and regulation (providing more consistent flows of clean water for drinking and agriculture), erosion control (preventing sedimentation of hydropower dams, and protecting other lands downstream), forest products (directly supporting livelihoods, for example through timber, fuelwood, foods, medicine and fibre) and cultural services (supporting cultural traditions and tourism) (Shvidenko *et al.*, 2005). Hence, well-chosen and implemented forest-related mitigation activities can contribute to many other domestic and international policy objectives, including those defined in the Convention on Biological Diversity's Strategic Plan for Biodiversity 2011-2020 and the Aichi Targets (CBD, 2010), the Sustainable Development Goals (Goal 13 on urgent climate action and Goal 15 including to halt deforestation by 2020) (UNGA, 2015), the UN Declaration on the Rights of Indigenous Peoples (UN, 2008), the UNCCD 10-year strategic plan and framework (UNCCD, 2007) and the Non-Legally Binding Instrument on All Types of Forests (UNGA, 2007). Synergies between adaptation and mitigation also exist in many cases and can, for example, be achieved through ecosystem-based adaptation (Rizvi *et al.*, 2015). Furthermore, forest-related mitigation opportunities are integral to landscape-level mitigation approaches, and complement actions to reduce emissions from agricultural land[4] and from non-forested peatlands (Smith *et al.*, 2014).

The variety of forest-related mitigation opportunities presented here demonstrates the potential for broad participation by countries in forest-related mitigation according to their national circumstances. Drivers of land-use change, potential for restoration, and climate impacts on forest ecology among many other factors will differ between countries and regions, and determine the appropriate forest-related mitigation activities.

3 Though around nine per cent of all deforestation emissions in the humid tropics between 2000 and 2005 resulted from forest cleared from within protected areas (Scharlemann *et al.*, 2010).

4 Responsible for a similar quantity of annual GHG emissions, based on CO_2 only from deforestation and forest degradation (Table 6.1) compared to all greenhouse gases from agricultural land in 2005 (Smith *et al.*, 2014, Figure 11.4).

6.4 Emission reduction potential of forest-related mitigation activities

The previous sections provided a global overview of countries' intentions regarding forest-related mitigation activities and illustrated the wide range of areas in which such activities can be undertaken. In addition, the estimated LULUCF mitigation contribution in the INDCs was highlighted. While acknowledging the importance of reducing forest-related emissions in all countries, the political interest and emphasis given to REDD+ as a key instrument to realizing forest-based emission reductions reflects the critical role of developing countries in reducing emissions from deforestation.

This section assesses the total potential contribution to bridging the emissions gap in 2030 that could be brought about by forest-related emission reductions in developing countries. More specifically, the section assesses the technical potential for reducing emissions through forest-related activities in developing countries based on a review of the published literature. The technical potential represents the full biophysical potential of a mitigation option without accounting for economic or other constraints (as defined in Smith *et al.*, 2014, p. 847). It represents a halt of emissions from deforestation and forest degradation including on peatland, and universal 'wide-scale' forest restoration on available and suitable areas. This represents an upper technical maximum and is estimated to be around 9 $GtCO_2$ in 2030 (range: 6.7-11.9) (Table 6.1).

Achieving the technical mitigation potential of the forest sector is limited by operational and socio-economic factors. Factors that can place increased demands on forest land include limited capacity to increase production in agriculture, national objectives for food self-sufficiency, infrastructure development, and wood product requirements. Demands can be reduced by factors such as restoring degraded lands to agricultural production, changing dietary preferences or reducing waste. Hence, country goals for forest-related emission reductions and enhancement of carbon stocks need to take into account potential competition with other land uses.

6.4.1 *Technical mitigation potential of reducing carbon dioxide emissions*

A wide range of estimates of global CO_2 emissions from deforestation and forest degradation exist (Ciais *et al.*, 2013; Smith *et al.*, 2014). The range reflects uncertainty in data sources, use of different methodologies to estimate emissions, and differences in the land use change processes included, the range of emission sources included and the land-cover definitions adopted (Houghton *et al.*, 2012). For example, the forest definitions used in international analyses are frequently based on those used by FAO's Global Forest Resources Assessment (forest area >0.5 ha, tree height >5 m and canopy cover >10 per cent, or trees able to reach these thresholds *in situ*, not predominantly under agricultural or urban use) (IPCC, 2006; FAO, 2010a). However, national forest definitions vary widely in terms of thresholds for canopy cover and tree height, and land uses included (Sasaki and Putz, 2009), meaning that vegetation types such as savannas, agroforestry systems, and mangroves may or may not be addressed by forest policies, depending on the country. Differences in definition, not only of land cover types but also land-use change processes, influence both the overall estimated mitigation potential and whether certain emissions result from deforestation or from forest degradation (Romijn *et al.*, 2013).

To estimate the technical mitigation potential of reducing deforestation and degradation and enhancing forest management in 2030 (second and third columns of Table 6.1), recent emissions given by published studies (referenced below the table) are used to approximate future emissions, assuming no further forest-related mitigation action. The business-as-usual scenarios in Clarke *et al.* (2014) suggest that total emissions from AFOLU (agriculture, forestry and other land use) may remain stable or decline, as they assume a slowing of population growth and increased efficiencies of food production that will contribute to reducing deforestation. Emissions from forest degradation in non-Annex I countries have declined marginally from 1.1 $GtCO_2$/yr in 2001-2010 to 1 $GtCO_2$/yr in 2011-2015, but the relative emissions from degradation compared to deforestation have increased from a quarter to a third (Federici *et al.*, 2015). Indeed, in scenarios that consider increased reliance on biofuels for energy generation and climate mitigation, demand for agricultural land continues to grow. Bottom-up assessments of drivers also suggest that pressures will increase (Kissinger *et al.*, 2012). For example, emissions from deforestation in the Congo basin are expected to increase in the future, with average annual deforested area between 2020 and 2030 varying amongst policy scenarios from 0.4 to 1.3 million ha (Megevand, 2013). Hence, the technical mitigation potential from reduced deforestation and forest degradation and enhanced forest management are estimated at 5.2 $GtCO_2$/yr (range: 2.1-6.3), and may be a relatively conservative approximation of total potential, assuming that emissions from these sources are likely to continue at present levels or increase.

In the two decades up to 2010, tropical deforestation emissions have been found to represent around 98 per cent of reported deforestation emissions from non-Annex I countries[5]. Therefore tropical deforestation derived from published studies (Harris *et al.*, 2012; Achard *et al.*, 2014) has been used to approximate the technical potential for reduced deforestation in developing countries, which amounts to between 1.7-4.7 $GtCO_2$/yr, with a mean of 3.4 $GtCO_2$/yr (Table 6.1).

Forest degradation in non-Annex I countries, including the effects of selective logging, fire or drought, and fuelwood harvest, accounts for around 1 $GtCO_2$/yr (between 2011-2015 (Federici *et al.*, 2015)), which is very similar to the results found by Grace *et al.* (2014) for 2000-2012 of a mean of 1 $GtCO_2$/yr (range: 0.3-1.7). In addition, emissions from drainage and fire in forested or deforested peatlands in Southeast Asia were estimated at a mean of 0.8 $GtCO_2$/yr (drainage in 2006, fire 1998-2009 (Smith *et al.*, 2014, Box 11.1)). Therefore the total

5 Percentage calculated from FAO (2010b) Global Forest Resources Assessment 2010. Global Tables: Table 11 Trends in carbon stock in living forest biomass 1990-2010. Available at: http://www.fao.org/forestry/fra/fra2010/en/

technical potential of reducing degradation and enhancing forest management would equal 1.8 $GtCO_2$/yr.

6.4.2 *Technical mitigation potential of enhanced carbon sequestration*

As noted, increased sequestration, or enhanced removals, of carbon can result from increasing forest area, or through enhancing sequestration in existing forest (for example, rehabilitating degraded forest). When tree density increases, carbon is removed from the atmosphere by the increasing plant biomass, and soil carbon stocks are protected from erosion and may also increase.

Reforestation can take place at a variety of scales, from increasing tree cover in small areas within a mosaic of other land uses (so called 'mosaic restoration') to restoring larger areas ('wide-scale' restoration, see Glossary). The estimated global potential for 'wide-scale' restoration of closed-canopy forest is up to half a billion ha, excluding areas in intensive use (WRI, 2011)[6]. An additional 1.5 billion ha globally may have the potential for mosaic restoration (WRI, 2011). Mosaic restoration may be easier to undertake as it allows a greater range of land uses, whilst restoring areas to closed-canopy forest is likely to remove more CO_2 per unit of area. Depending on ecosystem type, and whether the result is a natural forest or a plantation, areas converted to forest are estimated to remove between about 1 and 35 tCO_2 per ha per year in above- and below-ground biomass (from default data in IPCC (2006)[7]). If natural forest were simultaneously restored over the 351 million ha with potential for wide-scale restoration in non-Annex I countries in Africa, Asia-Pacific and Latin America and the Caribbean regions, calculated from WRI (2011), this could equate to 3.8 $GtCO_2$/yr while the forest was re-growing.

Standing, secondary and planted forests also contribute to the global 'terrestrial carbon sink', absorbing CO_2 from the atmosphere. The forest carbon sink is estimated to be large and vary widely, from a global value of 3.4 ± 1 $GtCO_2$/yr (for the period 2001-2010 (Federici *et al.*, 2015)), to estimates for tropical sinks alone of 6.8 $GtCO_2$/yr (for the period 2005-2010 (Grace *et al.*, 2014)). The IPCC states with high confidence that increased atmospheric CO_2 will lead to increased terrestrial carbon uptake (Ciais *et al.*, 2013), and a recent review suggests that the largest increase has been in woody biomass within savanna (included in some national forest definitions) and non-forest ecosystems (Liu *et al.*, 2015). Carbon sink figures for existing forests are not included in the technical potential for reduced deforestation given here, as a result of the uncertainty surrounding how carbon sinks and their capacity to absorb CO_2 will change in the changing climate (Bellassen and Luyssaert, 2014).

6.4.3 *Economic mitigation potential of forest-related mitigation*

A number of recent studies estimate the global economic mitigation potential in 2030 of various forest-related activities given economic and land-use constraints, at different levels of costs and for different regions of the world.

Table 6.1: Technical potential for forest related mitigation activities for developing countries ($GtCO_2$ in 2030, median (range)).

	Reduced deforestation	Reduced degradation and forest management	Afforestation and reforestation	Totals
Regions	Technical (tropics)[a,b]	Technical (degradation, tropics)[c,d]	Technical (non-Annex I countries)[e,f]	Technical
Africa	0.6 (0.2-0.8)	0.5 (0.2-0.9)	1.6	2.7 (1.9-3.3)
Latin America and Caribbean	1.9 (1.2-2.5)	0.1 (0-0.2)	1	3 (2.3-3.7)
Asia-Pacific	1 (0.4-1.4)	0.3 (0.1-0.6)	1.2	2.5 (1.7-3.1)
Peatland degradation	-	0.8	-	0.8
Totals	**3.5 (1.8-4.7)**	**1.7 (0.3-1.7)**	**3.8**	**9 (6.7-11.9)**

Notes to Table 6.1:

[a] Achard *et al.* (2014), Table 2: annual carbon losses from gross loss of tropical forest cover (>30% cover) and other wooded land (<30% cover) for 2000-2010. Three estimates from Achard study (Ecozone/IPCC, max and min Saatchi). Tropical regions: Central and South America, Africa, Southeast Asia.

[b] Harris *et al.* (2012), Table 1: WHRC and Winrock team's estimates of gross carbon emissions from tropical deforestation, 2000-2005. Tropical regions: Sub-saharan Africa, Latin America, South and Southeast Asia. Only forest biomass carbon stocks.

[c] Grace *et al.* (2014), Table 5: estimated annual degradation flux from tropical degradation, 2000-2012. Tropical regions: Africa, America, Asia.

[d] Total technical potential for degradation includes peatland degradation. Emissions from drainage (in 2006 according to Hooijer *et al.*, 2010 in Smith *et al.*, 2014) and fire in forested or deforested peatlands in Southeast Asia (lower estimate for 1998-2009, Box 11.1 in Smith *et al.*, 2014).

[e] Afforestation and reforestation, including any expansion of forest area (see section 6.3).

[f] Calculated for this chapter as: area of wide-scale restoration potential WRI (2011) in different FAO ecological zones (FAO, 2012) for non-Annex I countries in UNEP region codes (excluding Europe and West Asia), multiplied by net annual CO_2 uptake based on IPCC (2006) [annual net above + below-ground biomass growth, for natural forest in each ecological zone]/ [biomass to carbon conversion factor = 0.47] * [carbon to CO_2 conversion factor = 3.67]. This figure is greater than the maximum estimate of 3.4 $GtCO_2$ for the similar area of 350 million hectares at 2030 by Wolosin (2014); however that analysis was not restricted to non-Annex I countries and averages over restoration scenarios that include a large proportion of mosaic restoration and improved secondary and naturally regenerated forest, of which will result in a lower average biomass growth per hectare. Use of the IPCC biomass growth figures for plantation forest would yield a still higher estimate. Single source, no range.

6 In (WRI, 2011) closed-canopy forest has a canopy density greater than 45 per cent.

7 In (IPCC, 2006, Tables 4.4 and 4.12) ecosystems from boreal tundra woodland to tropical plantation.

They offer a very large range of estimates of global mitigation potential at different cost levels, ranging from 0-1.5 $GtCO_2e$ for costs <US$20/$tCO_2e$, to mitigation potentials of 0.1-9.5 $GtCO_2e$ for costs <US$50/$tCO_2e$, and ranging from 0-13.8 $GtCO_2e$ for costs <US$100/$tCO_2e$ (Smith *et al.*, 2014). Differences among models reviewed include the cost levels used, the economic assumptions, model approach (bottom-up or top-down), and the mitigation options considered. The economic mitigation potential for developing countries is not provided separately. However, it is highlighted that for developing countries the most cost-effective mitigation options in forestry are reducing deforestation, sustainable forest management and afforestation (Nabuurs *et al.*, 2007). Regional breakdowns show that reduced deforestation dominates as the most cost-effective forestry option for Latin America and Middle East and Africa regions, whereas forest management dominates the Asia region (Smith *et al.*, 2014).

In general, the economic mitigation potential will be smaller than the technical potential. Furthermore, estimates of economic mitigation potential do not consider policy incentives and socio-cultural and institutional barriers to implementation of forest-related mitigation activities (Smith *et al.*, 2014), which further affect in either direction the extent to which emission reduction potentials are realized.

Real-world examples of how the results of full-scale realisation of forest mitigation policies might compare to these economic mitigation potentials are limited. Nevertheless, Brazil's success in reducing deforestation by 82 per cent in the Brazilian Amazon between 2004-2014 (INPE, 2015) results from a mix of policies that included expansion of protected areas, supply chain interventions, and positive incentives for landholders (Nepstad *et al.*, 2014) as well as exogenous economic factors such as falling commodity prices (Assunção *et al.*, 2015). This emphasizes the role of socio-cultural, institutional and policy-related contexts for realising forest-related emission reductions. Nonetheless, the previous sections have indicated that there is significant potential to further reduce forest-related emissions, both compared to current practices and to the contributions indicated in the submitted INDCs. The last section of this chapter focuses on REDD+ as a key option under the UNFCCC for further enhancing forest-related mitigation in developing countries.

6.5 REDD+ as a key instrument to realize forest-related emission reductions in developing countries

The immediate and relatively large impact of preserving carbon through reducing deforestation and degradation, as well as the cost-effectiveness of this land use option compared to other mitigation measures (Golub *et al.*, 2010; Smith *et al.*, 2014) has driven the momentum behind development of the REDD+ mechanism. Originally recognizing the contribution of "reducing emissions from deforestation in developing countries" ('RED') (UNFCCC, 2005), the scope was expanded in 2007 to include emissions from degradation and became a component of enhanced action on mitigation ('REDD') (UNFCCC, 2007). In 2009 REDD+ was further expanded to include "conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks" ('REDD+') (UNFCCC, 2009) and now represents a specific suite of forest-related mitigation activities in the developing world (see Box 6.2) that countries can implement voluntarily to contribute to the global mitigation effort. Since 2005, the REDD+ framework has evolved under the UNFCCC, adapting to improved understanding of issues regarding potential impacts, methodological accounting, safeguards, and financing (Smith *et al.*, 2014).

At COP 16 in Cancun in 2010, a phased approach to REDD+ was decided "[...] beginning with the development of national strategies or action plans, policies and measures, and capacity-building, followed by the implementation of

Box 6.2: The REDD+ activities

While the five REDD+ activities are listed in UNFCCC decision text, it is useful to further define these to understand how REDD+ can contribute to forest-related mitigation. Noting that countries will have their own definitions, this chapter adopts:

a) Reducing emissions from deforestation – reducing emissions resulting from conversion of forest to other land uses

b) Reducing emissions from forest degradation – reducing emissions resulting from activities in forest areas that do not result in conversion of forest

c) Conservation of forest carbon stocks – the retention of existing forest carbon stocks. This activity can only make a contribution to mitigation if the carbon stock would otherwise be lost, so it is difficult to estimate mitigation potential separately from (a) or (b). The rationale for inclusion of this activity was to provide conservation incentives for those countries with limited deforestation or stable forest cover

d) Sustainable management of forest – though this could include the whole set of REDD+ forest activities, it is defined more narrowly here as the sustainable management of forest including for timber or fuelwood production (maintaining constant or increasing levels of carbon stocks over multiple harvest cycles) (Miles and Dickson, 2010). This contributes to reduced emissions from forest degradation, and rehabilitation of carbon stocks in degraded forest

e) Enhancement of forest carbon stocks – both the restoration of carbon stocks in degraded forest, and through expansion of forest cover.

national policies and measures and national strategies or action plans that could involve further capacity-building, technology development and transfer and results-based demonstration activities, and evolving into results-based actions that should be fully measured, reported and verified" (UNFCCC, 2010[8]). This was to provide a progressive pathway to full-scale REDD+ implementation, taking into account the differing capacities of countries.

Moreover, interventions at the national level are needed to overcome internal displacement of pressures from one area to the next. For this to happen, nationally coordinated cross-sectoral strategies are required, and should be based on an analysis of the drivers of deforestation and forest degradation, and barriers to the sustainable management of forest and enhancement of forest carbon stocks. National, and often, subnational institutions need to be mandated, resourced and have the capacity to implement these strategies. Safeguards need to be promoted and supported - to protect or enhance the many social and environmental values of forest, to respect the knowledge and rights of indigenous peoples and member of local communities, and to enable the full and effective participation of relevant stakeholders, in particular indigenous peoples and local communities. A robust and transparent national forest monitoring system is also required, enabling consistency in data and information to support the implementation of REDD+ activities (UN-REDD Programme, 2013).

Each of these pre-requisites to successful implementation is reflected in a series of decisions made under the 2013 Warsaw Framework on REDD+ (UNFCCC, 2013), which made significant progress on deciding on the coordination of financing, transparency and safeguards, development of national forest monitoring systems, verification at the international level, institutional arrangements to receive results-based finance, and action on drivers of deforestation (UNFCCC, 2013[9]). To access results-based payments for REDD+ activities, actions need to be fully measured, reported and verified. To this end, countries need to have in place:

- A national strategy or action plan,
- A national forest monitoring system (or interim subnational system),
- A safeguards information system and a summary of information on how the REDD+ safeguards have been addressed and respected, and
- A forest reference emission level or forest reference level (or interim subnational reference level).

The contribution of REDD+ to meeting the potential for forest-related mitigation is partly contingent on available resources, first to put these requirements in place and to develop enabling policy frameworks and institutional capacity to implement them (sometimes referred to as 'REDD+ readiness'), and later to supply the financing that creates positive incentives for enhanced results-based action on mitigation by developing countries[10].

The series of decisions made under the 2013 Warsaw Framework on REDD+ (UNFCCC, 2013) has been accompanied by an ongoing and diverse set of early action REDD+ activities and other multilateral, bilateral or country driven initiatives being implemented that contribute to REDD+ readiness or complement the goals of REDD+ (for example, conservation and sustainable forest management).

Despite the complexities that have slowed REDD+ implementation on the ground (Sills *et al.*, 2014), REDD+ is seen as a unique approach to better integrate the forest sector in the broader climate change and sustainable development plans of developing countries. Indeed, support to REDD+ readiness actions offers national benefits to many countries, including the development of national forest monitoring systems, understanding of drivers of deforestation, the strengthening of policies, laws and regulations relevant to the UNFCCC's REDD+ safeguards, the adoption of wider stakeholder engagement in decision-making, and development of better data and information on the distribution of forest carbon stocks, biodiversity and ecosystem services (Lee and Pistorius, 2015). It involves implementing policies and measures that contribute substantially to climate change mitigation, are based on positive incentives for action, and can deliver additional co-benefits. Hence, REDD+ continues to receive political support from many developed and developing countries.

Some major constraints on the potential for REDD+ implementation include the speed at which policies can be put in place and governance improvements can be implemented, as well as competition with other land uses (food security with a growing global population). In principle, national strategies and action plans should take account of these constraints when determining the scale of ambition for REDD+. The availability of finance to cover the readiness and upfront costs of REDD+, whether domestic or international, will also be a determining factor (Streck, 2012).

Many countries have included forest-related mitigation contributions within their INDCs, which can contribute to setting the stage for large-scale implementation of REDD+ in the coming years. Together with an awareness of the challenges facing implementation and building on the existing momentum in this sector, forest-related mitigation activities represent significant opportunities to narrow the emissions gap and facilitate the transition to a low-emission pathway consistent with limiting global average temperature increase to below 2°C in 2100 with >66 per cent chance.

8 Decision 1/CP.16 (UNFCCC, 2010).

9 Decision 9-15/ CP. 19 (UNFCCC, 2013).

10 "Results-based finance may come from a wide variety of sources, public and private, bilateral and multilateral, including alternative sources" (UNFCCC, 2013).

Annex 1

Country-specific findings

This Annex presents detailed country-level findings for 13 of the G20 countries that had submitted their INDCs by 1 October 2015. The EU is considered as one (EU28). Accounting for around three quarters of global GHG emissions, the G20 has the largest effect on the aggregate, global findings of this assessment.

For each country, a brief description of the INDC elements considered by the modelling groups is provided. Reasons for discrepancies between different data sources are discussed. Data are sourced from global studies (if available), national studies, and official government sources. It should be noted that the current policy trajectory emissions are based only on the CAT (2015) and PBL (2015), as well as official and national studies. Other studies do not provide current policy trajectory emission projections.

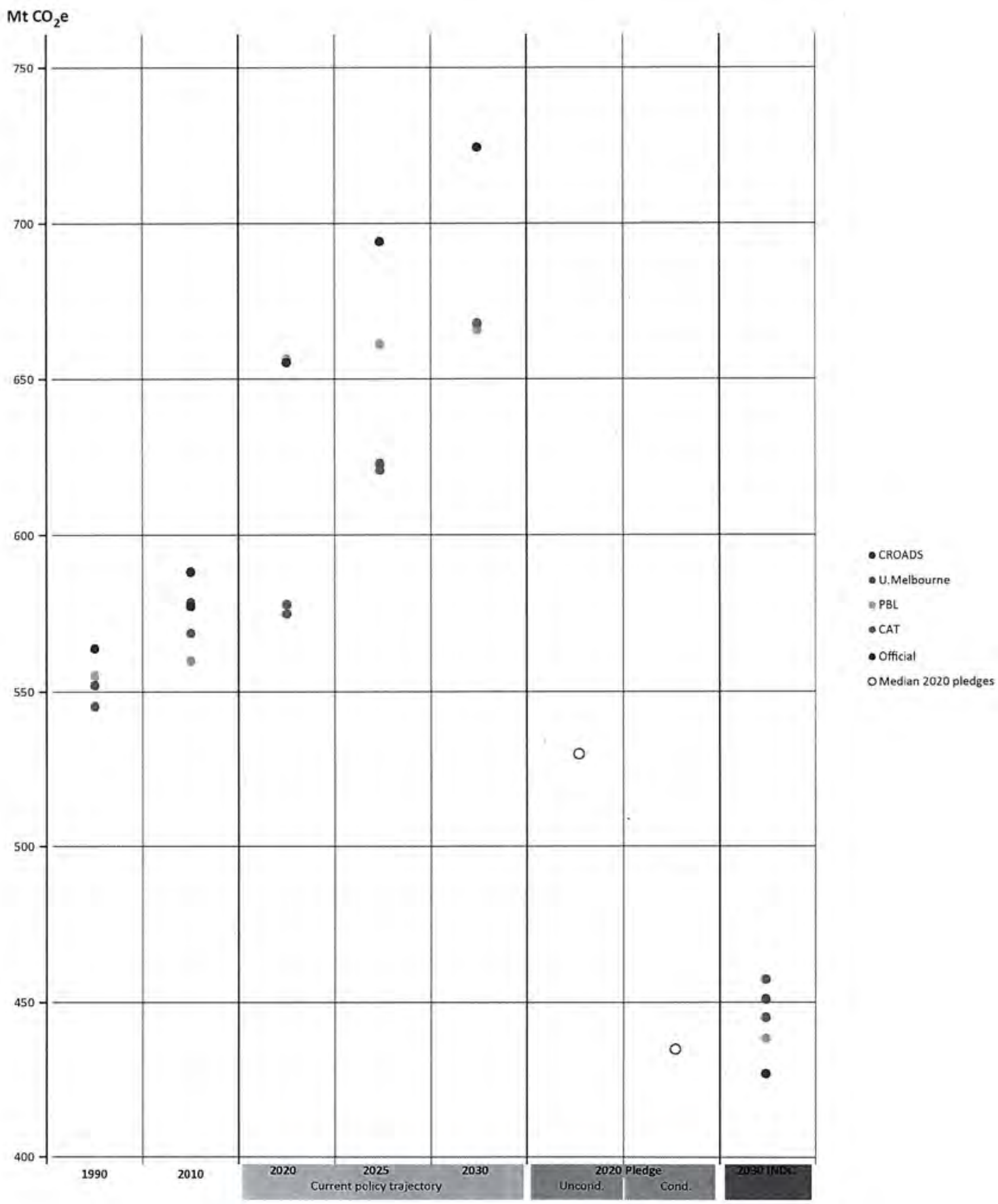
Australia

Australia intends to reduce GHG emissions by 26–28 per cent from 2005 levels including land use, land use change and forestry (LULUCF) by 2030. Australia's target covers all sectors (energy, industrial processes and product use, agriculture, LULUCF, and waste) and gases (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3).

The four modelling groups which estimated the INDC scenario in 2030 all agree on the impact of Australia's INDC on its emissions in 2030. As an official estimate is not available in Australia's INDC itself, an alternative official country-specific data source was used (Australian Government, 2015). This source provided the 'official estimate' in the Figure below. All models demonstrate a significant difference between current policy trajectories and the INDC trajectory in 2030.

Figure A1.1: GHG emissions of Australia under the 2020 pledge, INDC and current policy trajectory case

The official study is: Australian Government (2015). Noted, CROADS, IEA (adjusted) and NIES are excluded as the results of these studies are presented at a regional level, only cover limited countries



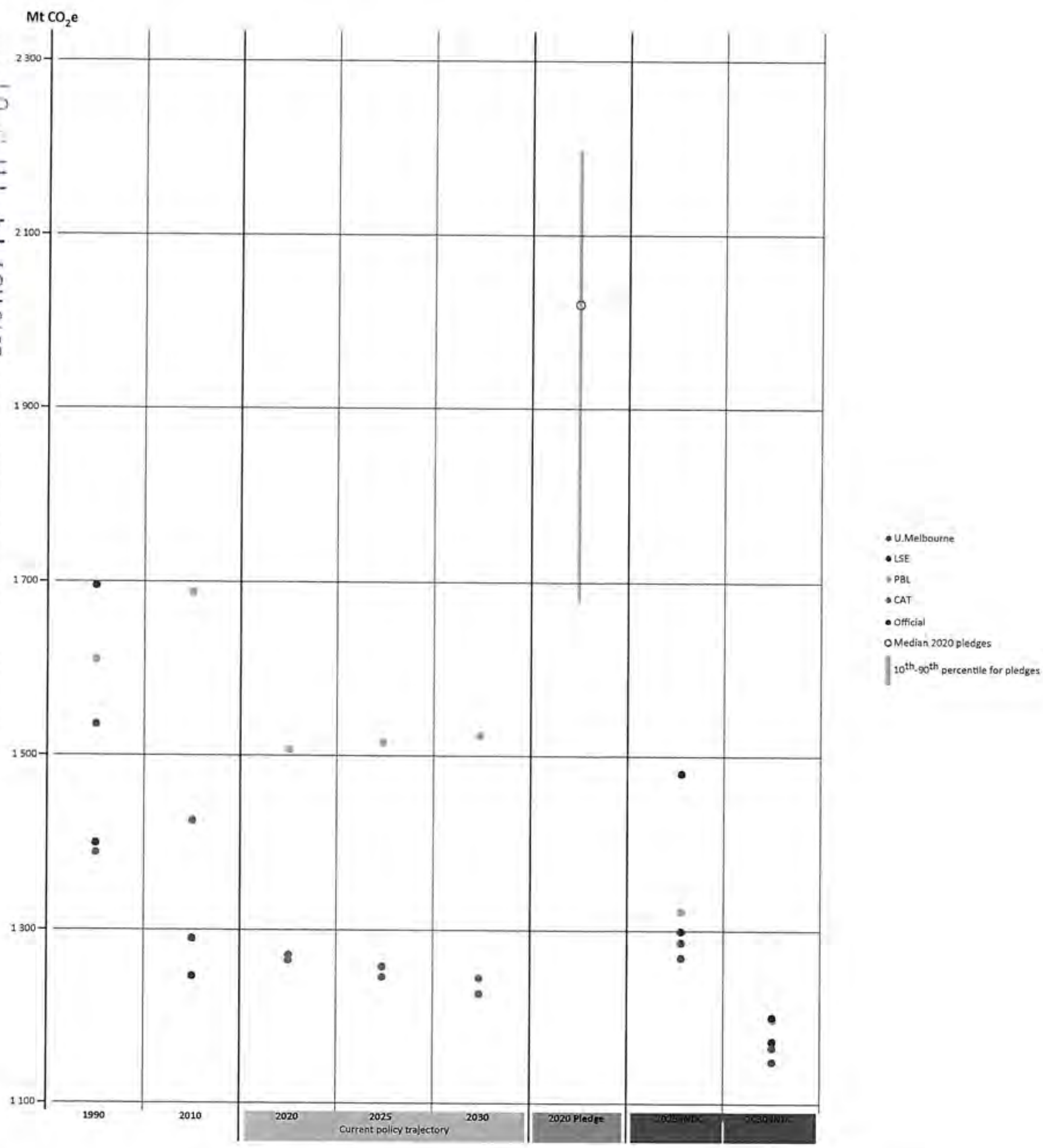
Brazil

The Brazilian INDC establishes an absolute target relative to 2005, reducing GHG emissions by 37 per cent in 2025 and indicating further reductions by 43 per cent in 2030. These percentage reductions are relative to reported emissions of 2.1 $GtCO_2e$ in 2005, corresponding respectively to emission levels of 1.3 $GtCO_2e$ in 2025 and 1.2 $GtCO_2e$ in 2030, using IPCC AR5 GWP-100. Brazil's INDC is economy-wide, covers all IPCC sectors and six gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6), and is unconditional. Actions to achieve the targets focus mainly on the forest sector and on increasing the share of biofuels and renewable electricity in the Brazilian energy mix.

Modelling groups estimate higher historical emission levels than official estimates, but do roughly agree with the projection of the current policy trajectory for 2020. Modelling group estimates for emission levels in 2025 and 2030 are similar to national estimates as they also used official INDC projections.

Figure A1.2: GHG emissions of Brazil under the 2020 pledge, INDC and current policy trajectory case

The official study is: INDC Brazil (UNFCCC, 2015)



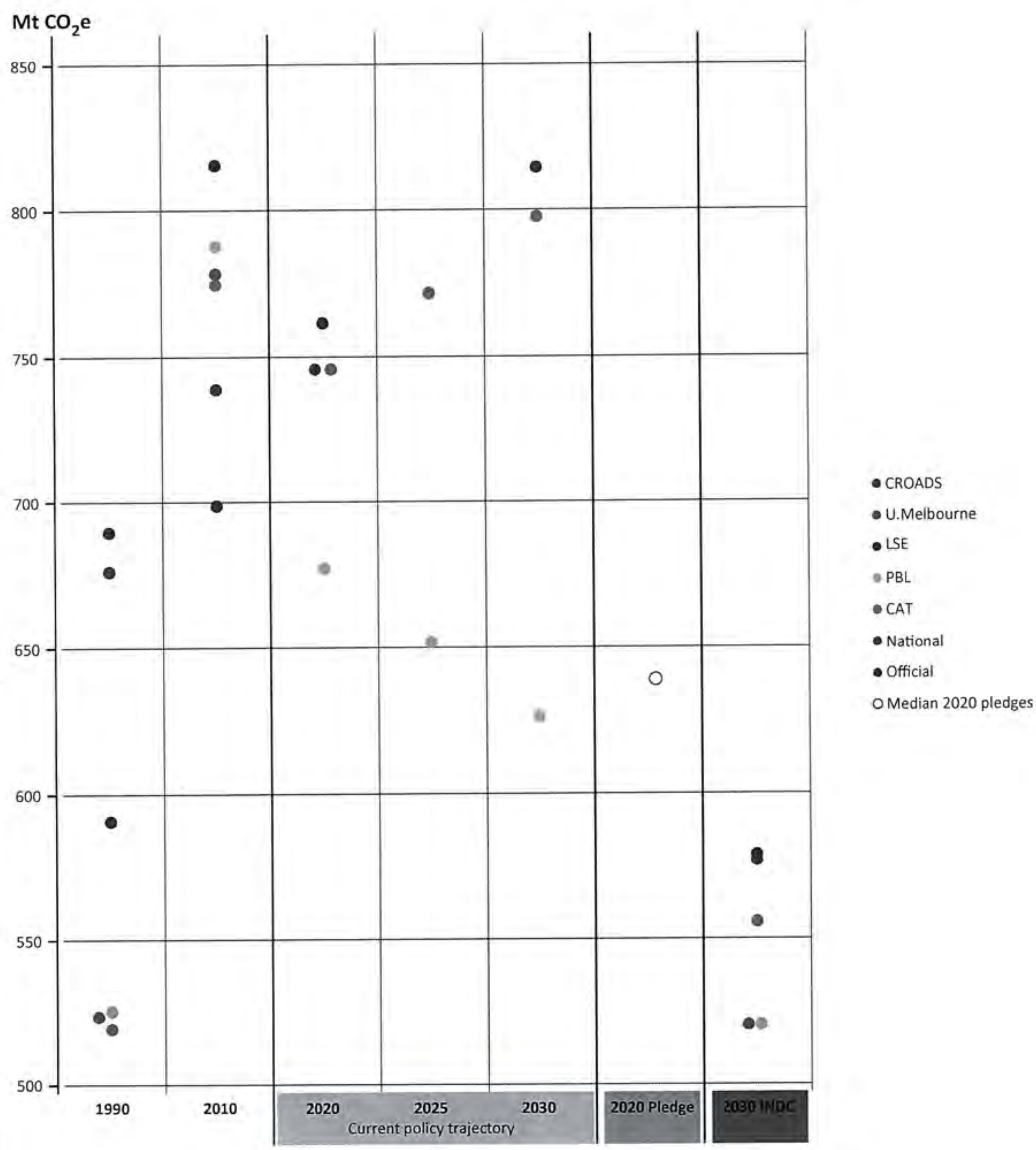
Canada

Canada proposes an economy-wide target to reduce GHG emissions by 30 per cent below 2005 levels in 2030. Canada's INDC is said to include all sectors and GHG gases. However, there are some uncertainties on the treatment of LULUCF. Although the country declares its target to include *all* IPCC sectors (excluding emissions from natural disturbances), the LULUCF sector does not appear to be included in the base year (based on the information presented in the INDC). For that reason, it is possible that the LULUCF sector will be treated separately from the other sectors.

The modelling groups largely agree on the impact of Canada's INDC on its emissions. Projections of Canada's future emissions under current policies, however, vary widely.

Figure A1.3: GHG emissions of Canada under the 2020 pledge, INDC and current trajectory policy case

The official and national studies are: UNFCCC inventories for historic data/6th National Communication for projections and the first Biennial Report of Canada (Government of Canada 2014a) and Government of Canada (2014b)



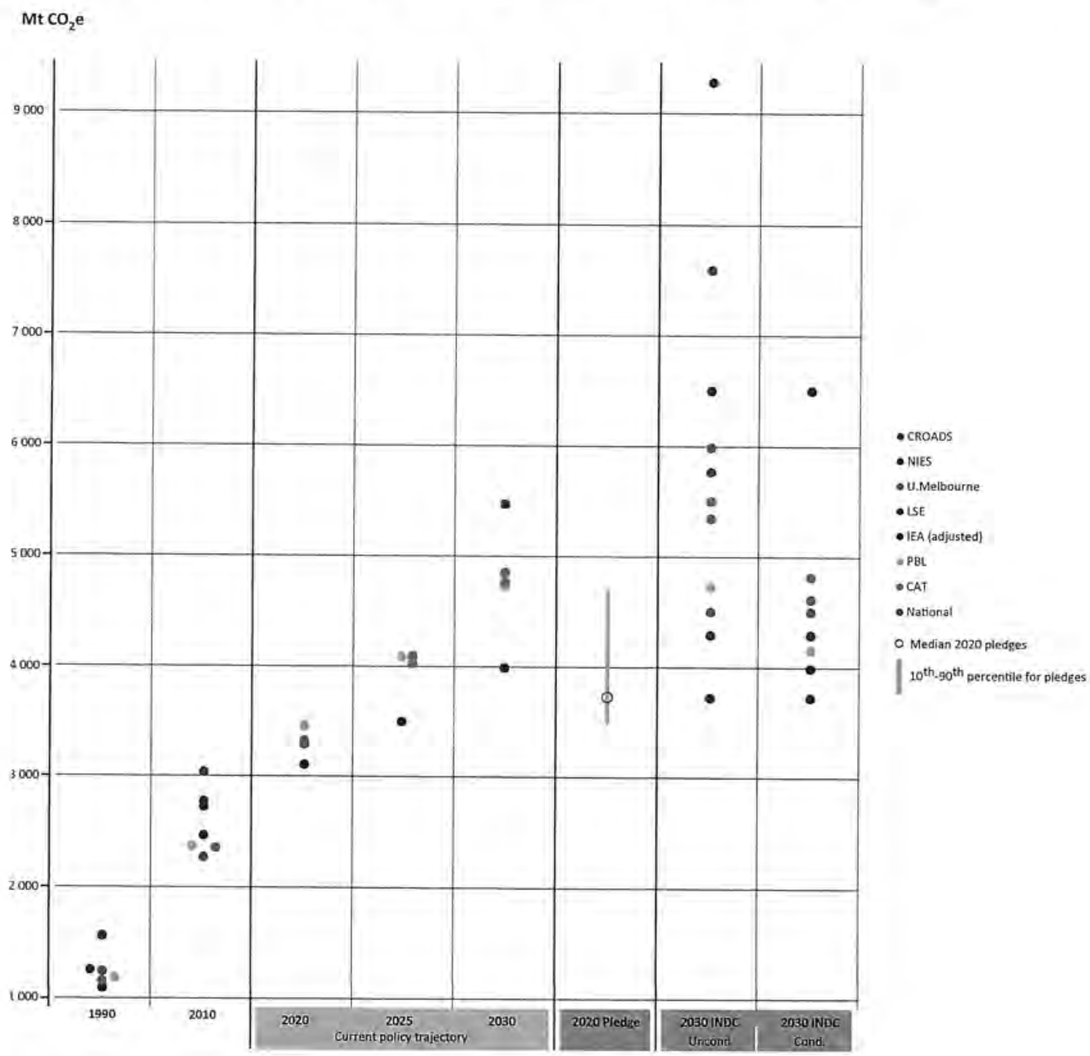
India

India's INDC for the period 2021 to 2030 included the following intentions: "[...] to put forward and further propagate a healthy and sustainable way of living based on traditions and values of conservation and moderation; to adopt a climate friendly and a cleaner path than the one followed hitherto by others at corresponding level of economic development; to reduce the emissions intensity of its GDP by 33 to 35 per cent by 2030 from 2005 level; to achieve about 40 per cent cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030 with the help of transfer of technology and low cost international finance including from Green Climate Fund (GCF); to create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030" (UNFCCC, 2015). The sectors and gases covered by the intensity target are not specified.

The studies assessed show a wide range of potential mitigation impacts of India's INDC on national emissions, varying from 3.7-4.8 $GtCO_2e$ by 2030 for the conditional INDCs (assuming a full implementation of the INDC, including the non-fossil fuel target), and varying from 3.7-6.5 $GtCO_2e$ by 2030 for the unconditional INDCs (assuming current policies, or only accounting for the intensity target). The wide ranges are caused mainly by different assumptions regarding GDP growth rate, different base year data, and interpretation of the conditionality of the INDCs. The higher estimates of LSE and the national study stem from a focus on the INDC intensity target calculations only, and do not consider other INDC elements, such as the non-fossil energy target.

An official estimate of emissions under the INDC is not available. National estimates for CO_2 emissions from the energy sector (and cement) are available from Dubash *et al.* (2015), which are not included here. From Damassa *et al.* (2015, forthcoming), there are national 'all GHG' projections including land-use for India based on a relatively large range of GDP assumptions (6.3-7.4 per cent average GDP growth for the period 2005-2030), resulting in emissions of 5.7-7.5 $GtCO_2e$ in 2030.

Figure A1.6: GHG emissions of India under the 2020 pledge, INDC and current policy trajectory case
The official and national studies are: INDC India (UNFCCC, 2015) and Damassa et al. (2015, forthcoming)



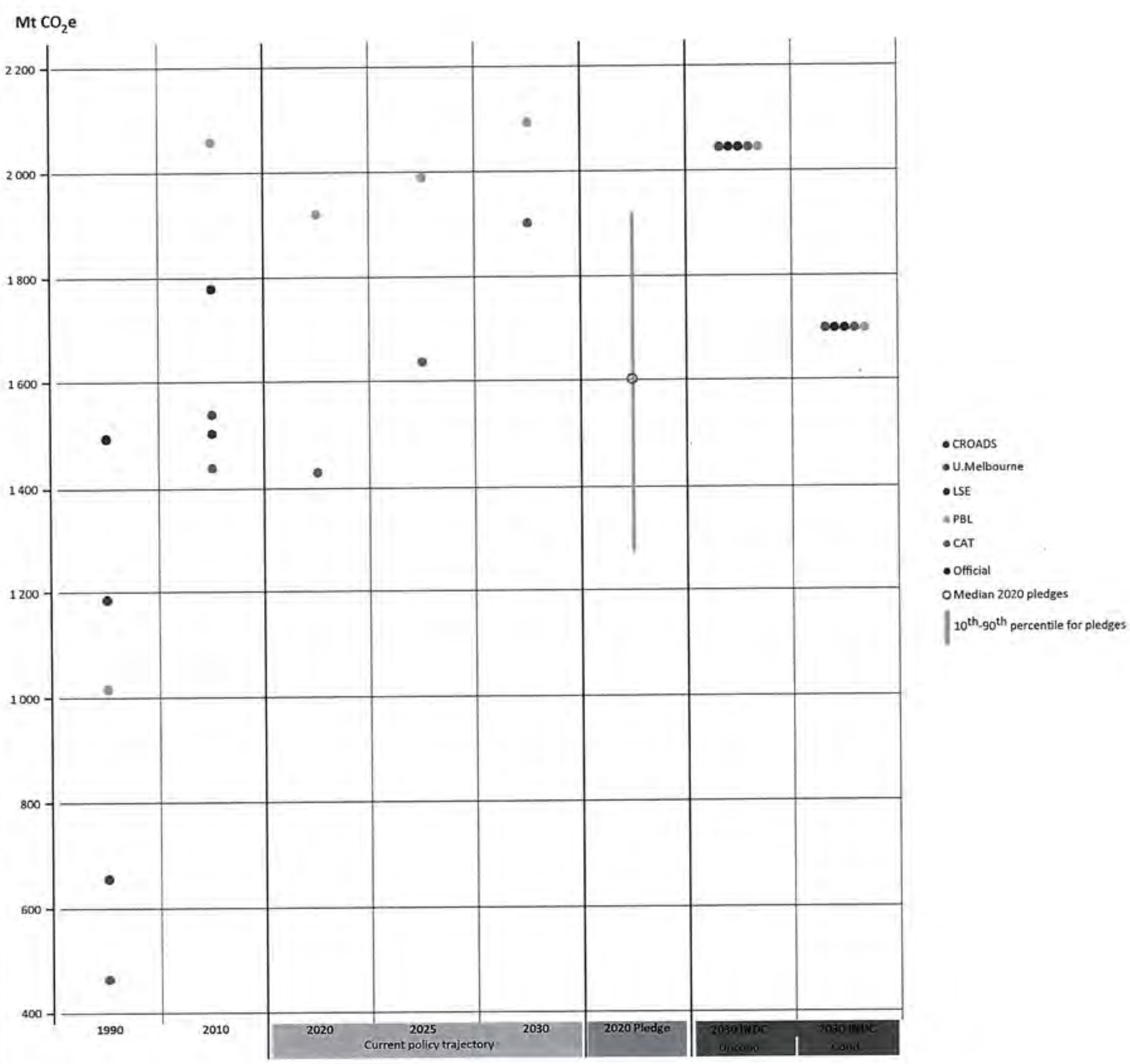
Indonesia

Indonesia's INDC states that the country "[...] has committed to reduce unconditionally 26 per cent of its greenhouse gases against the business as usual scenario by the year 2020. Indonesia is committed to reducing emissions by 29 per cent compared to the business as usual (BAU) scenario by 2030". Furthermore, "Indonesia's target should encourage support from international cooperation, which is expected to help Indonesia to increase its contribution up to 41 per cent reduction in emissions by 2030" (UNFCCC, 2015). Indonesia defines its baseline emissions as 2 881 $GtCO_2e$ in 2030. The INDC covers all sectors and CO_2, CH_4, and N_2O.

Studies diverge on Indonesia's emissions in all cases, due in part to different assumptions regarding land use emissions, for which data are highly uncertain (for example, den Elzen *et al.*, 2015).

Figure A1.7: GHG emission of Indonesia under the 2020 pledge, INDC and current policy trajectory case

Official sources include: INDC Indonesia (UNFCCC, 2015)



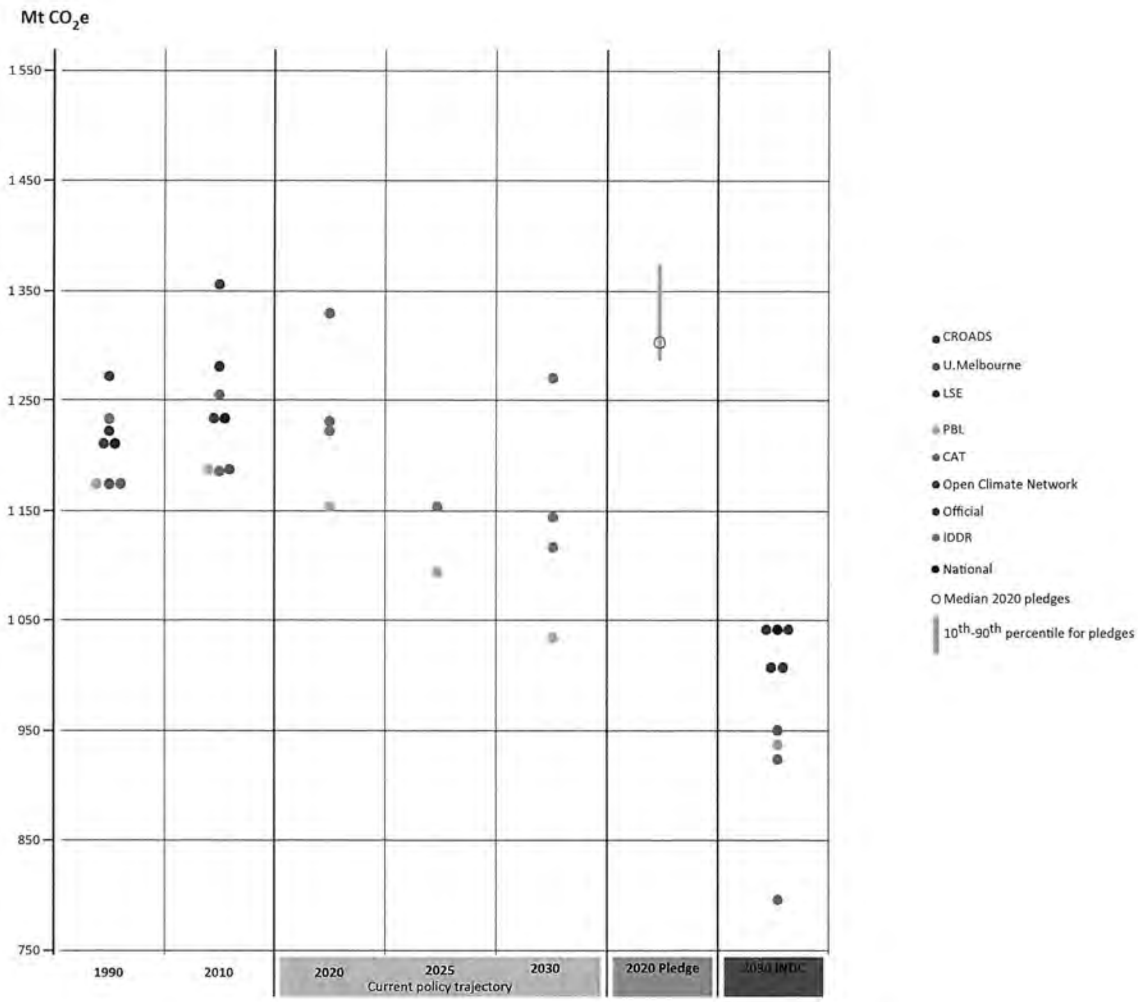
Japan

Japan's INDC proposes to reduce GHG emissions by 26 per cent by 2030 compared to 2013 levels, equivalent to a 25.4 per cent reduction against 2005 levels. All sectors and all GHGs (CO_2, CH_4, N_2O, HFCs, PFCs, SF_6 and NF_3) are covered (UNFCCC, 2015).

According to the official estimate that has been included in the INDC document, Japan's INDC would equate to emissions levels of about 1 042 Gt CO_2 in 2030. The modelling groups largely agree on the impact of Japan's INDC on its emissions.

Figure A1.8: GHG emissions of Japan under the 2020 pledge, INDC and current policy trajectory case

The official and national studies are: INDC Japan (UNFCCC, 2015), IDDRI (2015), Damassa *et al.* (2015, forthcoming) and Kuramochi (2014)



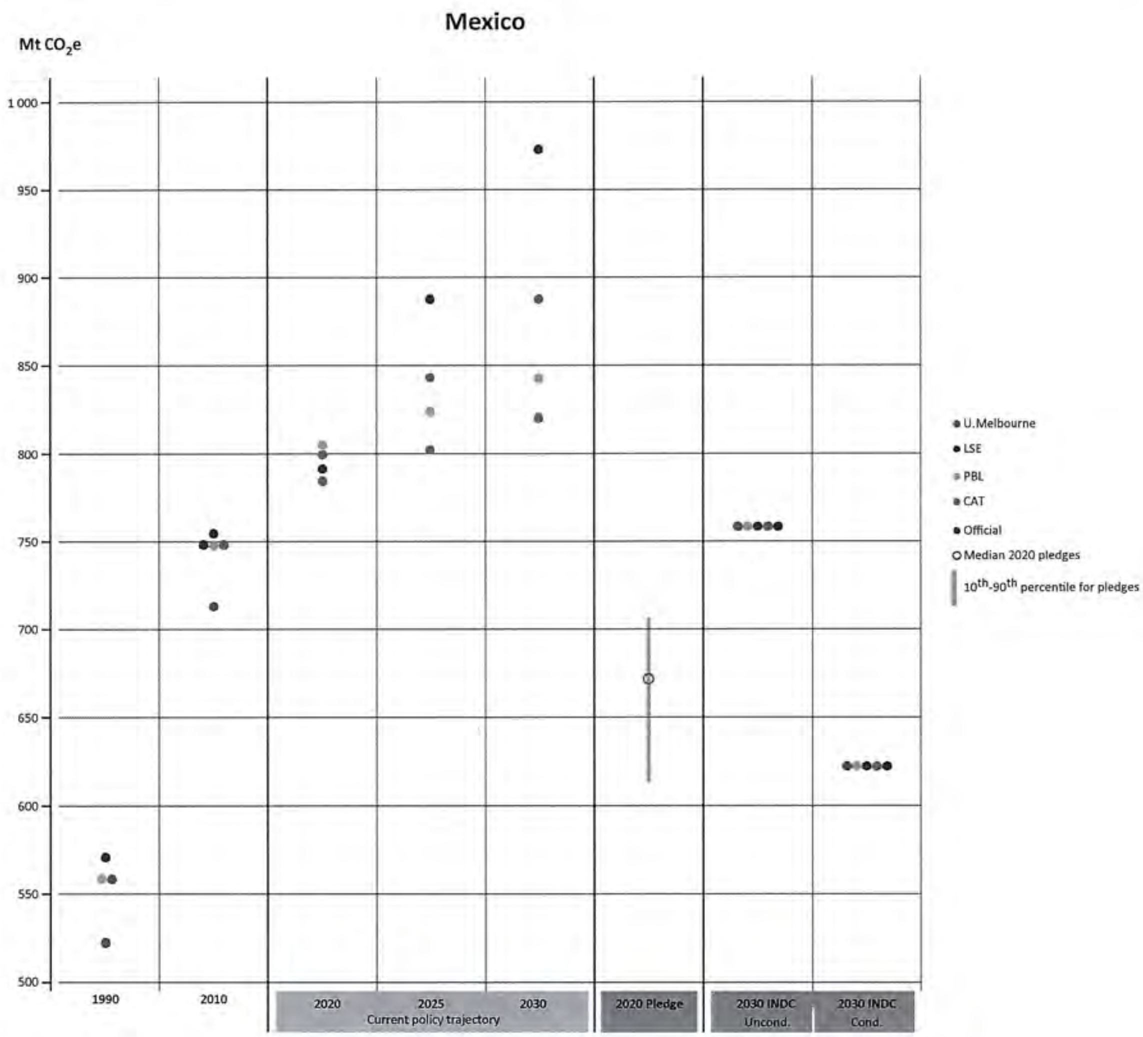
Mexico

Mexico aims to reduce its GHG emissions by 22 per cent (unconditional) and by 36 per cent (conditional) from BAU by 2030. Mexico's INDC provides the resulting 2030 emission levels in MtCO2e. The target covers all sectors (energy, industrial processes and product use, agriculture, LULUCF, and waste) and six greenhouse gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6).

The studies assessed adopted the official estimate of 2030 emissions from the INDC, and therefore agree on this figure. The 2020 pledge presented here is measured from a different baseline than that presented in the INDC (Fransen *et al.*, 2015).

Figure A1.9: GHG emissions of Mexico under the 2020 pledge, INDC and current policy trajectory case

The official study is: INDC of Mexico (UNFCCC, 2015), and national studies are: Government of Mexico (2012) and SEMARNAT (2013)



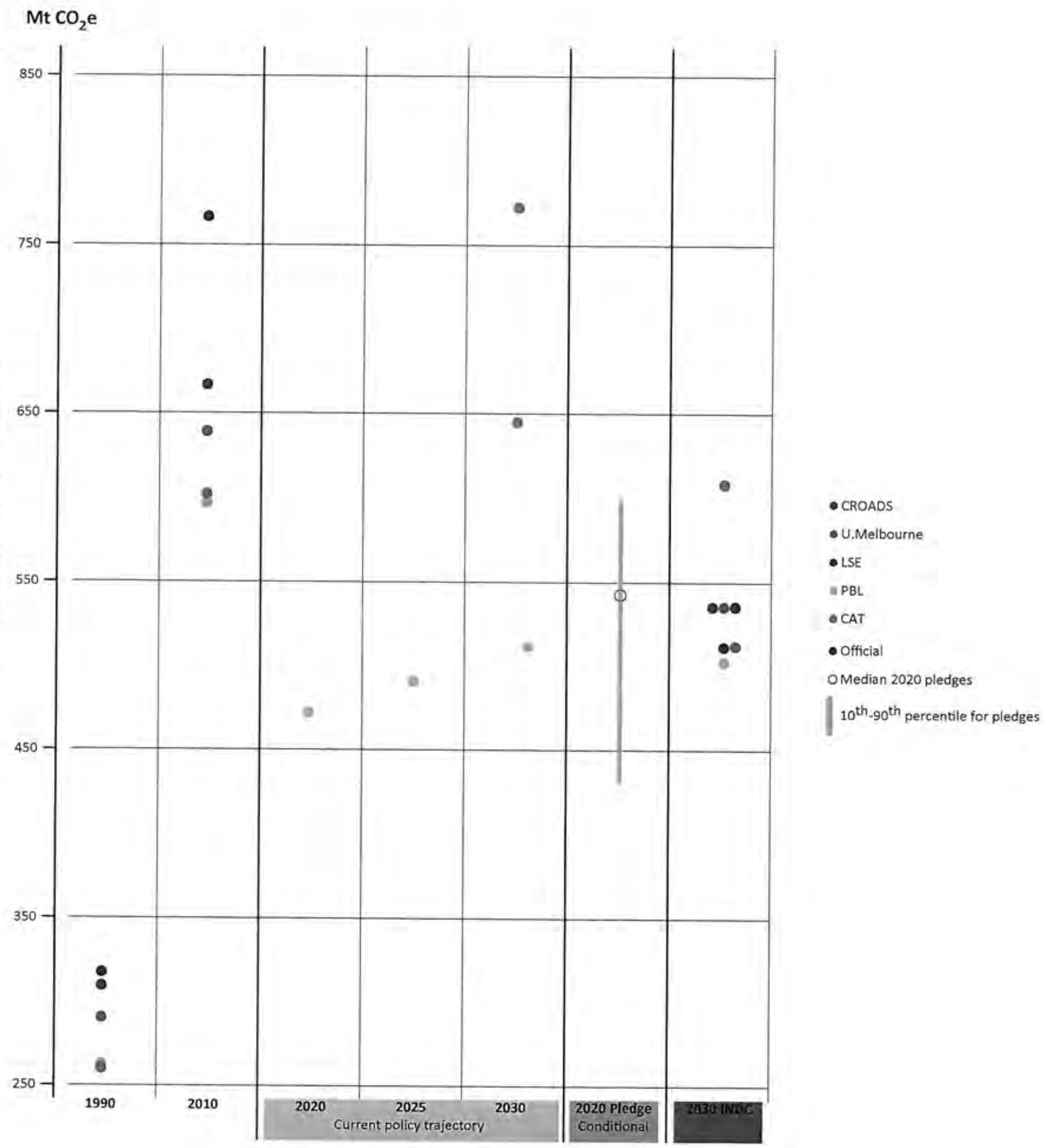
Republic of Korea

The Republic of Korea put forward an economy-wide target to reduce its GHG emissions by 37 per cent from business-as-usual (BAU) by 2030. The Republic of Korea intends to achieve a 25.7 per cent emissions reduction from BAU domestically. The INDC covers energy, industrial processes and product use, agriculture and waste, and states that "[...] a decision will be made at a later stage on whether to include greenhouse gas emissions and sinks of the land sector as well as the method for doing so" (UNFCCC, 2015). The target applies to five sectors (energy, industrial processes and product use, agriculture, LULUCF and waste) and six gases (CO_2, CH_4, N_2O, HFCs, PFCs and SF_6).

The Republic of Korea provides an official estimate in its INDC document, which would equate to emission levels of about 535.9 $MtCO_2e$ in 2030. Modelling groups agree on the emission levels in 2030 since they use the emission level taken from the INDC document. The Climate Action Tracker (CAT, 2015) provides a higher estimate indicating the levels of intended domestic reductions.

Figure A1.10: GHG emissions of the Republic of Korea under the 2020 pledge, INDC and current policy trajectory case

The official and national study is: UNFCCC National Reports (2015)



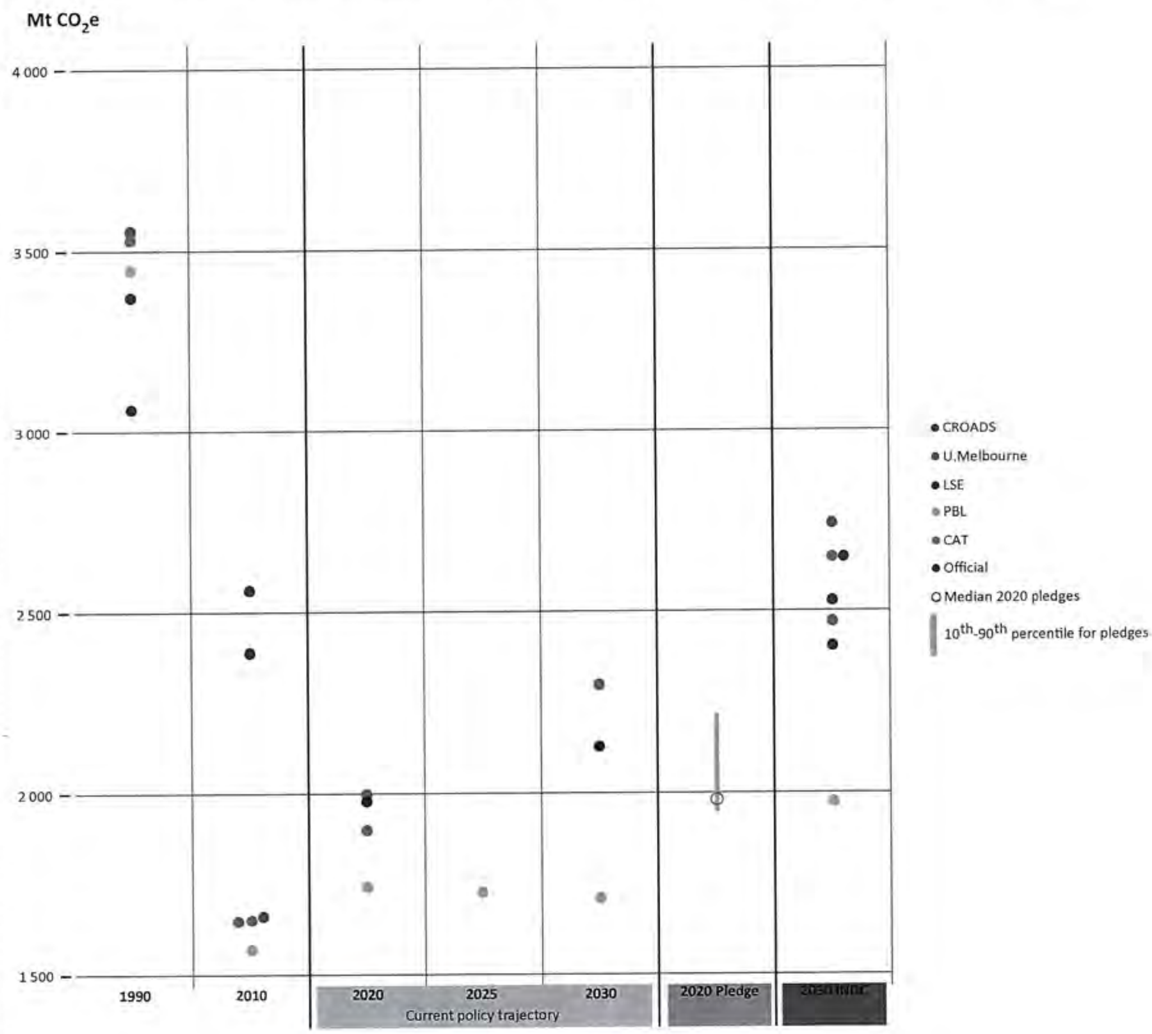
Russian Federation

The INDC of the Russian Federation states that "Limiting anthropogenic greenhouse gases in Russia to 70-75% of 1990 levels by the year 2030 might be a long-term indicator, subject to the maximum possible account of absorbing capacity of forests". This implies reducing emissions by 25-30 per cent below the 1990 level (UNFCCC, 2015). It is an economy-wide target and includes all greenhouse gases.

Study estimates diverge significantly on future emission trends under the current policy trajectory and under the INDC. This is due primarily to different assumptions on accounting of LULUCF emissions.

Figure A1.11: GHG emissions of the Russian Federation under the 2020 pledge, INDC and current policy trajectory case

The official studies are: UNFCCC inventories for historic data/6th National Communication for current policy projections (UNFCCC National Reports, 2015). For INDC: reductions from INDC submission applied to base year 1990 (UNFCCC, 2015)



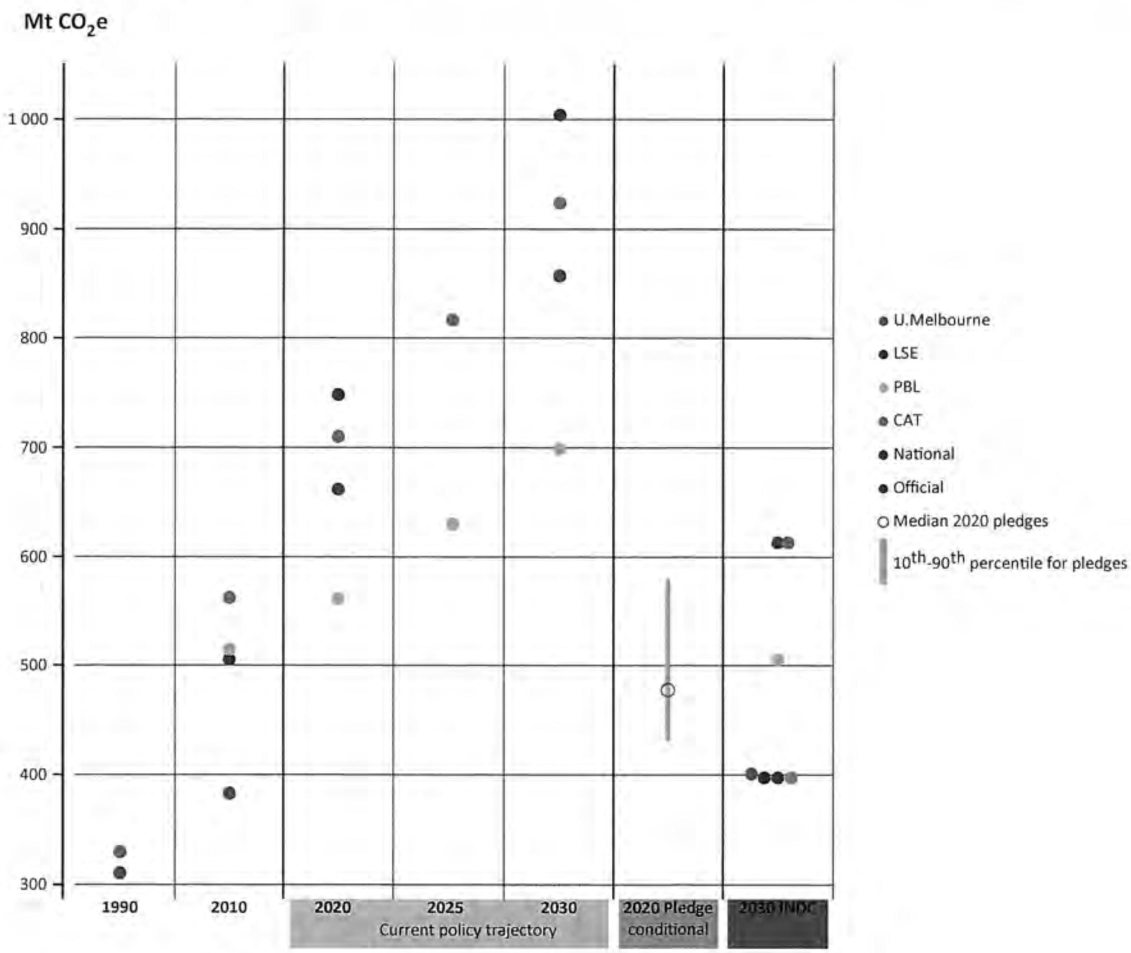
South Africa

South Africa proposes that the form of its mitigation INDC is a peak, plateau and decline GHG emissions trajectory range. South Africa's emissions by 2025 and 2030 will be in a range between 398 and 614 $MtCO_2e$. It includes all sectors and gases. No quantification of any unconditional share of mitigation is offered. Uncertainties are noted in relation to AFOLU emissions and trace gases, with the intention of reducing uncertainty over time and moving to a comprehensive accounting approach for land-based emissions and removals. South Africa proposes innovative methodologies for adaptation, both impacts and investments required, also noting that methodologies can be improved.

Given that the INDC states emission ranges in absolute units ($MtCO_2e$), modelling groups have greater certainty on the impact of South Africa's INDC. There is reference to more than one mitigation potential analysis, which has provided estimates of what mitigation can be implemented, the most recent being in 2014.

Figure A1.12: GHG emissions of the South Africa under the 2020 pledge, INDC and current policy trajectory case

The official and national studies are INDC of South Africa (UNFCCC, 2015) and the Mitigation Report (Department of Environmental Affairs, 2014)



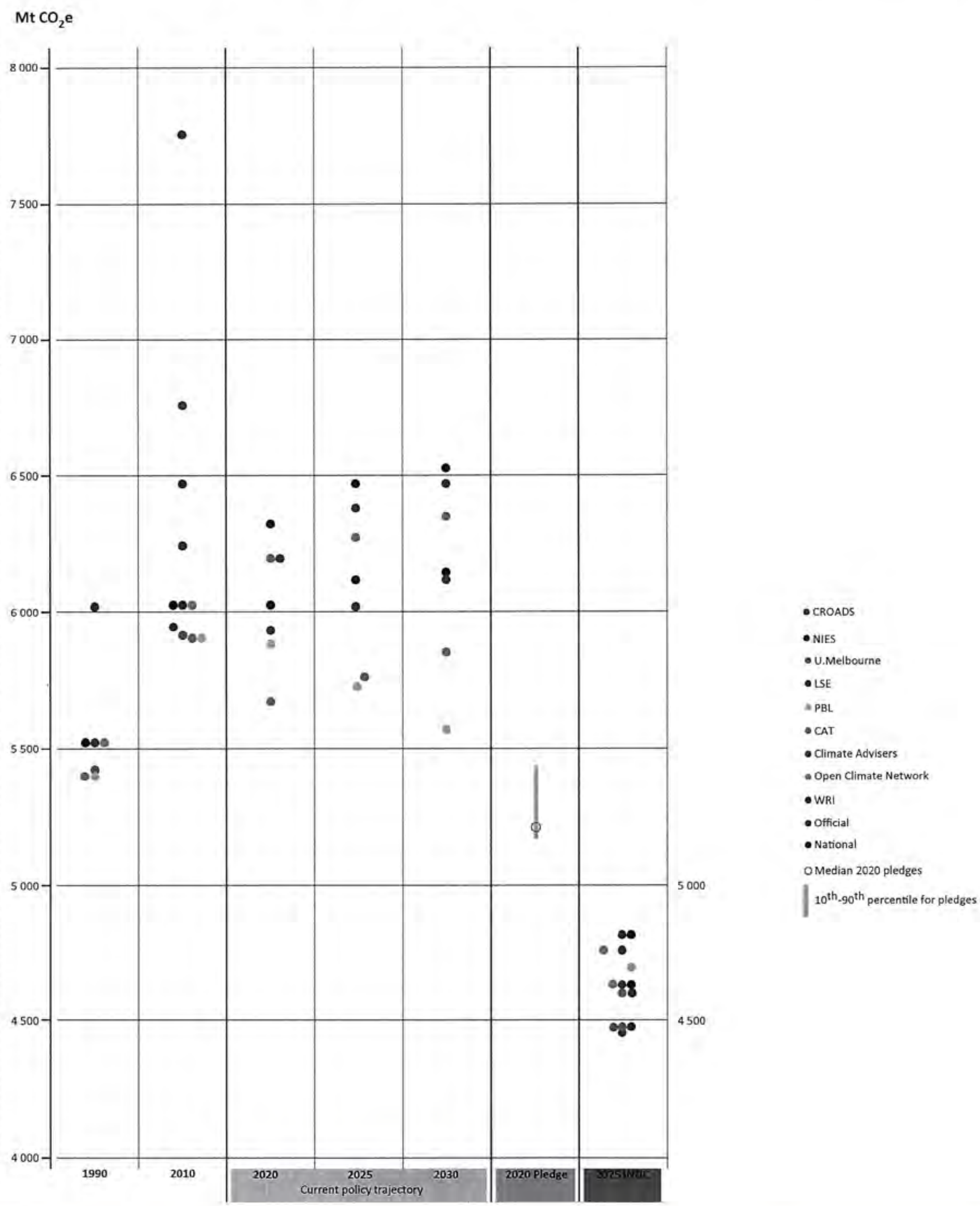
United States of America

The USA intends to reduce net GHG emissions by 26–28 per cent from 2005 by 2025, including LULUCF. The target covers all IPCC sectors and seven greenhouse gases.

The modelling groups largely agree on the impact of the USA's INDC on its emissions.

Figure A1.13: GHG emissions of the United States of America under the 2020 pledge, INDC and current policy trajectory case

The official studies are: UNFCCC inventories for historic data, 6th National Communication for current policy projections (UNFCCC National Reports, 2015). For INDC: INDC submission (UNFCCC, 2015). The analysis in this report uses the 'with measures' scenario from the 6th National Communication. The US indicates that its current trajectory is better represented by the 'with additional measures' scenario. The national studies are: Belenky (2015) and Hausker *et al.* (2015). Current policies only from Belenky (2015). 2030 INDC estimate only from Hausker *et al.* (2015)



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Chapter 6

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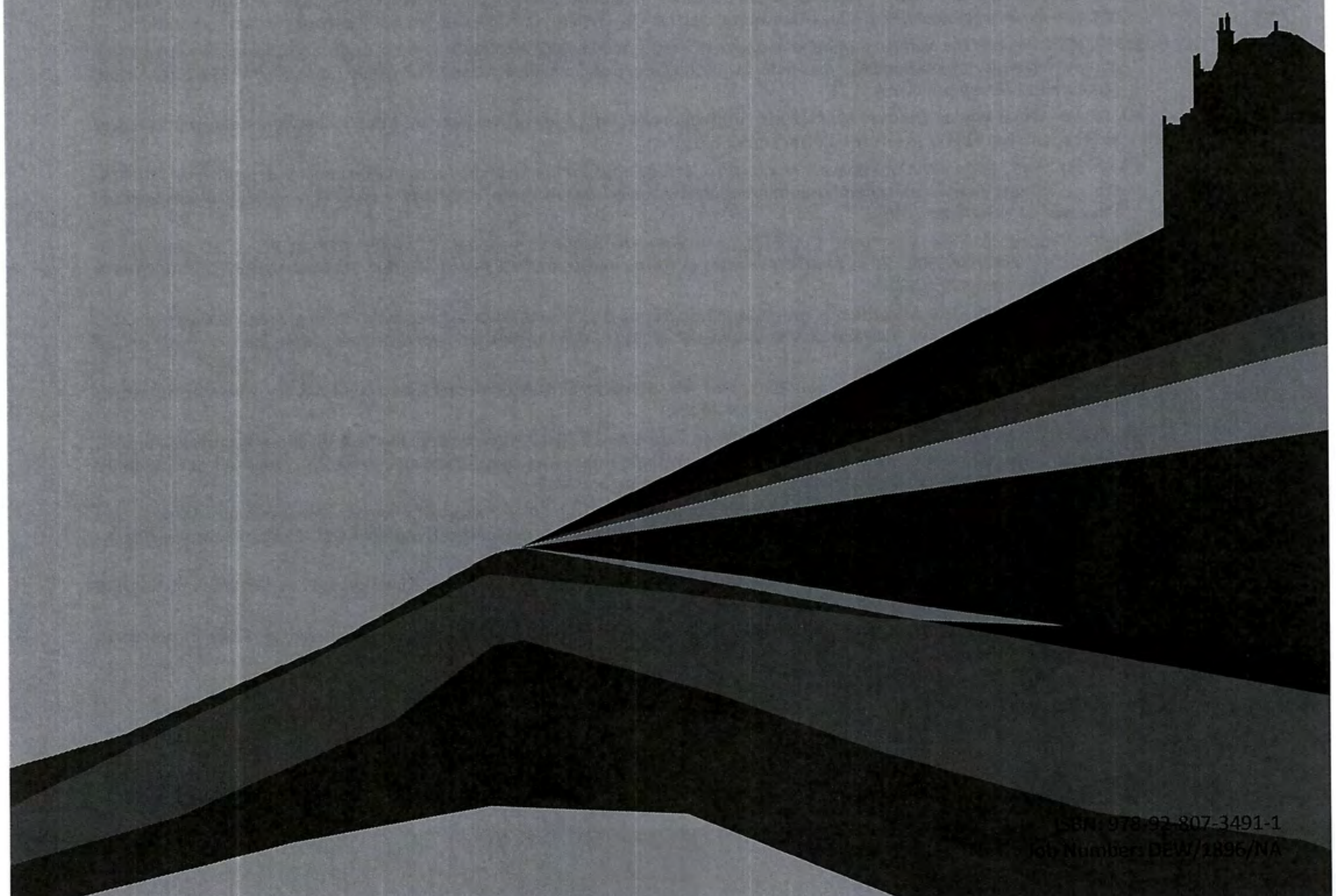

ISBN: 978-92-807-3491-1
Job Number: DEW/1896/NA

Exhibit 30

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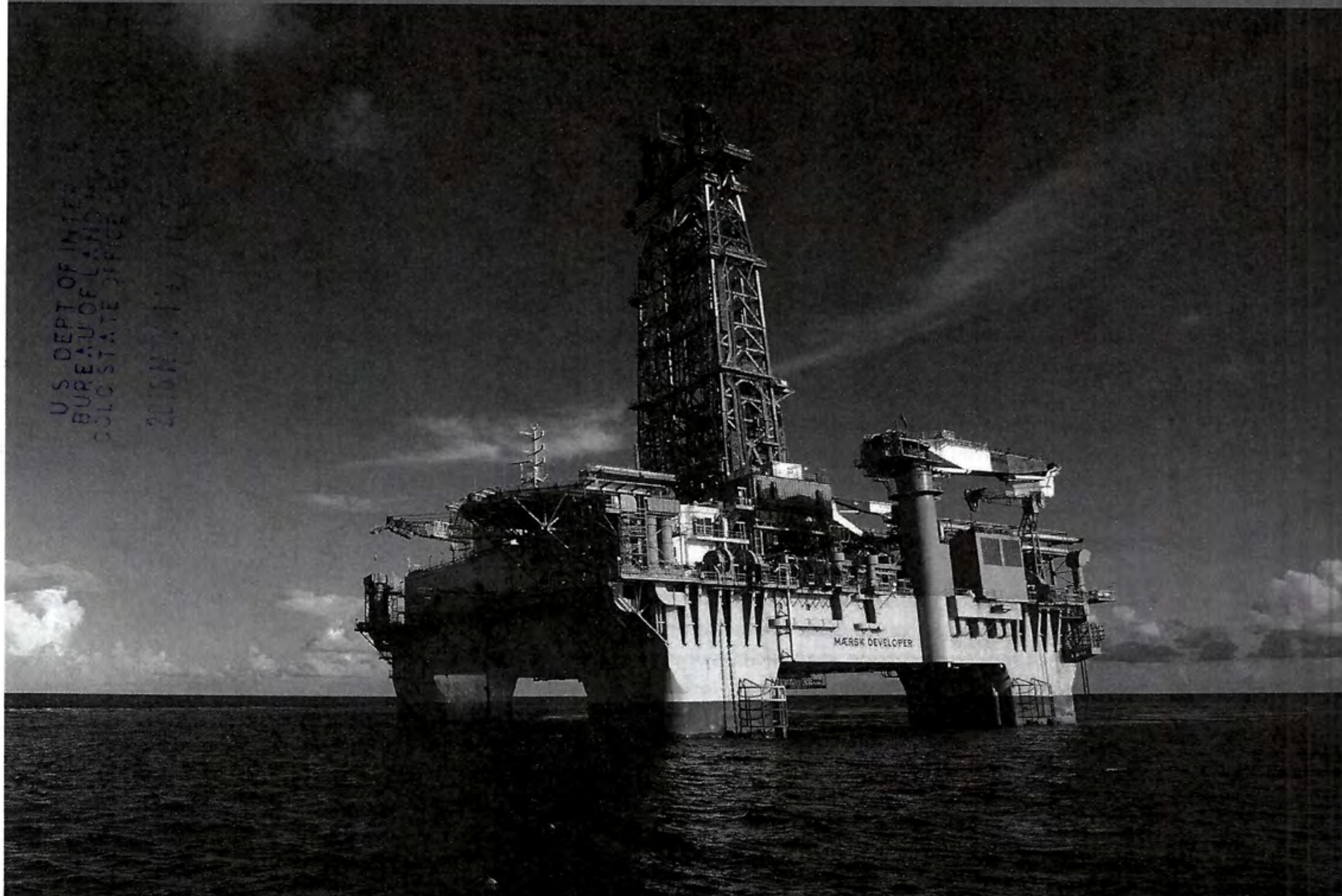

How would phasing out U.S. federal leases for fossil fuel extraction affect CO_2 emissions and 2°C goals?

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Cover photo: Onboard the Maersk Developer, operating the Hadrian-5 well for ExxonMobil in the KC-919 field in the Gulf of Mexico. Photo © Robert Seale – Maersk Drilling / Flickr

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WORKING PAPER NO. 2016-02

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ABSTRACT

Avoiding dangerous climate change will require a rapid transition away from fossil fuels. By some estimates, a phase-out of global fossil fuel consumption and production – particularly coal and oil – will need to be nearly complete within 50 years. Given the scale of such a transition, nations may need to consider a broad suite of policy approaches that aim not only to reduce fossil fuel demand – the current focus – but also constrain fossil fuel supply growth. In this paper, we examine the potential emissions implications of a supply-side measure under consideration in the U.S.: ceasing to issue new leases for fossil fuel extraction on federal lands and waters, and avoiding renewals of existing leases for resources that are not yet producing. Our analysis finds that under such a policy, U.S. coal production would steadily decline, moving closer to a pathway consistent with a global 2°C temperature limit. Oil and gas extraction would drop as well, but more gradually, as federal lands and waters represent a smaller fraction of national production, and these resources take longer to develop. Phasing out federal leases for fossil fuel extraction could reduce global CO_2 emissions by 100 million tonnes per year by 2030, and by greater amounts thereafter. The emissions impact would be comparable to that of other major climate policies under consideration by the Obama administration. Our findings suggest that policy-makers should give greater attention to measures that slow the expansion of fossil fuel supplies.

CONTENTS

ACKNOWLEDGEMENTS

The authors thank Jeff Archibald, Mike McCormick, John Larsen, Peter Marsters, Michael Mellish and Spencer Reeder for helpful discussions about data and methodology, Paul Ekins for providing a 2°C scenario for U.S. fossil fuel production, and Ben Schreiber and Marissa Knodel at Friends of the Earth US for supporting this research. Mark Haggerty of Headwaters Economics and Sivan Kartha of SEI-US reviewed this paper, and Adrian Down at SEI-US provided research support.

1. INTRODUCTION

Avoiding dangerous climate change will require a rapid transition away from fossil fuels. By some estimates, global consumption and production of fossil fuels – particularly coal and oil – will need to end almost entirely within 50 years (Rogelj, Schaeffer, et al. 2015). The Paris Agreement on climate change approved last December asserted world leaders' commitment to strong climate action and urged countries to step up their efforts. While many countries are taking measures to reduce fossil fuel demand – from pricing carbon to promoting low-carbon energy sources – these policies are not advancing at the pace needed.

The need for swifter progress has led to growing interest in adopting supply-side measures as well, measures that more directly aim to slow further investment and growth in fossil fuel production and thereby enable a smoother, more rapid transition to a low-carbon future. In the U.S., one option on the table is to reduce or end the issuance and renewal of U.S. government leases for fossil fuel exploration and extraction on federal lands and offshore. The Obama Administration is considering changes to its coal leasing program in light of concerns about "whether the leasing and production of large quantities of coal… is consistent the Nation's goals to reduce greenhouse gas emissions" (BLM 2016b). The Administration could similarly take climate implications into account in its decisions regarding further federal leases for exploration and extraction of oil and gas resources, a large share of which are offshore.

This paper aims to shed light on the climate implications of future leasing decisions by examining how ceasing further leases would affect coal, oil and gas production, consumption, and global carbon dioxide (CO_2) emissions relative to a reference case. It also explores how such decisions might affect progress towards the goal set in Paris of keeping warming "well below 2°C above pre-industrial levels and pursuing efforts to limit the increase to 1.5°C".[1]

The U.S. now produces more fossil fuels than ever. It ranks first in the world in oil and gas production, and second in coal production (BP 2015). Since 2010, U.S. fossil fuel production has grown by 20% in energy terms,[2] due in great part to technology advances in extracting oil and gas from tight and offshore resources (U.S. EIA 2015a). Increased production has helped natural gas eclipse coal as the top fuel for U.S. electricity production, slowing growth in CO_2 emissions (U.S. EIA 2015c). And despite current low oil prices, investment in fossil fuel extraction and trade infrastructure continues. For example, investments in new U.S. oil exploration and production infrastructure in 2015 amounted to $100 billion, which is down from an all-time high in 2014 but still among record levels, and is expected to be eclipsed again by 2018 (Rystad Energy 2015). Investments in capital-intensive, high-carbon fuel infrastructure can lock in long-term fuel supplies, while tying communities to fossil revenues, making it more difficult and expensive to later shift to a low-carbon pathway (Erickson et al. 2015).

About a quarter of all U.S. fossil fuels extraction (in energy terms), including two-fifths of all coal, occurs on federal lands and waters (U.S. EIA 2015a).[3] Producers obtain leases for these activities from the U.S. Department of the Interior (DOI) through bids and auctions, and pay fees, rents and royalties that are shared by the federal government and state and tribal governments (see Box 1).

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[1] See http://unfccc.int/paris_agreement/items/9485.php.

[2] For ease of comparison, much of the analysis in this paper presents coal, oil and gas production in energy equivalent terms, as quadrillion British thermal units (QBtu).

[3] Hereafter we refer simply to "federal lands" to encompass both lands and offshore areas that are subject to federal leasing provisions.

Box 1. Leasing and royalty practices for fossil fuels produced from U.S. federal lands and waters

The DOI administers fossil fuel production from U.S. federal lands and waters, as well as from lands where the federal government owns the sub-surface mineral rights but another entity owns the surface rights. DOI authority for administering onshore fuels originates from the Mineral Lands Leasing Act of 1920 and its subsequent revisions. For offshore fuels (i.e. those in federal waters), DOI authority originates from the Outer Continental Shelf Lands Act of 1953.

For onshore resources, the process for determining when and where leases occur is generally "bottom-up": interested firms identify eligible parcels and express their interest to the Bureau of Land Management (BLM), the DOI's implementing agency. For oil and gas, the BLM responds to interest by firms by holding a public lease auction, starting at a minimum of $2 per acre. If no bids are received, the land is offered to the first qualified applicant, with no requirement for a competitive bid. Initial leases are for 10 years.

For coal, a similar process called "lease by application" has been used for all federal coal (including in the Powder River Basin) since 1990. Companies propose specific parcels for sale; the BLM determines fair market value and the maximum amount of coal economically recoverable, and solicits sealed bids. The lease is then awarded to the highest bidder that meets or exceeds fair market value, for at least $100 per acre. Most leases are for parcels adjacent to existing mines (wholly new coal mines are rare), and typically receive only one bid, from the existing mining company. Initial leases are for 20 years.

Offshore oil and gas development is more top-down. DOI creates a five-year leasing plan that outlines a schedule of sales, including size and location of the proposed activities. The DOI's Bureau of Ocean Energy Management (BOEM) then publishes an announcement regarding the lease areas, in consultation with governors and local government officials of affected jurisdictions. Bids are solicited, and the lease is generally awarded to the highest bidder. Initial leases are for 5 years in waters less than 800 meters deep, 7 years in waters 800 to 1,600 meters deep, and 10 years in water depths greater than 1,600 meters.

For all fuels, onshore or offshore, the DOI will extend lease terms as long as the leasing firm continues to produce. In addition to the annual rental payments specified in leases, firms are responsible for future royalty payments of 12.5% of the sale price for onshore oil, gas, and surface coal; 8% for underground coal; and 18.75% (increased from 12.5% in 2007) for offshore oil and gas. The ONRR and BLM have been considering updating the royalty rates (and other associated terms), with the support of President Obama, as expressed in his 2016 State of the Union address.

Sources: Bureau of Land Management (BLM 2015); Congressional Research Service (Vann 2012; Vann 2014); Department of Interior (DOI 2012); Government Accountability Office (US GAO 2013); Office of Natural Resources Revenue (ONRR 2015b).

These leasing systems have been in place for generations, and they are a significant source of government revenue, including for local communities. However, government and civil society organizations are beginning to rethink these practices in light of climate and other concerns (BLM 2016b; The White House 2014). In his 2016 State of the Union address, on the heels of the Paris Agreement, President Obama announced his intention "to change the way we manage our oil and coal resources, so that they better reflect the costs they impose on taxpayers and our planet" (Obama 2016). Just days later, the DOI announced its intention to prepare a Programmatic Environmental Impact Statement (PEIS) of the federal coal program to, among other goals, consider "adjustments to the scale and pace of leasing", including the possibility of a "declining schedule consistent with the United States' climate goals and commitments" (BLM 2016b). Legislation has also been introduced in Congress to stop all future leasing activity (Merkley et al. 2015; Huffman et al. 2016). In addition, royalty regimes are being re-examined with an eye to eliminating apparent subsidies or possibly applying a carbon charge (Haggerty et al. 2015; Krupnick et al. 2015; BLM 2016a).

The debate about federal fossil fuel leases is complex, involving not only climate considerations, but also questions about broader environmental protection, government revenue, jobs, and the resilience of regional economies that now depend heavily on fossil fuel production (Haggerty 2014). Our analysis focuses on the climate implications, aiming to fill what we see as a critical knowledge gap.

Proposals to end or reform federal fossil fuel leases take what we call a *supply-side* approach to climate policy (Lazarus, Erickson, et al. 2015). Supply-side measures aim to complement demand-side measures, to ensure that energy and climate policies are more coherent and increase the likelihood of achieving climate goals. Yet the implications of supply-side policies remain poorly understood, as do their interactions with demand-side measures.[4] Until recently, few studies have assessed the CO_2 emissions impacts of supply-side policies – in stark contrast to the long history of demand-side analyses. Recent studies have examined the CO_2 emissions associated with past and current U.S. production (Stratus Consulting 2014) and with fossil fuel resources under federal jurisdiction (Mulvaney et al. 2015). Studies have also looked at the emission implications of specific infrastructure investments (e.g. coal export terminals) or of restricting or increasing production of specific resources (Power and Power 2013; Vulcan/ICF 2016).

Our paper builds on this growing literature, aiming to help answer key questions arising in the current debates over federal leasing. In particular, the paper:

- Reviews recent U.S. fossil fuel production and explores future trends (Section 2);
- Shows how future U.S. fossil fuel extraction might need to decline under a 2°C pathway, consistent with the Paris Agreement;
- Analyzes how fossil fuel production might be affected if the U.S. government stopped issuing new leases (Section 4);
- Estimates how a cessation of federal leasing might affect overall energy use and CO_2 emissions (Section 5), taking into account market responses; and
- Examines how a cessation of federal leasing would affect U.S. progress towards a 2°C pathway (Section 6).

This analysis may be useful to policy-makers who are considering how to manage the nations fossil fuel resources in a way that is, in Interior Secretary Sally Jewell's words, "consistent with our climate change objectives" (Jewell 2015; U.S. DOI 2016).

[4] For example, future federal coal leasing policy could complement or conflict with efforts to implement the CPP, as both will affect the pace and extent of a transition away from coal in the US power sector.

2. RECENT TRENDS AND OUTLOOK FOR U.S. FOSSIL FUEL PRODUCTION

U.S. fossil fuel production, which was relatively flat (in energy terms) for decades, has recently seen a substantial increase. Enabled by new technological developments for oil and gas extraction, especially hydraulic fracturing and horizontal drilling, production of these fuels has risen sharply in the last decade. The turnaround has been particularly dramatic for oil, which, after peaking in 1970, had been declining steadily until 2007. Since then, oil production has grown rapidly, overtaking the previous 1970 high (U.S. EIA 2015a). By contrast, coal production peaked around 2008 (U.S. EIA 2015a) and has since declined, due to global oversupply, slowing domestic and international demand, and competition from abundant, lower-cost natural gas supplies.

Table 1 displays fossil fuel production in the U.S. since 1990, by fuel, on federal and non-federal lands (see also Figure 1). The data show that, between 1990 and the mid-2000s, production on federal lands increased, while non-federal production decreased. Since then, however, these trends have reversed. Indeed, the vast majority of growth in U.S. fossil fuel production since 2005 has occurred on non-federal lands, with an increase of 20 QBtu (quadrillion Btu or "Quads"), while federal oil production grew by just 0.2 QBtu. (Federal gas production has declined by nearly 3 QBtu, and all coal production has declined.) As of 2014, an estimated 24% of all U.S. fossil fuels production occurred on federal lands and waters (U.S. EIA 2015a).

Table 1: U.S. fossil fuel production, 1990-2014, in quadrillion BTU

Fossil fuel production	1990	1995	2000	2005	2010	2014
Coal	**22.5**	**22.0**	**22.6**	**23.0**	**21.9**	**20.2**
Federal	6.1	8.0	9.3	9.1	9.2	8.1
Non-federal	16.3	14.0	13.3	13.9	12.7	12.1
Gas	**18.3**	**19.1**	**19.7**	**18.6**	**23.4**	**26.6**
Federal	6.6	6.8	7.3	6.2	5.2	3.6
Of which: offshore	*5.2*	*4.8*	*4.8*	*3.2*	*2.3*	*1.2*
Non-federal	11.7	12.3	12.3	12.3	18.2	22.9
Oil	**17.7**	**16.3**	**15.0**	**13.3**	**14.4**	**22.5**
Federal	3.0	3.6	4.4	4.4	5.2	4.6
Of which: offshore	*2.1*	*2.7*	*3.6*	*3.1*	*3.6*	*3.2*
Non-federal	14.7	12.7	10.6	8.9	9.2	17.9
Total	**58.5**	**57.4**	**57.2**	**54.9**	**59.7**	**69.2**
Federal	15.7	18.5	21.0	19.7	19.6	16.4
Non-federal	42.8	39.0	36.3	35.1	40.1	52.9

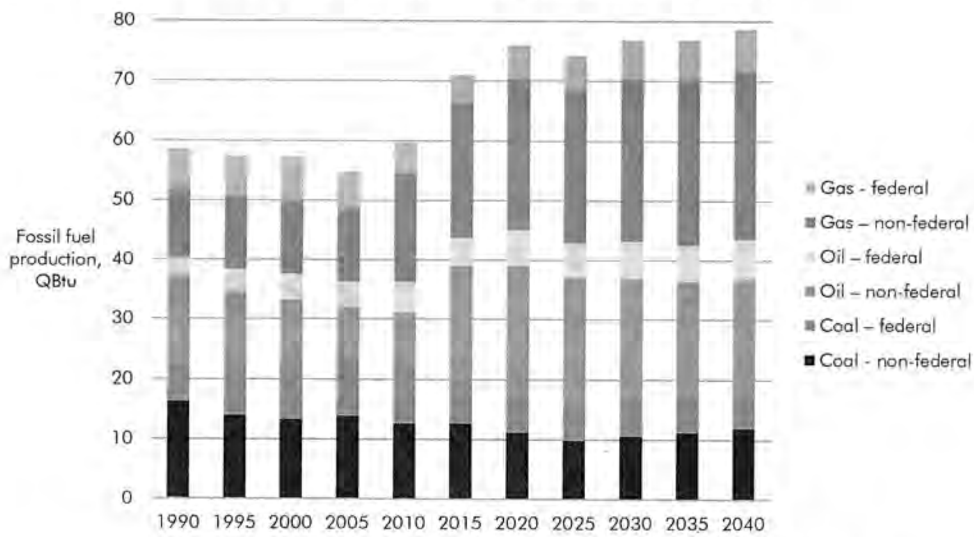
Source: SEI analysis based on ONRR (2015) and U.S. EIA (2015a).

In recent scenarios, the U.S. Department of Energy projects that U.S. oil and gas production will continue to increase, and coal production will continue to decline. Figure 1 displays both historical (as in Table 1) and future domestic fossil fuel energy production through 2040, as drawn from the U.S. Energy Information Administration's *Clean Power Plan* scenario (U.S. EIA 2015b). This scenario assumes implementation of the Clean Power Plan, which was finalized in October 2015 (U.S. EPA 2015c), and is expected to lead to continued declines in coal use and production over the next decade, followed by a slow rise nearly to current levels.[5]

We use the EIA's Clean Power Plan scenario as the reference case for our analysis. We consider this scenario, among several the EIA developed for its Annual Energy Outlook (see Box 2), to be closest to a "business as usual" case, given finalization of the Clean Power Plan in October 2015, and the assumption of no further policy action or unforeseen technological advancement. (In Appendix A, we consider another reference case without the Clean Power Plan.)

We split the EIA's scenario into fractions extracted on federal vs. non-federal land by assuming that fuel- and region-specific shares of federal (vs. non-federal) production remain constant at recent (2014) levels.[6]

Figure 1: Historical and future U.S. fossil fuel production, 1990–2040



Source: SEI based on ONRR (2015) and U.S. EIA (2015a; 2015b), assuming implementation of the Clean Power Plan.

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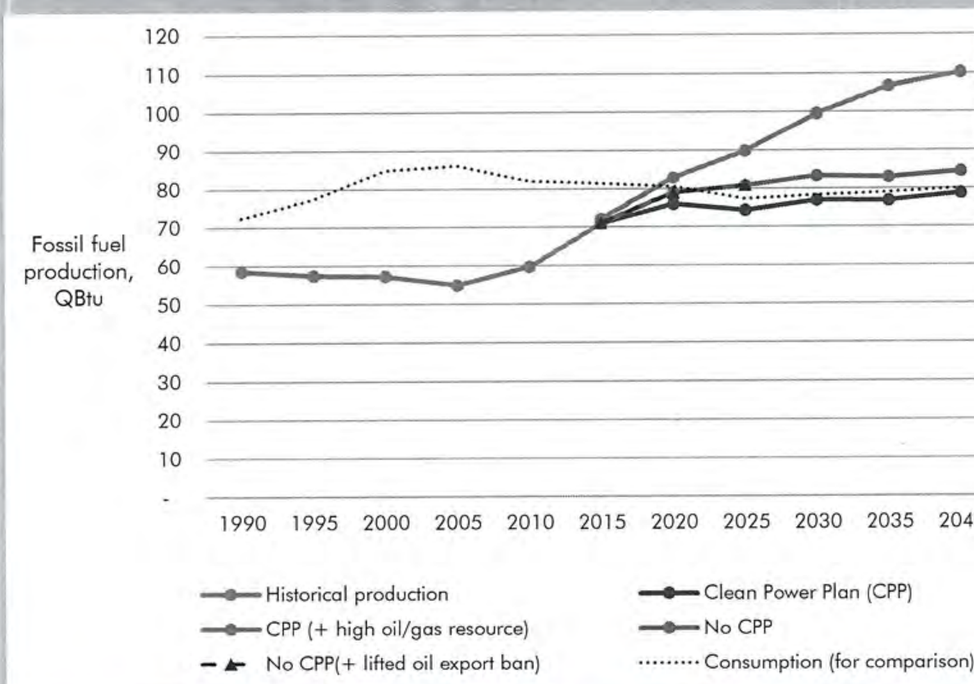
[5] At the time of this analysis, EIA had conducted an analysis of the draft Clean Power Plan, but not the final plan as placed into law. EIA staff told us in early 2016 that *Annual Energy Outlook 2016* will include the final Clean Power Plan in the reference case, but it was not available in time to inform our analysis. The EIA Clean Power Plan scenario does not extend CPP targets beyond 2030 (the last target date specified in the current plan) and thus emissions begin to rise thereafter. As several aspects of the final Clean Power Plan differ from the draft version, EIA's yet-to-be-released forecasts of fossil fuel production under the final rule could differ from those used here.

[6] We do this by dividing DOI data on federal production (ONRR 2015) by EIA data on total (federal and non-federal) production (U.S. EIA 2015a). We then apply these ratios to forecast region- and fuel-specific production estimates in the Clean Power Plan scenario of the EIA's Annual Energy Outlook (US EIA 2015b).

Box 2: Alternate EIA scenarios of future U.S. fossil fuel production, 1990–2040

The EIA has developed a number of scenarios to explore how U.S. fossil fuel production may evolve (U.S. EIA 2015b; U.S. EIA 2015c). The chart below shows the results of four of these other scenarios, chosen to reflect a wide range of possible outcomes. In addition to the Clean Power Plan case (our study's reference scenario), the scenarios include the lifting of the oil export ban (finalized in late 2015), the possibility of higher future oil and gas production than anticipated, and the possibility that the Clean Power Plan is not implemented (the rule had not yet been finalized at the time of the mid-2015 EIA analyses used here, and it is under legal challenge).

In the EIA assessment, the Clean Power Plan leads to a 20% decline in coal production in 2040 relative to the case without Clean Power Plan, and thus to a decline in overall fossil fuel production. Further advances in oil and gas extraction technology could also result in U.S. fossil fuel production being as much as 40% greater in 2040 than would otherwise be the case, due to even greater increases in oil (70%) and gas (50%) production that also lead to a drop in coal production (20%) due to greater competition from gas.



Source: U.S. EIA (2015b; 2015c).

3. U.S. FOSSIL FUEL PRODUCTION IN A 2°C WORLD

At the Copenhagen Climate Change Conference in 2009, which President Obama attended, world leaders embraced the long-term goal to keep global warming below 2°C above pre-industrial levels.[7] The Paris Agreement further raised ambition, with governments striving to keep warming "well below" 2°C, and agreeing "to pursue efforts to limit temperature increase to 1.5°C".[8] Even with large-scale deployment of bioenergy and carbon capture and storage technologies, scientific assessments show that limiting warming to 2°C, and avoiding dangerous climate tipping points, will require a rapid phase-out of fossil fuels around the world (Rogelj et al. 2011; IPCC 2014; Raupach et al. 2014).

The Paris Agreement makes no reference to fossil fuel *production*, nor is it reflected in the national commitments embedded in the agreement – but clearly, at a global level, producing more fossil fuels is not consistent with simultaneously trying to reduce their use. Yet it is also unclear how production should be phased down: Which countries should curtail production, of what fuels – coal, oil, or gas – and at what rate? For example, would only the most economically attractive resources be extracted, in keeping with emissions constraints and declining fossil fuel demand and prices? Or would political or equity considerations influence where remaining fossil fuel resources might be produced (Lazarus and Tempest 2014; Raupach et al. 2014)?

Though these questions are relatively unexplored, two studies provide scenarios of coal, oil and gas production in a 2°C world with enough detail to estimate how much of that production might occur in the United States. One, the International Energy Agency's *World Energy Outlook*, charts a 2°C ("450") scenario for regional fossil production through 2040 (IEA 2015). The other, published in the journal *Nature*, identifies a least-cost pathway for fossil fuel production under a 2°C scenario through 2050 (McGlade and Ekins 2015).

Each study has its merits and limitations for understanding U.S. fossil fuel production levels consistent with a 2°C goal. The *Nature* study uses a more stringent (and common) definition of a 2°C scenario – one that maintains a 66% chance of limiting warming to this level. It specifies fossil production for the U.S., but may underestimate it, since the study uses a data set from 2010 that misses much of the subsequent boom in U.S. oil and gas production capacity.[9] Accordingly, this scenario may represent a *low* scenario for U.S. fossil fuel production in a 2°C world, at least for oil and gas. (It also does not reflect global equity considerations that might suggest less-developed countries should be allowed to produce a greater share of the total.)

The IEA study starts with 2013 data, and thus better captures the U.S. boom in oil and gas production capacity. However, it uses a weaker definition of a 2°C scenario – a 50% chance of keeping warming below 2°C – and therefore does not curtail fossil fuel production and consumption as rapidly.[10] Together, these factors suggest that IEA's ("450") scenario may a *high* scenario for U.S. production in a 2°C world.

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[7] See http://unfccc.int/meetings/copenhagen_dec_2009/meeting/6295.php.

[8] See http://unfccc.int/paris_agreement/items/9485.php.

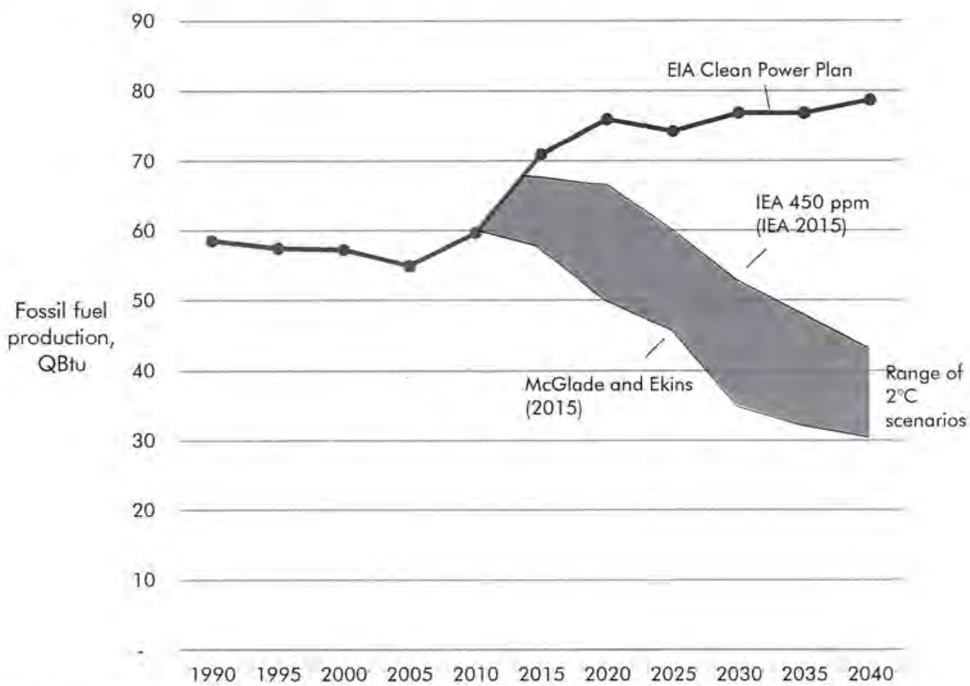
[9] We thank Drs. McGlade and Ekins for providing the U.S. extraction pathway from their analysis.

[10] The IEA reports findings for U.S. fossil fuel production in its New Policies Scenario, but not in its 2°C 450 Scenario, for which it reports fossil fuel production only for OECD Americas, a grouping that includes Canada, Chile, Mexico and the U.S. To impute U.S. results for the 450 Scenario, we adjust the findings for OECD Americas according to the ratio of U.S. to OECD Americas production in the New Policies Scenario. For example, in the New Policies Scenario, U.S. fossil fuel production comprises 91% of OECD Americas coal production in 2040, 50% of oil production, and 71% of gas production, and so we approximate U.S. production in the 450 Scenario as these same fractions of OECD Americas production in IEA's 450 Scenario. Were the marginal source of U.S. resources

Figure 2 shows the projected levels of U.S. fossil fuel production out to 2040 from these two studies, compared with our reference scenario, the EIA's Clean Power Plan case. Between them, these studies suggest **that to be consistent with a 2°C goal, the U.S. would need to cut aggregate fossil fuel production by 40–60% from current levels by 2040**, instead of an anticipated increase of 11% under the Clean Power Plan scenario.

Although scientific understanding of 1.5°C pathways is limited, U.S. fossil fuel production in a 1.5°C world would almost certainly be lower than in the 2°C scenarios. Studies suggest that cumulative global fossil fuel consumption between now and 2050 must be about 40% lower to meet a 1.5°C vs. a 2°C goal (Rogelj, Luderer, et al. 2015; Baer et al. 2013).

Figure 2: 2°C scenarios of U.S. fossil fuel production, 1990–2040



Source: SEI analysis based on U.S. EIA (2015a; 2015b), IEA (2015), and McGlade and Ekins (2015).

to be more or less expensive than the respective marginal sources in other OECD America countries, this approximation could over- or under-estimate, respectively, the cost-efficient level of U.S. production.

4. THE EFFECT OF FEDERAL LEASING DECISIONS ON FOSSIL FUEL PRODUCTION

To bring U.S. fossil fuel production more closely in line with a 2°C production pathway, the DOI could phase out leasing and/or provide incentives to reduce fossil fuel production on public lands. The DOI intends to consider such measures, at least for coal, as parts of its upcoming review of its coal program (U.S. DOI 2016; BLM 2016b).

To inform these and related discussions, in this section we look at how fossil fuel production would be affected if the DOI stopped issuing new leases for fossil fuel extraction on federal lands and waters, and did not renew any leases on resources that are not yet producing when each lease comes up for renewal.[11]

We look at what such a lease phase-out policy might mean for fossil fuel production on federal lands, and consider how this compares with what might be required to meet the 2°C goal. Except for the restrictions on leasing, we assume that all other factors, such as broader economic trends and policy actions, proceed as in the EIA's Clean Power Plan scenario.

4.1 Approach

Before we can analyze the effect of leasing reform on future fossil fuel production, we need to understand trends in expected leasing activity in the absence of any changes to leasing policy. We start with our reference case projection of future fossil fuel production on federal lands and waters, as shown in Figure 1. We then further analyze it to estimate what fraction of production would come from new or renewed leases (that DOE could decide not to issue) instead of existing leases (which must be renewed as long as they are producing).

To estimate future leasing activity for oil and gas, we draw from an extensive database of U.S. oil and gas fields that estimates economics and production from each field over time (Rystad Energy 2015). From this database, we estimate the shares of fuel-, region- and year-specific U.S. production that would arise from existing (already producing), renewed (not yet producing), or new leases, and apply these ratios to our EIA-based reference scenario.[12]

For coal, we estimate future lease dynamics using industry data and guidelines. In particular, we assume that producers will seek new leases at a rate that maintains reserves at a level equal to 15 years of expected production.[13] This is roughly the ratio observed in recent years,[14] and is consistent with ranges, typically 10–20 years, reported by the U.S. Geological Survey (Pierce and Dennen 2009) and coal industry consultants (Miller and Bate 2011). Starting from estimates of existing reserves of federal coal (explained further below), we then assume that producers will seek new leases at rates that maintain reserves equivalent to the next 15 years of expected production (from federal lands) in our reference scenario. We further assume that producers do

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[11] This closely resembles what seven U.S. Senators proposed in the Keep It in the Ground Act of 2015 (Merkley et al. 2015). It also resembles a permanent version, for all fuels, of the temporary moratorium on new coal leasing implemented by the DOI in early 2016 (U.S. DOI 2016). We assume that in all cases, the moratoria would not affect leases that are already producing fuels, as these leases would automatically continue.

[12] More specifically, we use shares of *Field*, *License* and *Open* asset designations in Rystad's Base scenario. For oil, we calculate and apply the ratios separately for each year of production for oil from lower 48 offshore deposits (which is strongly federal), in the Rocky Mountain and Dakota states (also strongly federal), natural gas liquids, and all other crude.

[13] Where expected production follows the reference scenario as in Figure 1.

[14] Based on analysis of production (ONRR 2015), reserves (Miller and Bate 2011) and lease (Headwaters Economics 2015) data.

not wait to begin mining their newly acquired leases, but extract the same fraction of these new stocks each year as they do of existing stocks.[15]

To estimate starting reserves for the Powder River Basin, we rely on a coal industry report that estimated year-end 2010 reserves of 5.8 billion short tons[16] (Miller and Bate 2011). Outside the Powder River Basin, we rely on a U.S. Government Accountability Office report that estimated year-end 2012 reserves of 0.9 billion short tons (U.S. GAO 2013). We then update these sources to 2015 by debiting the totals based on subsequent actual annual production (ONRR 2015) or incrementing them based on new lease inflow since (Headwaters Economics 2015). In total, this process yields an estimate of total federal coal reserves of 7.1 billion short tons as of the end of 2015.[17]

4.2 Overall results

In total, our analysis indicates that, of expected federal fossil fuel production in 2040 (20 QBtu), about two-thirds (13 QBtu) is either not yet under lease or is under lease but not yet producing.[18] Figure 3 shows historical and forecast U.S. fossil fuel production by status of federal lease.

Note especially that, under a 2°C pathway (red shading, just as in Figure 2), U.S. production will need to drop at some point to levels below what is expected on non-federal lands alone. This point comes sooner (after 2017) under McGlade and Ekins' (2015) 2°C scenario, and not until after 2025 under the IEA's less stringent pathway (IEA 2015). However, in either case these findings suggest that, at some point in the next two decades, there is potentially no need for federal fossil fuels in a 2°C pathway. This is not to suggest, however, that under a 2°C pathway, all U.S. fossil fuel production could, or should, shift wholly to non-federal lands; rather it simply illustrates a 2°C pathway will likely require a drop in production far exceeding what is expected from federal lands.

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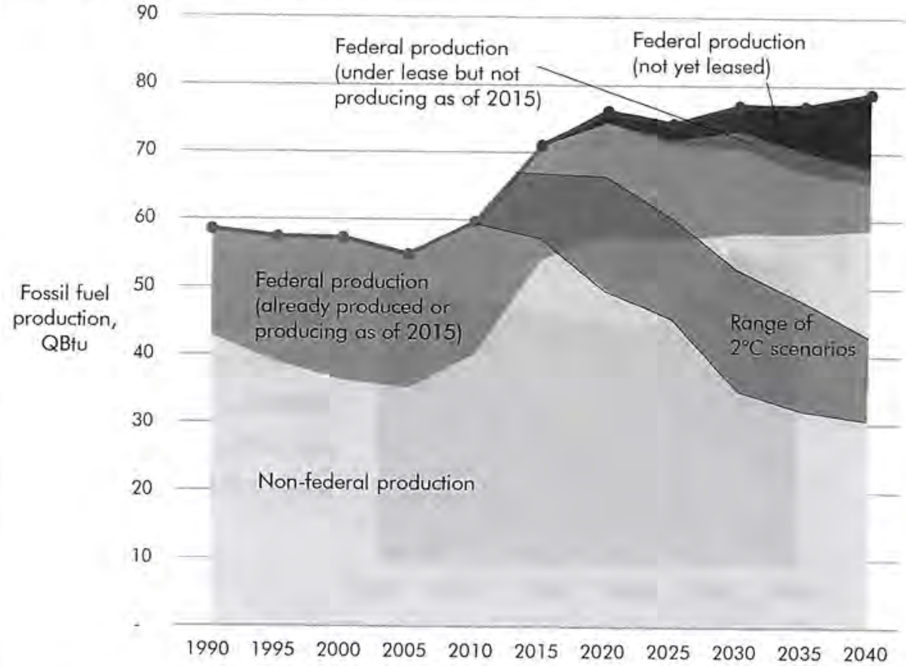
[15] Collectively, these assumptions imply that producers from federal lands do not draw down their existing stocks at faster than normal levels. If they did so, they could conceivably maintain production levels through 2035 (under a Clean Power Plan reference case), after which production from federal lands would cease entirely.

[16] Most U.S. coal production data are given in short tons, while CO_2 emissions are usually given in metric tons, or tonnes. For clarity, we consistently use "short tons" to refer to the U.S. weight measure, and "tonnes" or Mt (million tonnes) or Gt (gigatonnes, or billion tonnes) when referring to CO_2.

[17] This estimate is lower than that reported for 2012 by the GAO, 9.0 billion short tons, for two reasons. First, the GAO describes that its estimate for Wyoming, 8.0 billion short tons, is high by an unknown amount because it includes coal in mines that is not ultimately saleable, because it is along property boundaries or is left in place for structural mine support (U.S. GAO 2013). Second, the inflow of new coal leases since 2012 has been smaller than mine production (ONRR 2015; Headwaters Economics 2015).

[18] As explained in Box 1, the DOI will extend leases as long as the leasing firm continues to produce – but it can refuse to renew leases for resources that are not producing.

Figure 3: Historical and forecast U.S. fossil fuel production, 1990–2040, in energy terms, by status of federal lease



Source: SEI analysis based on ONRR (2015), U.S. EIA (2015a; 2015b), assuming implementation of the Clean Power Plan.

Of the prospective federal fossil fuels from areas not yet leased or producing (orange and dark blue areas in Figure 3), about half is coal. Cumulatively, an estimated 70 QBtu of coal extracted between 2016 and 2040 from federal lands has not yet been leased, whereas 40 QBtu of oil and 30 QBtu of gas has either not yet been leased or is in leases that are not yet producing and are subject to renewal.[19] Findings specific to each fuel follow below.

4.3 Coal

Figure 4(a) shows the significant role that coal from newly leased federal lands could play over the next 25 years. Most of the federal coal in already-leased reserves will be extracted by 2040, with the majority of federal coal coming from new leases by 2030.[20]

Cumulatively between 2016 and 2040, 4 billion short tons (70 QBtu) of federal coal will be extracted (mostly, but not exclusively, in the Powder River Basin) from lands not yet under lease. This represents an estimated 7 Gt CO_2 of emissions once the coal is combusted.

Under the reference case, total U.S. coal production drops sharply after 2020, then rebounds gradually such that, in 2030, the U.S. produces about 16 QBtu of coal. In a cost-efficient 2°C scenario, however, U.S. coal production would likely need to keep declining rapidly, by more

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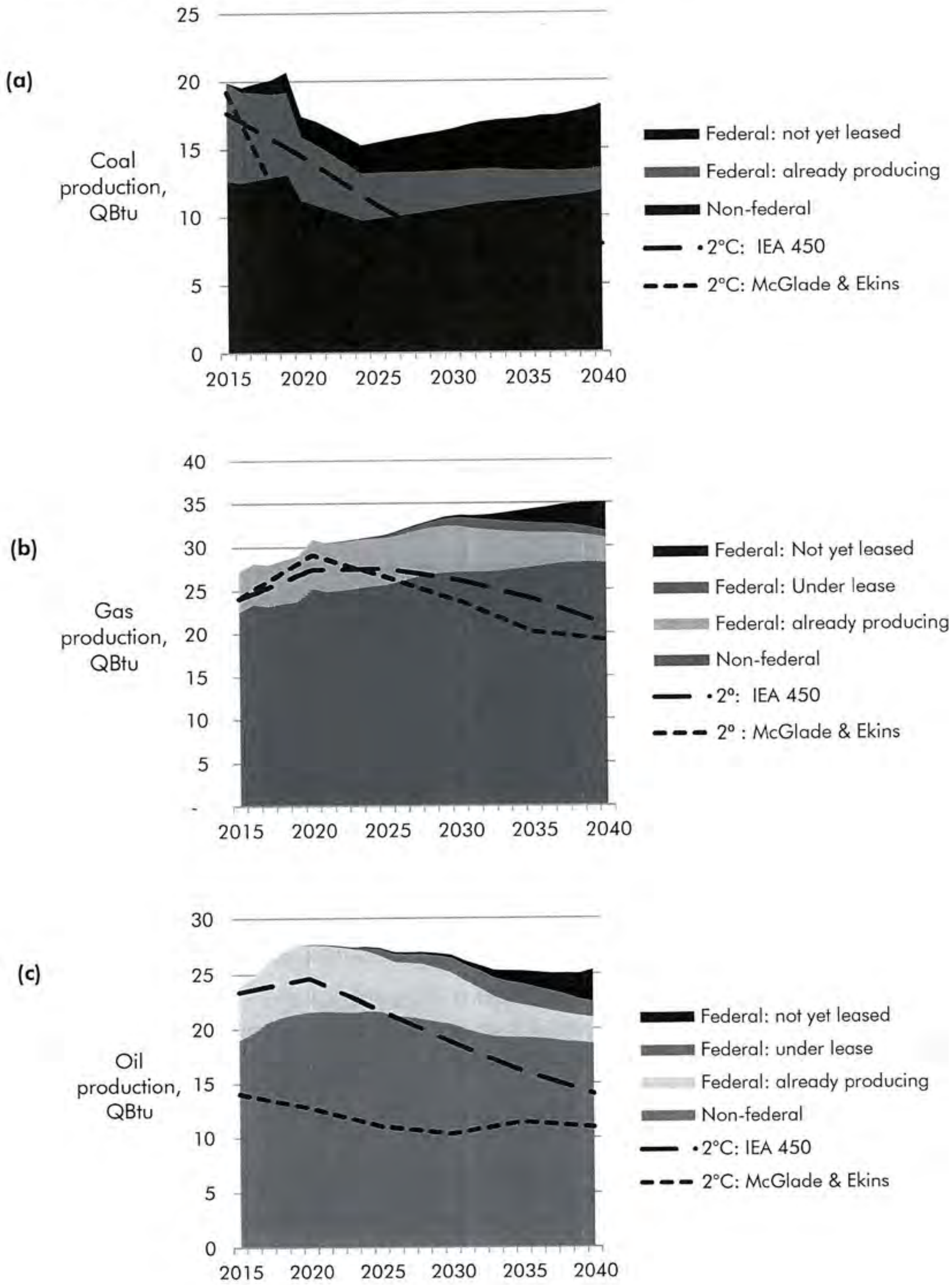
[19] We could not find data on lands leased for coal but not yet producing. Because the production on coal lands could be seen as trivial (i.e., very little infrastructure is needed to extract a minimal amount of saleable coal and therefore prove the lease), we assume that no coal extraction could be avoided by not renewing leases because leaseholders could easily prove production and avoid the non-renewal.

[20] This finding is based on the assumption that producers draw from existing and new leases at the same proportional rates.

than half: to 8 QBtu annually under IEA's 2°C scenario by 2030, or 1 QBtu under McGlade and Ekins's 2°C scenario. Compared with these 2°C scenarios, reference case U.S. production is on pace to substantially over-produce coal, such that both federal and non-federal coal supply would need to be reduced to attain a pathway consistent with 2°C.

Figure 4: Future U.S. fossil fuel production in reference case (by status of federal lease) and under 2°C scenario, 1990–2040



4.4 Gas

As shown in Figure 4, of all three fossil fuels, gas has the lowest fraction (less than one-fifth) produced from federal lands and waters. Roughly half of this gas is from lands in Rocky Mountain states, especially Wyoming and Colorado. About a third is from offshore deposits, almost all of which are in the Gulf of Mexico.

Gas (and oil) projects tend to have longer lead times than coal, as companies must first conduct exploratory drilling and put wells or offshore platforms in place. (By contrast, new federal coal leases are often next to existing mines and can be accessed readily with existing equipment.) Accordingly, changes to leasing practices for gas may take many years to affect production. In our analysis, new leases produce only a negligible quantity of gas before 2030. Existing (but not yet producing as of 2015) leases could produce slightly more gas in the near term (e.g. rising to 15% of production by 2030), but their importance diminishes in the longer term.

Between now and 2040, the reference case sees an estimated 30 trillion cubic feet (30 QBtu) of gas will be extracted from federal lands and waters not yet under lease or that are under lease but have not yet started producing. This represents 2 Gt CO_2 of emissions once the gas is burned. About two-thirds of this is likely to be from offshore deposits, indicating the growing role of offshore sources of gas. And although most of the offshore gas is still expected to come from Gulf sources through 2040, Pacific and Atlantic sources (notwithstanding the Obama administration's recently announced cancellation of mid-Atlantic lease sales) could take on increasing roles over time, making up 10% of offshore production in 2040 (up from 1% today, all in the Pacific). In the reference case, U.S overall (federal and non-federal) gas production rises gradually through 2040. By contrast, under the 2°C scenarios considered here, U.S. gas production would instead level off and peak in the next 10 years, then decline steadily to about 20 QBtu in 2040, indicating that the role of gas as a "bridge" fuel between coal and renewables in a 2°C world is short-lived. This finding is consistent with that of other studies (Lazarus, Tempest, et al. 2015; Davis and Shearer 2014).

4.5 Oil

Slightly more than one-fifth of current and expected U.S. oil extraction is from federal lands and waters. Thus, in contrast to coal, the impact of federal leasing through 2040 is more modest.

Leasing practices for offshore oil, especially in the Gulf of Mexico, could have the largest impact on federal oil extraction, since the Gulf is the source of about 70% of federal oil in the reference case. Most of the remaining oil comes from federal lands in Western states, including New Mexico, Wyoming and North Dakota.

As for gas, the longer lead times for oil projects – especially offshore oil – mean that new leases do not have much impact on oil production until after 2030. However, as production from existing fields declines more rapidly in later years, the importance of new leases grows.

Between 2016 and 2040, the reference case sees an estimated 7 billion barrels (40 QBtu) of oil will be extracted from federal lands and waters that were not under lease as of 2015, or had not yet started producing. This would equal 3 Gt CO_2 of emissions once the oil is burned (primarily as vehicle fuel). Over half of this oil is from offshore deposits in the Gulf of Mexico that are already under lease, which indicates that lease *renewal* rather than new leasing practices are likely to be the major determinant of federal oil production through 2040.

Overall, across both federal and non-federal lands and waters, U.S. oil production in the reference case peaks around 2020 at around 28 QBtu, then declines gradually to about 25 QBtu. By contrast, in the IEA 2°C scenario, U.S. oil production would peak at around 25 QBtu and then decline more rapidly, to less than 20 QBtu by 2030; in McGlade and Ekins' 2°C scenario, U.S. oil production would begin declining immediately, to less than 15 QBtu in 2020.

Table 2 summarizes the findings of our analysis of coal, oil, and gas production scenarios, especially the amount of federal fossil fuel extraction that might be avoided by cessation of new leases and by not renewing existing, non-producing leases.

Table 2: U.S. federal fossil fuel production in reference case and quantities avoided by ceasing new leases and not renewing non-producing leases, 1990–2040, in QBtu

Federal fossil fuel production	2015	2020	2025	2030	2035	2040
Coal	**7.3**	**6.2**	**5.6**	**5.9**	**6.1**	**6.3**
Avoided from non-renewals	–	–	–	–	–	–
Avoided from cessation of lease sales	–	(1.5)	(2.2)	(3.1)	(3.9)	(4.7)
Avoided (total)	–	(1.5)	(2.2)	(3.1)	(3.9)	(4.7)
Avoided, as % of reference case		(24%)	(40%)	(53%)	(64%)	(74%)
Gas	**4.6**	**5.7**	**5.8**	**6.6**	**6.7**	**7.0**
Avoided from non-renewals	–	(0.0)	(0.3)	(1.0)	(1.1)	(0.8)
Avoided from cessation of lease sales	–	(0.0)	(0.1)	(0.3)	(1.6)	(3.3)
Avoided (total)	–	(0.0)	(0.4)	(1.3)	(2.7)	(4.1)
Avoided, as % of reference case		(0%)	(6%)	(19%)	(40%	(59%)
Oil	**4.8**	**6.1**	**5.8**	**6.3**	**6.1**	**6.8**
Avoided from non-renewals	–	(0.0)	(0.6)	(1.4)	(1.9)	(1.4)
Avoided from cessation of lease sales	–	(0.0)	(0.1)	(0.3)	(1.2)	(3.0)
Avoided (total)	–	(0.0)	(0.7)	(1.6)	(3.1)	(4.4)
Avoided, as % of reference case		(1%)	(12%)	(26%)	(51%)	(65%)
Total	**16.7**	**18.0**	**17.2**	**18.8**	**18.8**	**20.1**
Avoided from non-renewals	-	(0.0)	(0.9)	(2.4)	(3.0)	(2.2)
Avoided from cessation of lease sales	-	(1.5)	(2.4)	(3.6)	(6.7)	(10.9)
Avoided (total)	-	(1.6)	(3.3)	(6.0)	(9.7)	(13.2)
Avoided, as % of reference case		(9%)	(19%)	(32%)	(52%)	(66%)

Source: SEI analysis based on sources described in prior charts.

5. REDUCTIONS IN CO_2 EMISSIONS FROM RESTRICTED LEASING

The prior section examined how fossil fuel production would be affected by ceasing new leases and not renewing existing, non-producing leases. In this section, we assess what this reduction in fuel extraction might mean for energy use and global CO_2 emissions.

We characterize these impacts on a net basis, meaning that we estimate the change in global CO_2 emissions *after* taking into account how other fuels may substitute for the federal fuels no longer extracted. Accordingly, our analysis directly addresses the potential for carbon leakage, or the whack-a-mole" phenomenon, that has characterized much of the debate around limiting fossil fuel extraction (Roberts 2015; Lazarus, Erickson, et al. 2015). Specifically, we quantify how, in response to reduced supply of federal fossil fuels:

- **Other non-federal fuels of the same type could substitute,** such as if coal from private, tribal, or state lands replaces coal no longer extracted from federal portions of the Powder River Basin. In oil markets, other supplies could come either from non-federal domestic sources, or from other global oil producers.
- **Different fossil fuels could substitute,** such as if, in response to a drop in coal production, U.S. power systems instead used more natural gas for power generation.

We apply economic tools commonly used to assess fuel markets. In each case, these tools consider that a cut in production is a shift in the supply curve for the fuel. Other producers, and consumers, then respond by consuming more or less of different fuels based on the resulting changes in prices. This approach situates our analysis in the broader economic literature on supply and demand for energy, and allows for a relatively straightforward quantification of the potential CO_2 effects, since the carbon contents of each fuel (coal, gas, and oil) are well known.[21] However, these tools are incomplete, as they do not capture the potential broader political or economic implications of what would be a high-profile climate measure taken by a major world economy. For example, were the prospective leasing restrictions by DOI to lead other decision-makers or investors to similarly move away from expanding fossil fuel supply, the impacts could be far greater. We will return to this possibility later in the discussion.

We conduct our analysis for the two energy resources – coal and oil – for which reduced federal leasing is likely to have the greatest implication on global CO_2 emissions. We do not consider the net CO_2 impact of reduced federal leasing for gas: as described in Box 3, it is not clear that changing the availability of natural gas would have a significant impact on CO_2 (or total greenhouse gas) emissions, either positive or negative.

We focus on net CO_2 emissions impacts in a specific year, 2030, as it serves as a common reference year for future climate action and commitments in the UN climate negotiations, including the Paris Agreement.

In Section 4, we developed estimates of the impact of fossil fuel extraction from federal lands (Table 2) if the DOI were to cease issuing new leases for coal or oil extraction and stop renewing non-producing leases as they come due.[22]

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[21] We do not conduct analysis of the change in CO_2 emissions associated with extracting, processing, or transporting each resource because these impacts are generally small compared to the emissions associated with combustion of the resulting fuel.

[22] As explained in Box 1, lease terms for oil are 10 years onshore or 5, 7, or 10 years for offshore (depending on water depth). It is possible that, should these leases (not producing as of 2015) start producing before the end of the lease term, they would be "held by production" and, by law, automatically renewed. In such a scenario, the estimates

Box 3. Changing the supply of gas has little impact on net CO_2 and GHG emissions

The decision to use coal or gas in power generation depends on the relative price and availability of these fuels, as well as their non-fossil alternatives, such as renewable power. The CO_2 implications of changes to gas supply are highly dependent on these dynamics, as well as on economy-wide effects on energy prices and overall energy use.

A number of studies have looked at the relative balance of these effects in assessing the CO_2 implications of increased availability of gas in the U.S. (Lazarus et al. 2015). Some indicate a slight CO_2 benefit of increased gas availability (Newell and Raimi 2014; Shearer et al. 2014; US EIA 2014), especially if gas tends to displace coal power. Other studies indicate a slight net increase in CO_2 emissions is possible, due increased energy use and displacement of low-carbon energy (Brown, Krupnick, and Walls 2009; US EIA 2014).[1] A model comparison exercise by the Energy Modeling Forum suggests, on average, no significant CO_2 emissions impact over the next few decades, as the "scale" effect of increased overall energy use largely offsets the "substitution" effect of shifting away from coal (Energy Modeling Forum 2013). Studies looking at gas supply internationally have come to similar conclusions (Lazarus et al. 2015; McJeon et al. 2014).

Given the findings of these studies, we do not ascribe a net CO_2 emissions impact to decreased leasing of federal natural gas resources, at least for the time scale we focus on here (through 2040). That said, the leasing decisions considered in this analysis would play out well beyond this time scale. Over the longer-term, natural gas is more likely to compete with low-carbon energy sources, especially if nations such as the U.S. and China continue to move away from coal. Thus, while reduced leasing of federal natural gas resources may have little effect on global CO_2 emissions over the next two decades, it could help in easing the longer-term transition to a low-carbon economy.

The effect of expanding natural gas supply on greenhouse emissions other than CO_2 will depend on other factors, namely, how much of methane (CH_4), a greenhouse gas many times more potent than CO_2, leaks to the atmosphere. Methane leakage can occur during fuel extraction (e.g. conventional or unconventional production, including fracking), transportation (e.g. via pipelines), or distribution (e.g. to homes and businesses via metal or plastic pipes.) At leakage rates most commonly suggested in the literature, methane leakage is unlikely to counteract the GHG emissions balance of natural gas relative to other fuels when that gas is used in most stationary energy applications, such as power generation or heat provision (Lazarus et al. 2015).[1] Some suggest that leakage rates and impacts could be much higher (Howarth 2015), especially for shale gas, though such estimates have yet to be widely accepted. We therefore consider that restricting leasing would not have a substantial net GHG emissions impact, just as we do not ascribe it a net CO_2-only impact, though we note that further efforts are needed to address methane leakage in natural gas production and distribution.[1]

5.1 Coal

U.S. coal markets are particularly complex, given the stock of coal power plants, many of which were built (or were substantially rebuilt) with boilers designed for a specific grade (or even supplier) of coal, thereby limiting the possibilities for substitution among coals from different suppliers (Joskow 1987; Haggerty et al. 2015). For example, a power plant built for the uniquely low-sulfur, sub-bituminous coal from the Powder River Basin may not be able to switch to other coal, at least not without major retrofits (e.g. to coal processing or pollution controls, or

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of avoided production due to non-renewals in Table 2: could be too high and, accordingly, also the estimates of CO_2 impacts in this section. However, nearly all of the production expected from already-held (but not-yet-producing) leases is from offshore oil, and very little of this is expected to start producing before 2025 in Rystad Energy's assessment (Rystad Energy 2015). With a maximum lease term of 10 years, most of these leases would be expected to come up for renewal before 2025, and therefore be subject to non-renewal.

potentially, a complete rebuild of the boiler). A simple model of supply and demand, by treating each ton of coal as equivalent in a competitive market, could miss these dynamics and thus likely overestimate the tendency for other coal, with much different characteristics, to substitute for the drop in federal coal. For this reason, a model that represents the costs and fuel requirements of specific power plants and coal resources has distinct advantages that here outweigh the lack of transparency that a simpler model might provide.

Therefore, to assess the response of the U.S. power market to a drop in domestic coal supply, we look to a recent study (which we refer to as the "Vulcan study") that analyzed how changes to federal leasing practices would affect coal consumption and power-sector CO_2 emissions in the U.S. (Vulcan/ICF 2016). It is the most recent and comprehensive study we identified that looks at changes to U.S. coal supply, and it is also the most closely aligned with the focus here on coal from all federal lands.[23] It uses the Integrated Planning Model, IPM, a tool also used by the U.S. Environmental Protection Agency (EPA). Furthermore, it takes into account the impact of the Clean Power Plan as well as the specific, power-plant-level dynamics – such as coal grade requirements and the cost of pollution control technologies or other plant retrofits – that would constrain substitution of other coals for the drop in federal coal.[24]

We summarize the results of the Vulcan study in terms of net decrease (or increase) in fuel consumption per unit drop in coal production in the year 2030.[25] The study found that, under the Clean Power Plan, each QBtu of coal no longer supplied (due to lease restrictions) to domestic power markets would be replaced by 0.64 QBtu of other coal, for a net drop in national coal consumption of 0.36 QBtu. Electricity production would remain virtually unchanged, such that gas consumption would increase 0.23 QBtu to make up for the lost coal-based electricity. (Gas power generation is more efficient than coal, thus less gas would be needed to provide an equivalent amount of electricity).[26]

Were the Clean Power Plan not in place, the Vulcan scenario found a larger effect: a net drop in 0.69 QBtu coal for every federal QBtu cut (with gas increasing 0.35 QBtu).

Table 3 summarizes these market responses. The effect under the Clean Power Plan is smaller, as the Plan would already lead power producers who can replace coal with low-cost alternatives

[23] Other studies reviewed, including the "North Fork" study (USFS et al. 2015) and the Tongue River Railroad study (OEA 2015), looked at a particular coal going to a more limited market.

[24] As described in the EPA's documentation of the IPM Model, (U.S. EPA 2013), IPM aggregates existing actual power plants into a smaller number of "model plants" with similar characteristics, each of which is modeled individually. For example, IPM models about 759 coal-fired "model plants" to represent 1,003 actual existing coal-fired plants.

[25] The Vulcan study analyzed over a dozen cases that varied in terms of policy considered (royalty rate increases and leasing restrictions), whether and how the Clean Power Plan might be implemented (mass vs. rate basis), and base case assumptions regarding future resource costs (Base Case A vs. Base Case B). To characterize the reduced coal and increased gas consumption per unit of gross drop in coal production (as in Table 3), we looked at the impact of a phasing out coal production by increasing coal prices (by imposing the social cost of carbon on royalty rates), assuming: a) the Clean Power Plan is implemented using a "mass-based" approach in which each state pursues a fixed CO_2 emissions target but can trade emissions allowances with other states in regional trading programs; b) fuel and renewable cost projections consistent with the EPA's analysis of the final Clean Power Plan (Base Case B). The Vulcan study also modeled a simpler (and total) phase-out of federal fossil fuel production between 2028 and 2037 due to cessation of new lease issuance, but we do not consider that case here because it uses an older, "Base Case A" with higher renewables costs than forecast by EPA, and because it takes a more simplistic approach to lease phase-out.

[26] Given the much higher average efficiency of gas-fired electricity generation, this amount of gas is sufficient to nearly completely substitute for lost coal-based electricity (i.e. nearly all of the substitution is by gas not renewables), e.g. as shows in Exhibit 118 of the Vulcan study (Vulcan/ICF 2016)

to do so, leaving coal generation mostly in places where the relative cost of alternatives is high. As a result, in response to a drop in federal coal, these remaining coal-fired power systems would shift more heavily to other coal supplies, as from the Illinois Basin and Appalachia. (It is also possible that other, non-federal Powder River Basin coal could substitute, were large new mines to be developed on state, tribal, or private lands, though the Vulcan study does not appear to envision such projects being economic at scale to replace the forgone federal coal.)[27] Another reason that the effect under the Clean Power Plan is smaller in the Vulcan analysis is because of interactions between the leasing restrictions and provisions that states must meet specific emission rate goals. To the extent these goals – or more accurately, the policies and measures states put in place to achieve them – are "binding", and states allow for interstate trading of allowances and credits, further CO_2 emission reductions beyond those required by the Clean Power Plan may be more difficult to achieve. While increases in coal prices spurred by restricted leasing would lead to further decreases in coal-based generation and emissions, those decreases could be offset by increased gas-based generation and emissions. They could also be offset by reductions in renewable power or energy efficiency, due to the added "headroom" under the cap and associated decreases in allowance or credit prices within and across states (to the extent that state and regional trading is adopted).

Table 3: Change in net consumption of coal and gas per 1 QBtu decrease in gross production of coal, QBtu basis

	Clean Power Plan case (Reference scenario)		No Clean Power Plan Case (Alternative reference scenario)	
	Coal	Gas	Coal	Gas
Domestic market	-0.36	0.23	-0.69	0.35
Export market	-0.30	0.07	-0.30	0.07

In principle, this effect could be so strong as to nearly eliminate any CO_2 emissions reductions from leasing restrictions under the Clean Power Plan. This could happen, for example, if the state emission rate goals assigned by EPA under the Clean Power Plan were "binding" for all states, fully determining power sector CO_2 emissions. A fully binding outcome for the Clean Power Plan is not foreseen in the Vulcan analysis used here. If future renewables or gas power costs were to be greater than currently foreseen by the EPA, then the likelihood of such an outcome would increase – a possibility we consider in the sensitivity analysis in Appendix B.

For exports, which are not described in detail in the Vulcan study, we develop and apply a simple model of supply and demand, similar to prior approaches (Power and Power 2013). The EIA expects exports of steam coal, including from federal lands in the Powder River Basin, to rise slowly but steadily over the next two decades. Producers in the Powder River Basin are particularly looking to emerging economies in East and Southeast Asia, especially Korea, where coal demand is still expected to increase (Considine 2015; Leaton et al. 2014; IEA 2015).

Information on the price elasticity of coal demand in Korea and Southeast Asia is sparse, however (Leaton et al. 2014). We assume that, in the long term, this market is roughly as price-

[27] For example, were the Otter Creek mine on state and private lands in Montana or the Big Metal Mine on Crow Reservation lands to be developed, the coal supply curve could "flatten", facilitating coal substitution beyond that foreseen in the Vulcan study, decreasing the net effect on coal consumption in Table 3.

responsive as Chinese power systems were during their period of rapid growth (Jiao et al. 2009), for an elasticity of demand of -1.12. We assume that the Pacific Coal market is highly competitive, with substantial low-cost supplies from Indonesia and Australia (Aldina 2013), for elasticity of supply of 2.6. Together these assumptions imply that each QBtu of U.S. coal no longer exported to Asian power markets would be replaced with 0.7 QBtu of other coal, for a drop in net coal consumption of 0.3 QBtu (Table 3).[28] Given the limited supply of gas in Asia to substitute, gas would not fully offset this net drop in coal. Based on a meta-analysis of fuel substitution research (Stern 2012), we find that natural gas in these markets would increase by 0.07 QBtu, only partially substituting for the drop in coal consumption.[29]

We now apply the ratios in Table 3 to the gross drop in coal production from cessation of lease issuance (Section 4) to yields estimates of net change in coal and gas consumption. First, however, we make two adjustments to our estimates of the gross drop in coal production.

The first adjustment is simply to exclude metallurgical coal, such as for use in iron and steel mills. Though this coal is much higher-value than coal for energy production (steam coal), it has smaller CO_2 emissions implications. This is because metallurgical coal has few, if any, readily available low-carbon alternatives, so reducing its supply would be unlikely to affect CO_2 emissions substantially. We assume that 7% of the coal extracted goes to metallurgical, not power, markets, based on national averages from the U.S. EIA (2015b).

The other adjustment involves additional deposits of coal that may be affected by leasing restrictions since in some instances cutting the availability of *federal* coal would also constrain the accessibility or profitability of mining adjacent *non-federal* coal. This could especially be the case in Wyoming, as hundreds of relatively small plots of state lands are entirely contained within federal parcels (Luppens and Scott 2015). These non-federal parcels may not be accessible or economic to extract if federal leasing were restricted (a similar situation may exist with some private lands). The Vulcan study, for example, estimates the associated reduction in non-federal coal to be as much as half the reduction in federal coal (Vulcan/ICF 2016), magnifying the effects of federal lease restrictions. Here, we assume, based on a review of U.S. EIA (2015a) and ONRR (2015) data, that non-federal coal makes up about one-sixth of federal production in Wyoming, and so we increase our estimates of the drop in coal supply from Wyoming by this fraction. (We do not adjust the drop in coal production from other states.)

Together, these adjustments result in an estimated cut in coal supply in 2030 of 2.9 QBtu to domestic markets and 0.3 QBtu to export markets relative to our Clean Power Plan reference scenario.

Applying the ratios in Table 3 to these totals yields estimates of the impacts on net consumption of coal and gas in energy terms (Table 4). Applying standard carbon contents for coal and gas

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[28] We assume an elasticity of demand of -1.12 (Jiao et al. 2009) and an elasticity of supply of 2.6, as imputed from Wood Mackenzie's coal supply curve (Aldina 2013) at expected consumption levels. Together, and using the equation $E_d/(E_d-E_s)$ as from basic microeconomics (Perloff 2007) and prior studies (Power and Power 2013; Erickson and Lazarus 2014), suggests a net effect on consumption of 0.30. See the next section, on oil, for further discussion of this equation.

[29] We estimated the ratio of increased gas consumption to drop in coal supply by introducing two adjustments to the equation described in the prior footnote. The adjustments are the elasticity of substitution between coal and gas (E_{cg}) and the starting ratio of gas to coal consumption (Q_g/Q_c), and are applied as follows: $(E_d+E_{cg})/(E_d-E_s)*Q_g/Q_c$. We use Table 4 of Stern's (2012) meta-analysis to estimate E_{cg} in Korea as 1.4. The IEA estimates that the ratio of gas to coal consumption in OECD Asian countries (such as Korea and Japan) in 2030 will be 0.9, and we use this as Q_g/Q_c. Were the consumers of exported U.S. coal instead countries with more coal and less gas, such as China or India, the ratio of gas to coal could be much lower and, therefore, also the extent of substitution of gas for coal.

(IPCC 2006) yields estimates of the emissions increases or decreases for each fuel in each market (also in Table 4).[30]

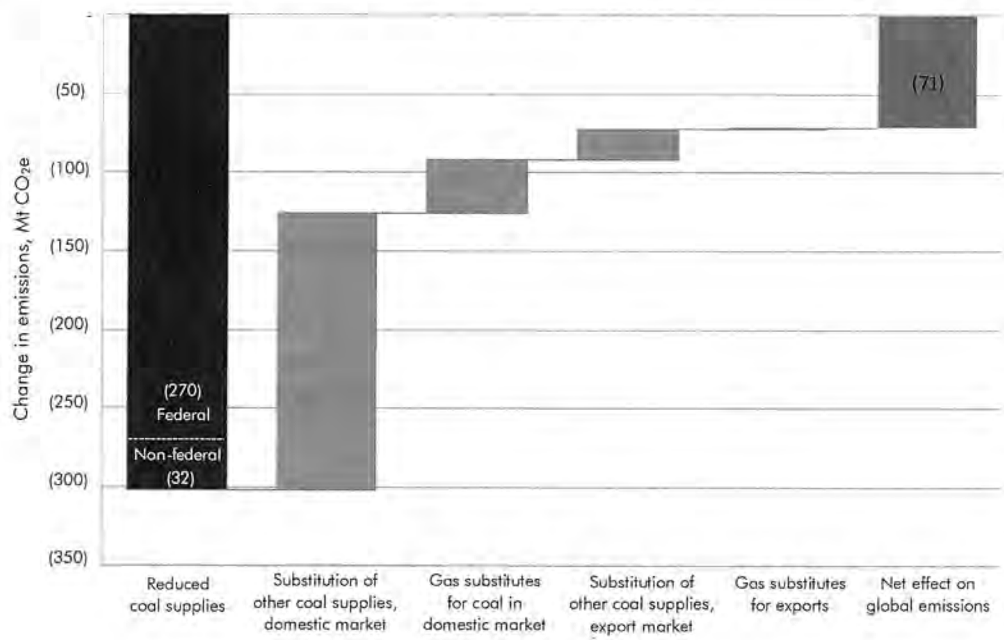
Table 4: Change in net consumption of coal and gas in response to decreased coal production, 2030

	Clean Power Plan Case		No Clean Power Plan Case	
	Coal	Gas	Coal	Gas
Energy content (QBtu)				
Domestic market	(1.03)	0.66	(3.33)	1.67
Export market	(0.09)	0.02	(0.10)	0.02
Total	(1.12)	0.68	(3.43)	1.69
Carbon content (Mt CO_2)				
Domestic market	(99)	35	(318)	88
Export market	(8)	1	(10)	1
Total	(107)	36	(328)	90

In our reference case, assuming Clean Power Plan implementation (Table 4), we find that leasing restrictions would reduce CO_2 emissions in 2030 from coal by about 107 Mt CO_2, but increased use of gas would increase emissions by about 36 Mt CO_2, resulting in a net reduction of 71 Mt CO_2. Figure 5 illustrates the individual effects that add up to this net reduction. As shown in the chart, leasing restrictions lead to a drop in coal extracted in federal or adjacent lands in 2030 equivalent to 300 Mt CO_2. Increased production in the Illinois Basin and (to a lesser extent) Appalachia makes up for about 60% of the lost coal production from federal and adjacent lands. Increased coal prices also lead to some substitution by gas in domestic power systems. Substitution also occurs in export markets, by gas and other coal supplies from countries such as Australia and Indonesia. The net reduction in CO_2 emissions, after accounting for all of these effects is, as stated above, 71 Mt CO_2 in 2030

[30] We do not conduct analysis of the change in CO_2 emissions associated with extracting, processing, or transporting each resource because these impacts are generally small compared with the emissions associated with combustion of the resulting fuel.

Figure 5: Impacts of decreased coal production on coal and gas markets, 2030, under the reference (Clean Power Plan) case, CO_2 basis



5.2 Oil

Oil is used primarily in transport, with more than half of current and expected future global oil used as transport fuel, especially for cars and trucks. The remaining portion is split among the industry, buildings and power sectors, though uses in buildings and power are expected to decline (IEA 2015). The oil market is also highly global, with oil readily traded among countries, and substantial infrastructure in place to do so. The U.S. both imports and exports oil, and world and domestic oil prices very closely track each other (U.S. EIA 2016).

For this reason, we expect that changes in U.S. oil production would affect an integrated global oil market, an assumption also made by many other analysts that have looked at changes in U.S. oil supply (Bordoff and Houser 2015; Rajagopal and Plevin 2013; Allaire and Brown 2012; Metcalf 2007; IEc 2012). Though in the past the oil market could be strongly influenced by cartel behavior among a small number of producers, many analysts now see the market as more likely to behave competitively (The Economist 2016; U.S. EIA 2016), meaning that increases or decreases in supply do translate into shifts in prices and, in turn, consumption.[31]

Accordingly, we model the impact of federal leasing policy on the global market as a shift in the global supply curve, just as in our prior assessment of oil markets (Erickson and Lazarus 2014). Assuming the decline in supply is small relative to this global market, the resulting change in consumption can be modeled as a direct function of the change in production, using

[31] A shift in supply will only affect consumption if it is not offset by a shift by another large producer, such as a cartel in the Middle East.

elasticities of demand (E_d) and supply (E_s) (Erickson and Lazarus 2014) and from basic microeconomics (Perloff 2007), using the following equation:[32]

$$\Delta Consumption \cong \frac{E_d}{E_d - E_s} * \Delta Production \tag{1}$$

Consistent with our prior work, we use a mid-range estimate of the long-run elasticity of world crude oil demand of -0.2 based on a literature review (Hamilton 2009), and within the range, from -0.072 to -0.3, found by a more recent review (Bordoff and Houser 2015). For the elasticity of supply, we use a value of 0.25 from Rystad Energy's oil supply curve for the year 2030.[33]

Applying these elasticities to equation (1), we estimate that, for each unit of production cut, other oil supplies will substitute for 0.56 QBtu, and that net oil consumption will drop by 0.44 QBtu (Table 5). This result is unaffected by Clean Power Plan implementation, since the law has little impact on oil consumption.

Table 5: Change in net consumption of oil and substitute fuels per unit decrease in gross production of oil, QBtu basis[34]

	Oil	Substitutes (biofuels, gas and electricity)
Global market	(0.44)	0.22

Some of this drop in oil consumption will be made up by alternative transport fuels, while some will represent a reduction in overall transportation energy use due to increased vehicle efficiency, transport mode shifts, or other measures. In the long term, other transport fuels (beside oil) may become viable alternatives at scale, including biofuels, compressed natural gas (CNG), or electricity. However, little information exists on the long-term elasticities of substitution between oil and these other transport fuels (Faehn et al. 2016). Furthermore, deployment of these other fuels and their corresponding vehicles will depend not only on fuel economics, but also on national policies (U.S. EIA 2013). Therefore, we look to the International Energy Agency's *World Energy Outlook 2015* (IEA 2015) to inform our estimates of substitution effects. A comparison of *World Energy Outlook 2015* scenarios suggests that, over the next few decades, the effect of price-induced decreases in oil consumption may be split roughly evenly between lower overall energy use and increased use of substitute fuels.[35] As

[32] This equation is the same one as that used to model the response to coal exports as described previously. We describe it here for oil in more detail since the flow of oil from U.S. public lands and waters to the global market is many times greater than the flow of coal from public lands to the Pacific coal market.

[33] We measure the slope of Rystad Energy's oil supply curve for 2030 at the expected equilibrium consumption level (99.5 mbpd), and use that to calculate the elasticity. In this range of the cost curve, offshore oil producers in Mexico and Malaysia, and tight oil producers in the U.S., are dominant, suggesting that these could be the marginal producers for oil supply in 2030.

[34] As described in the text, we assume 30% of the substitute fuel is biofuels (50% cut in GHG-intensity relative to oil), and the remainder is electricity and gas (same GHG-intensity as oil).

[35] We estimate this half-half split by looking at the response to oil and other fuel demand in IEA's Low Oil Price scenario relative to their New Policies Scenario. Figure 4.5 of *World Energy Outlook 2015* indicates that for each increase in oil consumption in the Low Oil Price scenario, about half is from higher demand and half is from less fuel switching away from oil (the substitution effect is slightly less than half in earlier years, slightly more in later

shown in Table 5, we apply this 50:50 ratio and estimate that for each 0.44 unit drop in oil consumption, the use of substitution fuels will increase by 0.22 units.

We further assume, again drawing from a comparison of *World Energy Outlook 2015* scenarios, that 30% of the fuels that substitute will be biofuels.[36] Though future production methods of biofuels remain in development, we assume that they will be half as GHG-intensive as petroleum-based fuels, on a life-cycle ("well to wheels") basis, and reflecting a higher penetration of second-generation and advanced biofuels in the future.[37]

Beside biofuels, the other fuels that substitute are natural gas (e.g. CNG in vehicles) and electricity (i.e. in electric vehicles). However, these fuels are not yet foreseen to offer, in aggregate across the globe through 2040, substantial GHG emission benefits for transportation uses relative to oil. This is because natural gas (methane) leakage during fueling erodes what would otherwise be a CO_2 benefit of gas (Alvarez et al. 2012). Electric vehicles, though they can bring substantial CO_2 benefits in regions adding low-carbon electricity, can increase net CO_2 emissions if the source of electricity is coal. On average, the IEA finds that, in its reference (New Policies) case, one effect does not clearly outweigh the other (IEA 2015), and so we assume, for simplicity, that *in aggregate*, there is no net CO_2 effect in substituting electric for petroleum-fueled vehicles.

Based on these assumptions about the GHG balance of biofuels, gas, and electricity, we estimate that the carbon-intensity of this alternative fuel mix is 85% of the carbon-intensity of oil-based fuels. Were the alternative fuels to be lower-carbon, such as renewable electricity or sustainable, second- or third-generation low-GHG biofuels, then the GHG benefits of reducing oil supply and, in turn, consumption, could be much greater, a possibility we explore further in the sensitivity analysis in Appendix B.

Applying the ratios in Table 3 to the gross oil production cuts from Table 2: (1.6 QBtu) yields estimates of the net increase or decrease in oil and its substitutes (Table). Further applying standard carbon contents of oil (IPCC 2006) yields estimates of net changes in CO_2 emissions.

As shown in Table , cutting oil production from federal lands reduces global CO_2 emissions in 2030 from oil consumption by 54 Mt CO_2, and leads to an increase in CO_2 emissions from other fuels of 23 Mt CO_2, for a net emissions benefit of 31 Mt CO_2. (Again, Appendix B provides sensitivity analysis.)

Table 6: Change in net consumption of fuels in response to lower oil production, 2030

	Oil	Substitutes (biofuels, gas, and electricity)
Energy content (QBtu)		
Global market	(0.73)	0.36
Carbon content (Mt CO_2)		
Global market	(54)	23

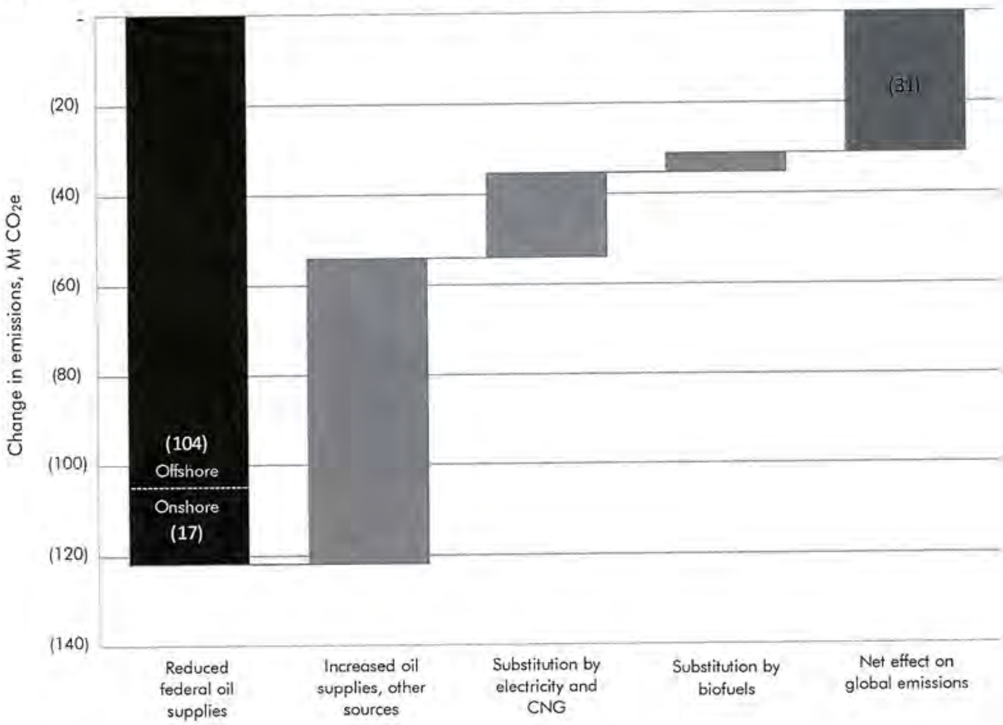
years). For our analysis, we assume the same dynamic would apply for decreases (rather than increase) in oil consumption.

[36] We derive this by comparing changes in (non-bunker-fuel) global transport energy demand for 2030 in the New Policies Scenario versus the Current Policies Scenario in the *World Energy Outlook 2015* (IEA 2015)

[37] The most widely used biofuel in the U.S., ethanol from corn, offers only modest (if any) GHG emission reductions relative to petroleum fuels, but sugarcane and other cellulosic ethanol and advanced biofuels still under development could cut the CO_2-intensity of fuels substantially (U.S. EPA 2010).

Figure 6 shows the individual effects that result in this estimated reduction. Leasing restrictions lead to a drop in oil extracted from federal lands and waters in 2030 equivalent to 120 Mt CO_2, 85% of which is from offshore oil leases not renewed or issued. Increased production in other global supplies makes up for more than half the lost federal oil production. Increased oil prices also lead to some substitution by other fuels: electricity, CNG and biofuels. The net reduction in CO_2 emissions, after accounting for all of these effects is 31 Mt CO_2 in 2030, as noted above.

Figure 6: Impacts of decreased oil production on oil and substitute fuel markets, 2030, under the reference (Clean Power Plan) case, CO_2 basis



5.3 Summary and discussion

Table 7 summarizes the net CO_2 emissions impacts of the cuts in coal and oil production. In total, we find that, by ceasing to issue new and renewed leases for fossil fuel extraction from federal lands and waters, the DOI could reduce net CO_2 emissions by about 100 Mt per year by 2030. Annual emission reductions could well increase over time, as federal fossil fuel production becomes even more dependent after 2030 on yet-to-be issued leases. Furthermore, over time, consumers are likely to be more sensitive to increased fossil fuel prices (Bohi 2013).

Table 7: Change in net consumption of fuels, 2030, in Mt CO_2

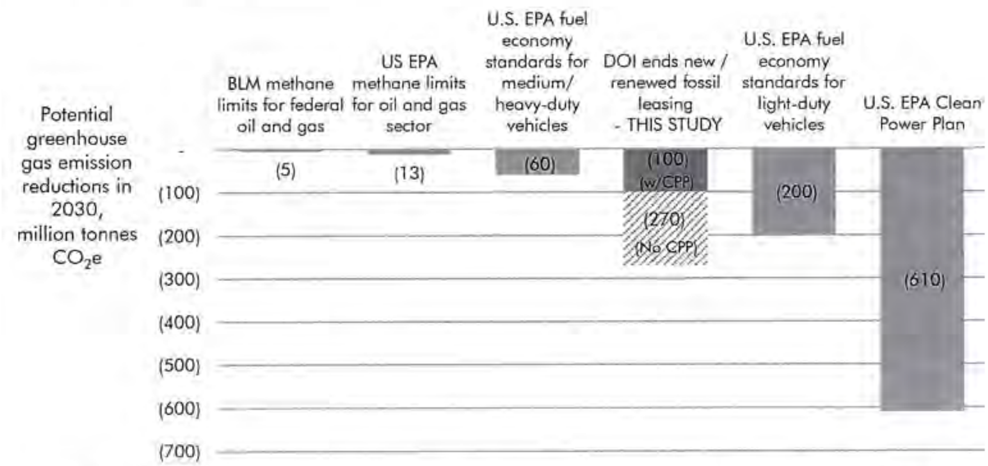
	Clean Power Plan Case			No Clean Power Plan Case		
	Impact on same fuel	Impact on substitute fuel(s)	Net	Impact on same fuel	Impact on substitute fuel(s)	Net
Coal						
Domestic market	(99)	35	(64)	(318)	88	(230)
Export market	(8)	1	(7)	(10)	1	(8)
Subtotal	(107)	36	(71)	(328)	90	(238)
Oil						
Global market	(54)	23	(31)	(54)	23	(31)
Total	(160)	58	**-100**	(380)	110	**-270**

Note: Figures may not add to totals due to rounding.

Our findings on the CO_2 emission savings that could result from leasing restrictions (100 Mt CO_2 per year in 2030 with the Clean Power Plan) are comparable to the savings from prominent policy initiatives of the Obama administration. As shown in Figure 7, the EPA's most recent proposed standards for light- and medium-/heavy-duty vehicles are expected to yield 200 Mt and 70 Mt in CO_2 savings, respectively, in 2030. The reduction from leasing restrictions is considerably greater than either the emission reductions that the EPA expects to achieve through regulation of the oil and gas industry's own (sector-wide) emissions, or what the BLM expects to achieve from methane restrictions on oil and gas operations on federal land.[38] Only the Clean Power Plan is expected to yield significantly greater emission benefits than potential federal leasing restrictions. In other words, cessation of new and renewed leases could make an important contribution to U.S. climate change mitigation efforts.

[38] In addition to the magnitude of greenhouse gas emissions reductions, planners may also consider cost-effectiveness as a criterion. From that perspective, one might prefer to phase out high-cost fossil resources first, which may or may not be federal resources. (For example, deepwater oil is often considered a high-cost oil resource; Powder River Basin coal, however, is generally considered lower-cost coal.)

Figure 7: Comparison of the potential global GHG emissions impact of federal leasing reform and other U.S. government policies, 2030



Source: SEI analysis. Estimate of emission reductions other policies adapted from BLM (2016a) and U.S. EPA (2012; 2015a; 2015b).

Several uncertainties underlie our analysis. We address an important one – the potential reversal of the Clean Power Plan – by conducting our analysis both with and without this policy in place. We find, in this case, that not issuing new leases for coal production could be an important complement to the Clean Power Plan, since ending leasing could phase down federal coal production and, should the Clean Power Plan not be implemented, reduce emissions by 270 Mt CO_2 in 2030. This amounts to nearly half of the 610 Mt in CO_2 savings that the EPA estimates the Clean Power Plan would achieve in that year.

Our findings are also particularly sensitive to the response of producers and consumers to changes in energy prices that would result from reductions in fossil fuel supply. For example, should coal producers on federal (or non-federal) lands respond to lease restrictions by more rapidly drawing down their reserves, perhaps in anticipation of broader and more ambitious efforts to address U.S. CO_2 emissions,[39] the impact in 2030 could be less than we estimate, though in later years, emission reductions could be greater.[40] On the other hand, should cessation of federal leasing send a market signal that leads to further tightening of finance for the coal industry, already in trouble, then coal production could decline even more rapidly. Similarly, should coal power plants be less able to substitute other sources of coal for the Powder River Basin and other federal resources, as at least one analysis has suggested (Haggerty et al. 2015), then the CO_2 emission reductions could be greater, as even more power systems would switch to lower-emissions resources such as gas or renewables.

Similar uncertainties affect our estimate of oil market impacts. This estimate is dependent on the responsiveness of other oil suppliers to lower U.S. federal supplies in global markets. Our analysis uses a relatively steeply sloping supply curve (from Rystad Energy) in 2030, with relatively high-cost producers on the margin, such as less-profitable tight oil and offshore-

[39] This would be a manifestation of what some have termed the "green paradox" (Sinn 2012).

[40] Vulcan/ICF's (2016) analysis would seem to indicate that this could occur, as producers of federal coal respond to lease restrictions by essentially maintaining (or slightly increase) production over the next decade, only to stop entirely by 2040.

producers. If oil production were to experience another surge of unexpected technological advancement, then the supply curve could "flatten" and reduce the impacts of lower federal oil production. Or if future oil production were constrained by unexpected resource declines (such as faster than expected decline rates from tight oil fields), slower technological progress, or other countries taking similar measures to slow future oil production, then the net CO_2 emissions impact could be even greater.

To understand the potential impact of these uncertainties, as described in detail in Appendix B, we conduct sensitivity analysis around several of the most important parameters in our analysis: the sensitivity of producers and consumers to shifts in supply and price. At one end of the spectrum, were fossil fuel markets and energy technologies to proceed unencumbered by climate policy, the world might see continued abundance of lower-cost fossil fuel supplies and slower development of low-carbon alternatives (such as renewable power or low-carbon vehicles). In a higher-carbon world, restrictions on federal fossil fuel supply could have less of an impact than we estimate here – as little as 4 Mt CO_2 in 2030 under our reference scenario. Restricting supply would have little impact on energy prices (due to higher supply elasticities), and fuel consumers would have fewer cost-competitive alternatives (as reflected in lower demand elasticities).

By contrast, in a lower-carbon world, where other countries take similar steps to limit fossil fuel supply and renewable power and alternative vehicles are even more available, the impacts of federal leasing policy could be greater. Fewer coal and oil producers would be able to step in to make up for the lower supply from U.S. federal lands (lower supply elasticities), and consumers would more readily respond to the price impacts by shifting to lower-carbon alternatives (higher demand elasticities). In such a case, the impact of U.S. leasing restrictions under the reference (Clean Power Plan) case could be twice as high as estimated – 210 Mt CO_2. Appendix B describes the assumptions that lead to these low- and high-end results.

Our analysis has thus far focused on overall CO_2 emissions impacts, without specifying the jurisdictions where these impacts would occur. The territorial emissions accounting system currently used under the UN climate regime only accounts for emission reductions that occur within each country's own boundaries, creating a political disincentive to adopt climate policies that would yield a large share of their benefits abroad (Erickson and Lazarus 2013).

In this context, it is notable that in our reference case, 30% of the estimated emissions benefit in 2030 of avoiding new federal fossil fuel leases and renewals would occur outside the U.S. Moreover, the majority of the emissions benefit of reduced U.S. oil production in particular would occur in other countries, due to the global nature of oil markets. If reductions in emissions are evenly spread, proportionate to projected oil consumption in 2030, then of the 31 Mt of CO_2 reductions, 5 Mt CO_2 in savings would occur in the U.S., and 26 Mt CO_2 in other countries.

In contrast, because domestic coal markets and prices are relatively distinct, and because most U.S. coal remains in the country, we project that nearly 90% of the emissions benefit of reduced coal supplies would occur within U.S. borders. Still, while the impact we calculate for export markets for 2030 is relatively small (reduction of 7 Mt CO_2), the long-term effect may be more significant if these countries are making enduring decisions regarding power infrastructure, and so U.S. leasing restrictions may also help avoid lock-in of long-lived coal-using infrastructure.

It is important to note that while the incremental emissions impact of reduced leasing over the next two decades is non-trivial, the broader, long-term implications with respect to global climate objectives would be more profound. As shown in Section 4, new leases begin to account for a majority of federal fossil fuel production only after 2030, as production from existing leased areas begins to play out. Thus, the incremental emissions impact will be far greater in the longer run.

In addition, a cessation of new federal leases would send a strong signal to other countries, encouraging them to take similar steps. Based only on the straightforward economic tools used here, we estimate that in such a case, with global fossil fuel supply more constrained and low-carbon renewables more available, the impact could be at least twice as high: 210 Mt CO_2 in 2030 alone.

Taken together, reduced government licensing and support for fossil fuel production could also help avoid further carbon lock-in in terms of investment in both fossil fuel-using and -producing infrastructure. Phasing out of federal oil supply could help accelerate the development of low-carbon transport options (such as electric vehicles powered by low-carbon electricity). Leases for offshore oil production, estimated to supply as much as three-quarters of U.S. federal oil (chiefly from the Gulf of Mexico), may be especially important as offshore oil production, with its high capital costs, is a key contributor to carbon lock-in, increasing the cost of meeting climate goals and making it harder to transition away from oil later (Erickson et al. 2015).

Finally, by ceasing new leases, the U.S. government would put fossil fuel production on a path to ending completely sometime in the second half of this century. That would be consistent with a long-term goal adopted in the Paris Agreement to achieve net zero greenhouse gas emissions from human activities later in the century, consistent with having a likely chance of keeping warming below 2°C (or 1.5°C).[41]

[41] The agreement says "achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, on the basis of equity, and in the context of sustainable development and efforts to eradicate poverty", which translates to net zero emissions.

6. CONCLUSIONS

Our analysis suggests that future leasing practices in federal lands and waters will play an important role in U.S. efforts to achieve its climate protection goals. Under a business-as-usual scenario, where federal leasing continues unabated, U.S. fossil fuel extraction will continue to rise through 2040, with 40% of coal and a quarter of overall fossil fuel production occurring in federal lands and waters. Should the Clean Power Plan survive legal and legislative challenges, overall coal production is likely to drop. Gas and oil production, however, (assuming a rebound in global oil prices) will likely continue upward, at least in the short term. By 2040, the U.S. could be producing 11% more fossil fuel energy and 7% more fossil fuel carbon than it does today.

At the Paris Climate Change Conference, the U.S. and other governments reaffirmed their commitment to keep warming within 2°C, further noting an intention to pursue a limit of 1.5°C. These goals would appear to call for a far different path for future U.S. fossil fuel production. As we illustrate in Section 3, **a cost-efficient pathway to meeting the 2°C commitment could require total U.S. fossil fuel energy production to decline by 40–60% from current levels by 2040**, and even more so for a 1.5°C goal. The percentage decline would be steeper for coal, and less so for gas, though production of all three fossil fuels would need to drop substantially over this period.

The U.S. has been a world leader in fossil fuel *consumption*, and the country has used this position to play a pivotal role in climate policies that seek to reduce fossil fuel *demand*. The U.S. is also a world leader in fossil fuel *production*, and could play a similar role for fossil fuel *supply*. By taking actions to curb investment in future fossil fuel supply infrastructure, federal policy-makers could limit carbon lock-in, limit the potential for asset stranding, and complement the policies needed to reduce fossil fuel use, such as the Clean Power Plan. In particular, modifying federal policies for leasing lands and waters for fossil fuel extraction – for example, by increasing royalties or removing lands or waters from future availability – could be an important element of a more comprehensive U.S. strategy aimed at fulfilling its long-term climate commitments.

In this paper, we have examined the potential energy and emissions implication of a decision to cease all new leases and non-producing lease renewals for fossil fuel production on federal lands and waters. Our main findings are that such an action could:

- **Send national coal production on a declining pathway**, potentially to levels more consistent with a 2°C pathway for U.S. coal extraction. Such an action could leave 4 billion short tons of federal coal in the ground that otherwise would be combusted between now and 2040, equivalent to about 7 Gt of CO_2 emissions
- **Take longer to play out for oil and gas extraction**, as many oil and gas projects, especially offshore, have substantially longer lead times from lease approval to full production. Stopping leases for these fuels could leave an estimated 7 billion barrels of federal oil (3 Gt CO_2) and 30 trillion cubic feet of federal gas (2 Gt CO_2) undeveloped between now and 2040.
- **Yield a net CO_2 emissions reduction in 2030 of 100 Mt CO_2** (relative to reference case levels), substantially more than other U.S. policies under consideration focused on fossil fuel extraction and on par with flagship policies of President Obama's Climate Action Plan, such as fuel standards for cars and trucks. Roughly 70 Mt CO_2 of the impact in 2030 would be from reduced coal emissions (especially in the U.S.). We find that the effect of ceasing new coal leases could range from virtually none (were gas generation to increase even more strongly) to 140 Mt CO_2 (were other coal supplies to be more limited and renewables able to fully substitute for reduced coal). The

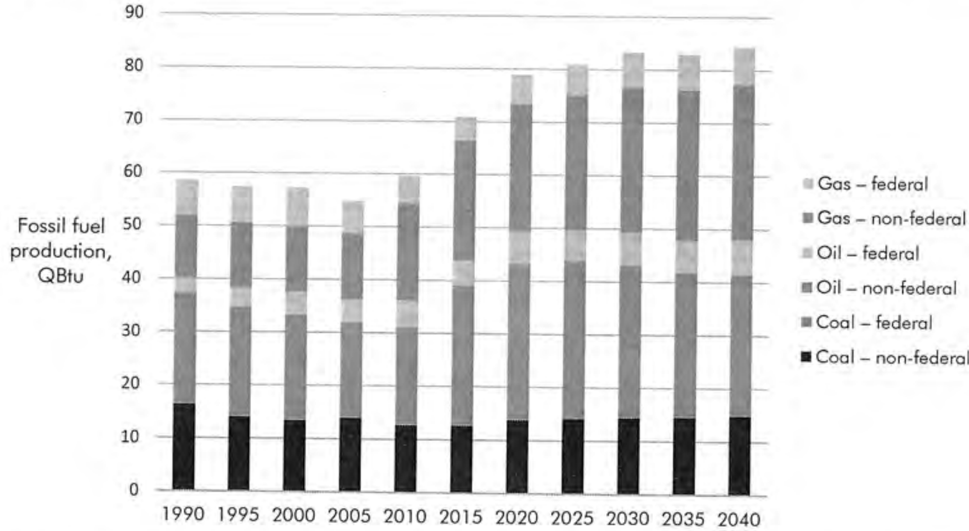
remaining decrease of 30 Mt CO_2 results from reduced global oil consumption resulting from an end to new leases and renewals (for non-producing areas) for oil production (largely off-shore), an effect that could similarly range from 4 Mt CO_2 to 64 Mt CO_2, depending on other policies put in place internationally. These emissions impacts would likely increase over time, as new, not-yet-issued federal leases comprise an even greater fraction of national fuel production after 2030.

Many nations are pursuing actions that reduce the demand for fossil fuels, including commitments ("intended nationally determined contributions") registered in the Paris Agreement and the policies that support them. Few nations, however, are pursuing actions to limit fossil fuel supply. Given the goal of limiting warming to 2°C (or 1.5°C) and the corresponding need to transition rapidly away from fossil fuels, many more policy measures need to be on the table than are currently considered. Our analysis here indicates that measures directed at fossil fuel supply – such as a phase-out of leasing federal lands and waters for fossil fuel extraction – could be an important complement to other measures designed to reduce fossil fuel consumption.

APPENDIX A: RESULTS FOR CASES WITHOUT THE CLEAN POWER PLAN

In the main body of this paper, we consider the EIA's Clean Power Plan scenario as the reference case for our analysis of U.S. fossil fuel production. In this appendix, we instead present findings for a reference case without the Clean Power Plan.

Figure A-1: Historical and forecast U.S. fossil fuel production, 1990–2040, case without the Clean Power Plan



Source: SEI analysis based on ONRR (2015) and U.S. EIA (2015a; 2015b), assuming the Clean Power Plan is not implemented.

Figure A-2: Historical and forecast U.S. fossil fuel production, by status of federal lease, 1990–2040, case without the Clean Power Plan

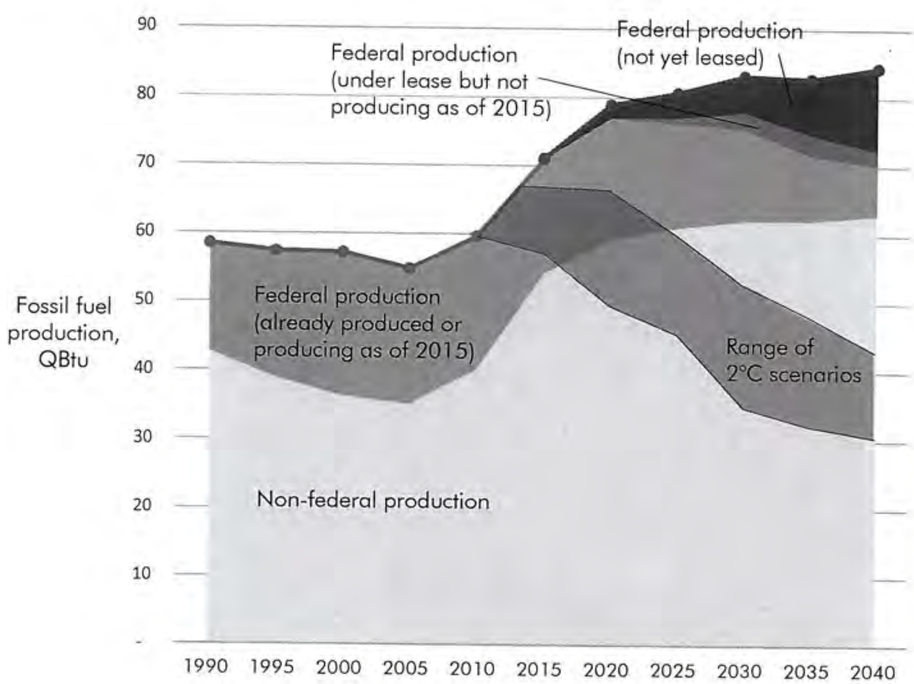
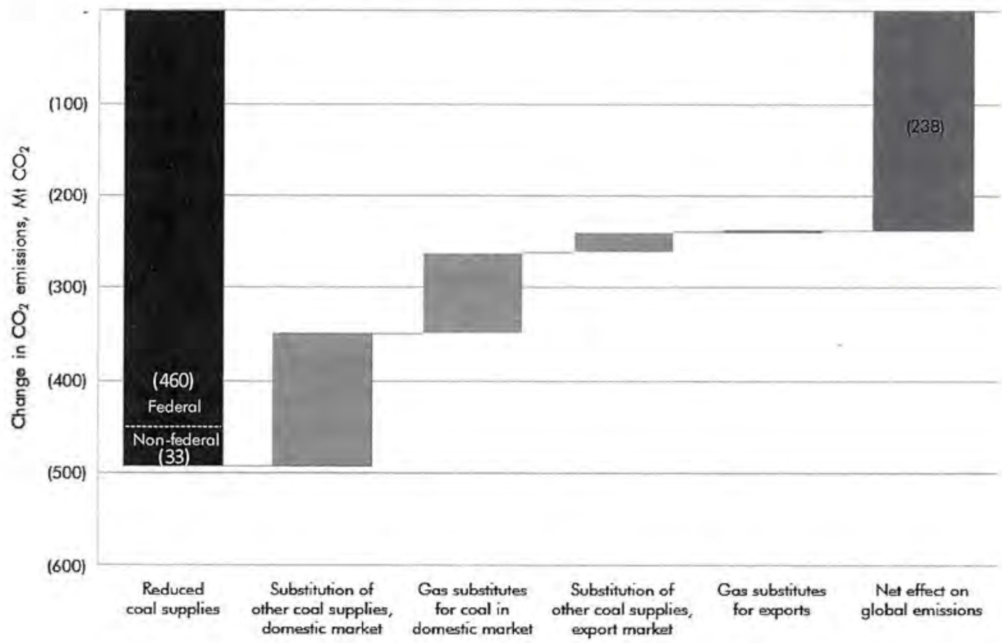


Table A-1: U.S. federal fossil fuel production in reference case (no Clean Power Plan case) and quantities avoided by cessation of new lease sales and non-renewals of non-producing leases, 1990–2040, in QBtu

Federal fossil fuel production	2015	2020	2025	2030	2035	2040
Coal	**7.3**	**7.9**	**8.4**	**8.3**	**8.0**	**7.9**
Avoided from non-renewals	–	–	–	–	–	–
Avoided from cessation of lease sales	–	(1.9)	(3.8)	(4.9)	(5.5)	(5.9)
Total avoided production		(1.9)	(3.8)	(4.9)	(5.5)	(5.9)
% of reference case production		(25%)	(45%)	(59%)	(69%)	(75%)
Gas	**4.6**	**5.5**	**5.8**	**6.7**	**6.7**	**7.1**
Avoided from non-renewals	–	(0.0)	(0.3)	(1.0)	(1.1)	(0.8)
Avoided from cessation of lease sales	–	(0.0)	(0.1)	(0.3)	(1.6)	(3.4)
Total avoided production		(0.0)	(0.4)	(1.3)	(2.7)	(4.1)
% of reference case production		(0%)	(6%)	(19%)	(40%)	(58%)
Oil	**4.8**	**6.1**	**5.8**	**6.3**	**6.1**	**6.6**
Avoided from non-renewals	–	(0.0)	(0.6)	(1.4)	(1.9)	(1.4)
Avoided from cessation of lease sales	–	(0.0)	(0.1)	(0.3)	(1.2)	(2.9)
Total avoided production		(0.0)	(0.7)	(1.6)	(3.1)	(4.3)
% of reference case production		(1%)	(12%)	(26%)	(51%)	(65%)
Total	**16.7**	**19.6**	**20.0**	**21.3**	**20.9**	**21.6**
Avoided from non-renewals	–	(0.0)	(0.8)	(2.4)	(3.0)	(2.2)
Avoided from cessation of lease sales	–	(2.0)	(3.9)	(5.4)	(8.3)	(12.1)
Total avoided production		(2.0)	(4.8)	(7.8)	(11.3)	(14.3)
% of reference case production		(10%)	(24%)	(37%)	(54%)	(66%)

Figure A-3: Impacts of decreased coal production on coal and gas markets under the case without the Clean Power Plan, CO_2 basis, 2030



APPENDIX B: ADDITIONAL SENSITIVITY ANALYSES

The analysis of market impacts and net CO_2 emissions impacts in Section 5 focuses on results of a central case, considered either with or without the Clean Power plan in place. That central case foresees coal and oil markets responding in ways consistent with current assessments by Rystad Energy, Wood Mackenzie, the International Energy Agency, and the U.S. Energy Information Administration. However, energy markets could also evolve in other directions, whether due to new policy developments (e.g. more or less-stringent climate policy) or other economic or technical developments (e.g. more or less-constrained fossil fuel resources.)

In this appendix, we look at how the net CO_2 impact might change were markets to evolve in different directions. We look especially at the prospective impact of U.S. federal fossil fuel leasing policy under cases where world leaders pursue either a lower-carbon or a higher-carbon world than the current pathway.

In the lower-carbon world, other countries also take similar measures to limit or otherwise move away from fossil fuel extraction, and to increase even further the availability of low-carbon power and other fossil-fuel demanding technologies. In this low-carbon world, coal and oil supply curves are steeper (lower elasticity of supplies), because fewer projects are brought online, not just in the U.S. but also in other major fossil-fuel producing countries poised for expansion (e.g. oil in Brazil, Russia, Canada, Nigeria, Norway). Demand curves are flatter (elasticities of demand are more strongly negative, and elasticities of substitution are higher) because consumers of oil, such as vehicle owners, can more readily purchase electric or other low-carbon-fueled vehicles, and power providers can more readily build and integrate renewable electricity.

By contrast, in the higher-carbon world, just the opposite conditions are present. Fossil fuel production from other U.S. and international resources can expand readily, and so the decline in federal coal (largely Powder River Basin) and federal oil could be made up by other producers with little impact on fuel prices. On the demand side, a high-carbon world would see consumers who are less sensitive to price, as higher-carbon power systems and lifestyles are "locked in", with low-carbon alternatives that are less available and more costly.

Below we explore the implications of these other energy market conditions for each of the energy markets analyzed in this report: the global oil market; the domestic coal market; and the export coal market.

Sensitivity analyses for global oil market

Table B-1, below, displays sensitivity analysis for oil markets. These cases explore variation in the elasticity of supply from 0.1 to 1 and elasticity of demand from -0.072 to -0.3, both as in a recent literature review and analysis (Bordoff and Houser 2015). The cases also explore variation in the emissions intensity of the fuels that would substitute for oil, based on a higher-carbon fuel mix that is no better than petroleum-based fuels (whether that is petroleum, first generation biofuels, or fossil-powered EVs) and a lower-carbon fuel mix as seen in the IEA's 450 scenario.[42]

[42] Specifically, we define the lower-carbon fuel mix here based on the transport fuels that substitute for oil in the IEA's 450 scenario: 60% biofuels, 30% gas, and 10% EVs. At a GHG savings of 50%, 0%, and 100%, respectively, this leads to a fuel mix that is 40% better than petroleum fuels.

Table B-1: Sensitivity in oil market analysis, 2030

			Elasticity of:		Change in net consumption of oil and substitute fuels per unit decrease in gross production of oil		Emissions intensity of substitute fuel, expresses as ratio of oil-based fuel			Net CO_2 emissions impacts		
	Drop in oil production (Qbtu)	Carbon content of crude, Mt CO2 / Qbtu	Supply (Es)	Demand (Ed)	Oil: Ed/(Ed-Es)	Substitutes: (Half of drop in oil)	**Higher-carbon:** First gen biofuels, fossil-powered Evs	**Base case:** 30% second-gen biofuels, two-thirds gas and EVs	**Lower carbon:** 60% second-gen biofuels, 30% gas, 10% renewable-powered Evs	Higher-carbon fuel mix	Base case fuel mix	Lower-carbon fuel mix
	(a)	(b)			(c)	(d)	(e)	(f)	(g)	a*b*(c+d*e)	a*b*(c+d*f)	a*b*(c+d*g)
Lower-carbon world	1.6	74.5	0.1	(0.3)	(0.75)	0.38	1.00	0.85	0.60	(46)	(52)	(64)
	1.6	74.5	0.1	(0.2)	(0.67)	0.33	1.00	0.85	0.60	(41)	(47)	(57)
	1.6	74.5	0.1	(0.072)	(0.42)	0.21	1.00	0.85	0.60	(25)	(29)	(36)
	1.6	74.5	0.25	(0.3)	(0.55)	0.27	1.00	0.85	0.60	(33)	(38)	(46)
Base case	1.6	74.5	0.25	(0.2)	(0.44)	0.22	1.00	0.85	0.60	(27)	(31)	(38)
	1.6	74.5	0.25	(0.072)	(0.22)	0.11	1.00	0.85	0.60	(14)	(16)	(19)
	1.6	74.5	1	(0.3)	(0.23)	0.12	1.00	0.85	0.60	(14)	(16)	(20)
	1.6	74.5	1	(0.2)	(0.17)	0.08	1.00	0.85	0.60	(10)	(12)	(14)
Higher-carbon world	1.6	74.5	1	(0.072)	(0.07)	0.03	1.00	0.85	0.60	(4)	(5)	(6)

Our base-case estimate of the global emissions impact of restricted federal leasing for oil is 31 Mt CO_2, as described in the main text and shown in Table B-1. The sensitivity analysis indicates that, in a higher-carbon world with relatively unconstrained oil supplies and little demand response, the impact could be as little as 4 Mt CO_2. By contrast, in a low-carbon world where other countries take similar steps to limit oil supply and consumers are more price-sensitive with regard to fuel price, the emissions impact could be twice as high, 64 Mt CO_2.

Sensitivity analyses for the domestic coal market

Table B-2 displays sensitivity analysis for domestic coal markets under the case of the Clean Power Plan. For transparency and to better enable comparison to other studies, we conduct our sensitivity analysis here using a simple, elasticity-based approach, using the same equation (equation 1) used for the global oil market and the coal export market. (By contrast, our base case results for the domestic coal market were derived from a run of the IPM model of the U.S. power market.)

To first demonstrate the application of the elasticity-based model to the domestic coal market, we construct a "parameterized base case", using only elasticities, that mimics the results derived from the IPM model. For this case, we use the mid-range long-term elasticity of demand from a recent analysis of long-term markets for PRB coal (Fulton et al. 2015) of -1.5. We derive an elasticity of supply from the same coal supply curve, itself constructed by Wood Mackenzie, that the EPA uses in its version of the IPM model (U.S. EPA 2013), and assuming reference levels of domestic coal consumption. This value is 2.5. Lastly, we assume that gas substitutes fully for any lost coal-based electricity, as Vulcan's IPM-based study (Vulcan/ICF 2016), and that gas power plants operate at an efficiency 1.5 times that of coal-based power (IEA 2014). Using this parameterized model, we calculate net CO_2 impact of 65 Mt CO_2, essentially equal to the full model results (64 Mt CO_2) presented in Section 5 of the main report and repeated in Table B-2.

With this parameterized model faithfully matching the base case, we use it to examine a sensitivity case for a lower-carbon world. We characterize coal demand in a lower-carbon world based on the higher end of the demand-response, elasticity -2, estimated by the same recent analysis of long-term markets for PRB coal used for the parameterized base case (Fulton et al. 2015), and where lower-carbon fuels are much more available and where coal supply is more constrained. Further, in a lower carbon world, the substitute fuels would be low-carbon renewables, not gas, and so we assume that no gas substitutes.[43] In the lower-carbon world, coal supplies would be even more constrained than under the Clean Power Plan (and not just from federal sources), and so we use a lower elasticity of supply of 2.

For the higher-carbon world, we take two approaches. One, as above, is to use an elasticity-based approach. Here, we use a much lower elasticity of demand, -0.13, derived from EIA's own assessment (U.S. EIA 2012). This value reflects the dynamics of the domestic power market in the previous decade (2005–2010), prior to the growth in domestic low-cost natural gas.[44] We use an elasticity of supply of 5 to reflect a more abundant domestic coal market characterized by a flatter supply curve.

The other approach assumes that the Clean Power Plan is fully "binding", meaning that it is the rule's state-specific targets (and corresponding compliance pathways established by the states) that reduce power-sector CO_2 emissions in each trading region to levels below what they would be in the absence of the rule. In such a case, any increase in coal prices resulting from leasing restrictions would have no effect on CO_2 emissions, since any further decreases in coal consumption would be met by equal (in CO_2 terms) increases in gas consumption, as spurred by increases in allowance prices (under mass-based trading) or credit prices (under rate-based trading), and which would also partially displace renewables.

The Clean Power Plan may be most likely to be fully binding if states adopt a national, rather than regional, trading system, since a national system would equalize the costs of compliance and eliminate the possibility that any one state or trading region exceeded its target. The national system would also need not to exceed the targets. The likelihood of this outcome could increase were renewables costs to be higher than currently expected (or gas costs lower). Were renewables costs to be lower, including due to extension of the federal renewable tax credits, this outcome could be less likely.

Table B-2: Sensitivity in coal market analysis, Clean Power Plan case, 2030

		Carbon contents, Mt CO_2/Qbtu		Elasticity of:			Relative market shares	Change in net consumption of coal and gas per unit decrease in gross production of coal		Net CO_2 emissions impacts
	Drop in coal production (Qbtu)	Coal	Gas	Supply (Es)	Demand (Ed)	Substi-tution	Starting ratio of gas to coal	Coal	Gas	
	(a)	(b)	(c)					(d)	(e)	a*(b*d+c*e)
Lower-carbon world	2.87	95.5	53.0	2.0	(2.0)	--	--	(0.50)	-	(140)
Base case	2.87	95.5	53.0	--	--	--	--	(0.36)	0.23	(64)
Parameterized "base case"	2.87	95.5	53.0	2.50	(1.5)			(0.38)	0.25	(65)
Higher-carbon world	2.87	95.5	53.0	5	(0.13)	0.20	1.5	(0.03)	0.02	(4)
Higher-carbon world (w/ CPP binding)	2.87	95.5	53.0	--	--	--	--	0	0	0

[43] This is equivalent to assuming an elasticity of substitution equivalent to the opposite of the elasticity of demand, or 2, which is, like the elasticity of demand, at the upper end of that found by empirical studies (Stern 2012).

[44] EIA reports an average U.S.-wide elasticity of demand for coal of -0.11. Further, they report an average elasticity of substitution between gas and coal of 0.17. They report an "adjustment parameter" of 0.82 that they state can be used to construct long-term elasticities. We therefore use an adjusted elasticity of demand of -0.11/0.82= -0.13 and an adjusted elasticity of substitution of 0.20. We use the elasticity of substitution to estimate the response of

Together, these sensitivity cases display how the impact of restricting federal coal leasing could have much greater or much less impact than we estimate. For example, in a lower-carbon world where coal supply is more constrained and power systems are more sensitive to changes in coal prices (in part because renewable power is more readily available), the impact of restricting leasing could be more than twice as great: an estimated 140 Mt CO_2. By contrast, were other supplies of coal to be much less constrained, such as if non-federal coal in the Montana portion of the Powder River Basin (or Illinois Basin or Appalachian coal) were able to readily substitute for the lost federal coal, and if power systems are not very sensitive to coal price (as in the past decade), than the impact of restricted leasing could be very little – only 4 Mt CO_2. The impact could even be zero, were the Clean Power Plan to be fully binding.

Sensitivity analyses for export coal market

We estimate the emissions impact of restricting federal coal leasing on coal export markets is less, approximately 7 Mt CO_2, at least given export quantities as foreseen by EIA. As a result, we do not conduct a detailed quantitative sensitivity analysis here. Instead, we observe simply that in a high-carbon world, plentiful alternative coal supplies from either non-federal suppliers in the Powder River Basin (as above) or other coal exporters or own-markets (e.g. Australia, Indonesia, and China) would be available, and could relatively easily substitute for the lost federal PRB coal. Furthermore, with the constrained gas markets in rapidly expanding power markets in Southeast Asia, switching to alternate fuels may also be constrained, such that the impact of declining exports of federal coal could be less. By contrast, in a low-carbon world, other supplies would be constrained, and renewables more available, and the impact could be greater than 7 Mt CO_2.

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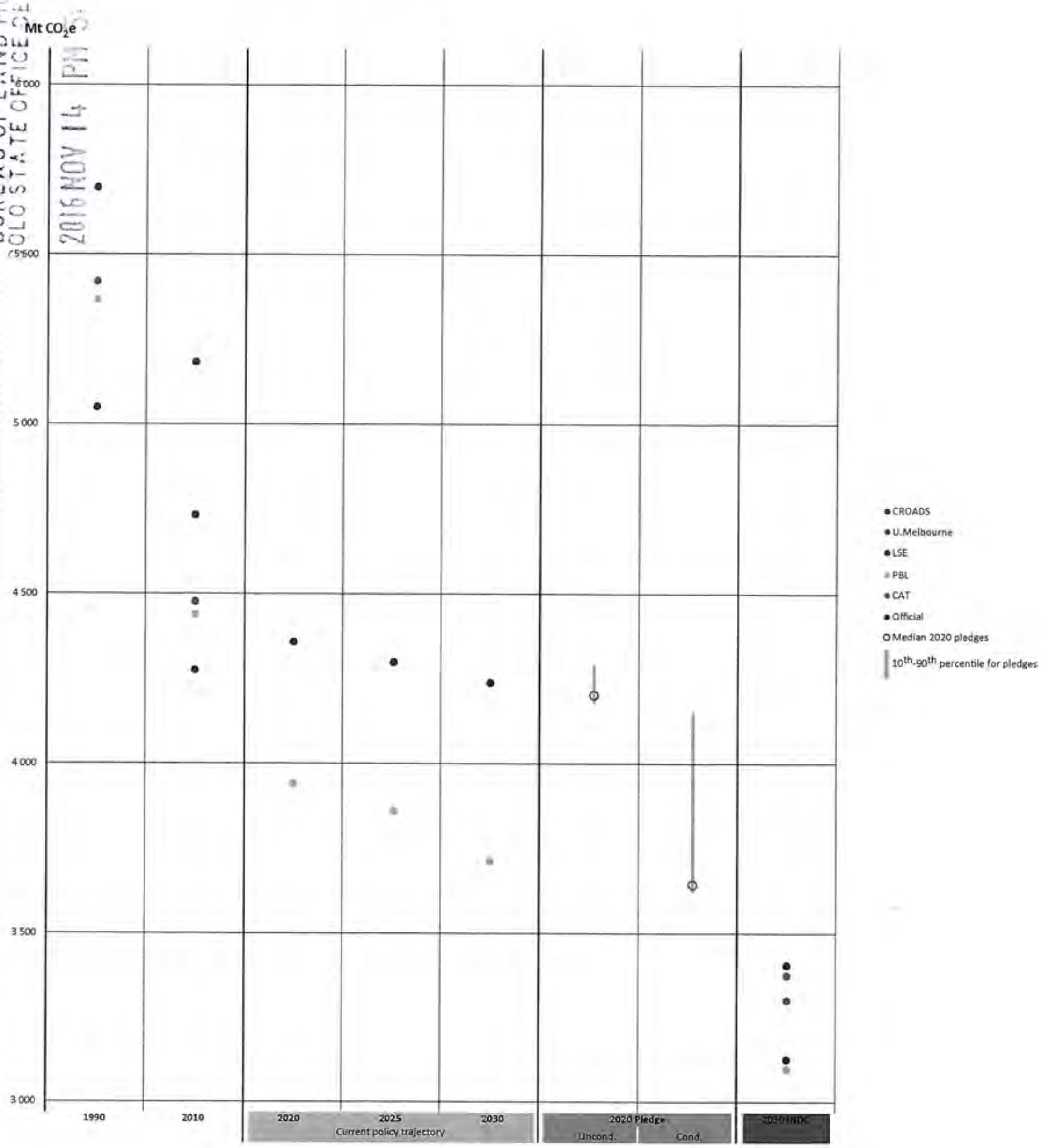
European Union

The EU proposes a binding target of at least 40 per cent domestic reduction in GHG emissions by 2030 compared to 1990. It includes all sectors and gases. The INDC also states a policy on including LULUCF in the 2030 GHG mitigation framework – to be established as soon as technical conditions allow and in any case before 2020.

While the modelling groups largely agree on the impact of the EU's INDC on its emissions, the Climate Action Tracker estimates a higher level of emissions in 2030 due to its accounting assumptions regarding LULUCF. CAT (2015) assumes that LULUCF accounting rules may lead to credits for 2030 of the order of 1-4 per cent of 1990 emissions. All other studies assume a net-net approach.

Figure A1.5: GHG emissions of the European Union under the 2020 pledge, INDC and current policy trajectory case

The official and national studies are: UNFCCC inventories for historic data/6th National Communication for projections (UNFCCC National Reports, 2015) and EEA (2015)



China

China's INDC includes an intention to peak CO_2 emissions around 2030, making best efforts to peak earlier, to reduce the carbon intensity of GDP by 60-65 per cent from 2005 levels by 2030, to increase the share of non-fossil fuels in primary energy consumption to around 20 per cent by 2030, and to increase the forest stock volume by around 4.5 billion cubic metres from 2005 levels by 2030. Although China's INDC is framed in terms of CO_2, the discussion text also implies action on other gases. China's INDC also includes a comprehensive list of actions. The GHG targets cover CO_2, but the sectors to which the targets apply are not specified.

The studies assessed show a wide range of potential impacts of China's INDC on national emissions (varying from 12.8-14 $GtCO_2e$ by 2030), with higher estimates (LSE, CROADS, Climate Advisers), arising, inter alia, from different assumptions on GDP growth rate, different base year data (varying from 9.1-11.3 $GtCO_2e$) and different estimates on emissions other than CO_2 emissions from the energy sector (and cement), etc. The higher estimates of LSE, CROADS and Climate Advisers are confined to the INDC intensity target calculations only.

An official estimate is not available, but two national estimates for CO_2 emissions from the energy sector (and cement) are available from NCSC (Sha *et al.,* 2015) and updated calculations from Energy Reserarch Institute (ERI) (Jiang *et al.,* 2013). Three studies (CAT, 2015; IEA, 2014, 2015; PBL, 2015) that estimated both China's current policy trajectory and the INDC scenario, demonstrate a further reduction from current policy trajectories to the INDC in 2030.

Only NCSC's estimate adjusts for the possible effect of including energy statistics from the 2014 economic census, which leads to a much higher estimate for China's CO_2 emission in 2030 (around 1 $GtCO_2e$ higher than the pre-adju ment estimate) (Sha *et al.,* 2015).

Figure A1.4: GHG emissions of China under the 2020 pledge, INDC and current policy trajectory case

The national studies are: NCSC (Sha, et al., 2015) and ERI (updated calculations based on Jiang et al. (2013)). Noted that the higher estimates of LSE, CROADS and Climate Advisers for China on INDC 2030 did not provide current policy trajectory estimates. Three studies (CAT, 2015; IEA, 2014, 2015; PBL, 2015) that estimated both China's current policy trajectory and the INDC scenario, demonstrate a further reduction from current policy trajectories to the INDC in 2030.