The INDC counter, aggregation of national contributrions and 2°C trajectories

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We publish here as an ICMC Scientific note a Working paper consisting of a series of analyses and briefing notes related to the Intended Nationally-Determined Contributions (INDC) and the 21st Conference of Parties (COP21). This Working paper is signed by a group of experts that was formed to analyze the scientific issues raised by the INDCs. It is referred to as the Groupe Interdisciplinaire sur les Contributions Nationales (GICN) or Interdisciplinary Group on National Contributions and consists of the following scientists:

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Summary

Groupe Interdisciplinaire sur les Contributions Nationales

The INDC counter, aggregation of national contributions and 2°C trajectories

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The INDC counter, aggregation of national contributions and 2°C trajectories

Summary

- **Considering that limiting global warming to below 2°C implies a CO_2 budget not to be exceeded and near-zero emissions by 2100 (IPCC), we can assess global 2030 greenhouse gas emissions implied by INDCs in comparison to long-term trajectories.**
- **Ahead of the COP21, we estimate that submitted INDCs would bring global greenhouse gas emissions in the range of 55 to 64 $GtCO_2eq$ in 2030.**
- **Under this assumption, global emissions in 2030 are thus higher than the level of 51 $GtCO_2eq$ for the year 2012. However, this is not in contradiction with a peaking of global emissions that can only be expected after 2020, given in particular the projected dynamics of emissions in China and other developing countries.**
- **The published INDCs represent a significant step towards trajectories compatible with the 2°C goal, but remain insufficient to join trajectories presenting a reasonable probability of success.**
- **In order to increase the chance of meeting the 2°C objective, the ambition of the short-term contributions needs to be strengthened in future negotiations.**
- **In order to sustain a high pace in emissions reductions after 2030, structural measures are also needed, which, in order to have a rapid impact, should be prepared as early as possible. Continued efforts are needed to accelerate the development of low carbon solutions on the one hand, and demonstrate the feasibility of negative emissions on the other hand.**

Context

The publication of INDCs since March 2015 has gradually revealed the intentions of the different countries on their emissions reductions ahead of the COP21, and consequently the resulting global emission profile. However, published INDCs only give a partial view of the situation; moreover, they often differ in terms of the identified year for the contribution (typically 2030 but sometimes 2025), covered perimeter (CO_2, all GHG, with or without LULUCF) and formulation (reduction compared to a base year, a baseline scenario or in terms of carbon intensity of GDP). This makes it difficult to build a coherent picture and especially to assess the compatibility of INDCs with the 2°C long-term target.

However, it is possible to develop a rigorous and consistent accounting method to translate the INDCs into comparable emission levels, aggregate these into a global emission level and compare it against trajectories of global emissions that are consistent with the 2°C objective.

In order to ensure consistency among published INDCs, our approach is based on EDGAR and FAO datasets for past greenhouse gas emissions (see Methods), and we compute future emission levels according to the information provided in the individual INDC in terms of emissions reductions and base year.

Countries typology

Countries that are treated individually belong to three categories: the Triad – consisting of the USA, China and the European Union, the ten countries, beyond those of the Triad, that are represented in the Deep Decarbonization Pathways Project (DDPP)[1] and finally ten other large emitters[2]. This accounting is complemented by international aviation and maritime transportation, traditionally not assigned to any country. The rest of the world (RoW) is itself separated into four categories according to groups with varying development levels as considered in the US Department of Agriculture's GDP projections: other Annex I UNFCCC countries[3], other emerging countries[4], other high income oil exporters[5] and the remaining countries. In 2012 the Triad represented 44% of global emissions, the 10 DDPP countries 27%, the 10 other important countries and international transport 10%. Thus, 23 Parties (including the EU and international transport) cover over 80% of the global greenhouse gas emissions, with the rest of the world only generating 19% of current emissions. This approach mostly helps to focus on a limited number of large emitters. The distribution of global emissions between these categories is displayed in Table 1.

[1] These are the following countries: Canada, Mexico, Brazil, South Africa, Russia, Japan, South Korea, Australia, India, and Indonesia.
[2] United Arab Emirates, Egypt, Iran, Saudi Arabia, Kazakhstan, Malaysia, Taiwan, Turkey, Thailand, Ukraine.
[3] Belarus, Iceland, New Zealand, Norway, Switzerland.
[4] Chile, Philippines, Vietnam, Singapore.
[5] Bahreïn, Brunei Darussalam, Kuwait, Oman.

INDCs MtCO2e GHG		1990	1995	2000	2005	2010	2012
		6 051	6 325	6 937	7 048	6 604	5 963
		-200	-298	-308	-370	-415	-420
	USA	5 539	5 778	6 451	6 352	5 917	5 268
		5 567	5 203	5 116	5 227	4 873	4 619
		-101	-269	-273	-327	-278	-277
	EU	5 466	4 934	4 842	4 900	4 595	4 342
		2 412	3 305	3 415	5 462	8 128	9 178
		3 781	4 810	4 943	7 480	10 535	12 916
		-104	-319	-332	-371	-292	-292
	China	3 678	4 491	4 611	7 108	10 243	12 625
		15 399	16 338	16 995	19 755	22 012	23 499
		-404	-886	-913	-1 068	-985	-989
44%	**Triad**	14 683	15 203	15 904	18 360	20 755	22 234
		584	673	716	750	715	703
		100	24	10	253	131	126
	Canada	596	767	694	898	810	778
		457	474	530	585	628	667
		39	27	28	26	24	24
	Mexico	497	501	558	611	652	691
		703	802	862	1 106	1 113	1 211
		1 028	1 031	1 043	1 196	789	792
	Brazil	1 732	1 833	1 905	2 301	1 902	2 003
		347	369	393	452	420	417
		4	0	1	1	0	0
	South Africa	350	370	394	453	421	418
		3 251	2 369	2 282	2 364	2 378	2 600
		0	194	186	11	-158	-123
	Russia	3 315	2 383	2 154	2 097	1 996	2 249
		1 295	1 411	1 407	1 440	1 366	1 643
		-74	-74	-74	-99	-137	-137
	Japan	1 221	1 336	1 333	1 341	1 229	1 506
		300	453	512	562	652	708
		-27	-26	-26	-31	-32	-32
	South Korea	274	427	486	531	620	676
		457	468	565	606	615	562
		18	12	11	48	32	35
	Australia	475	480	576	654	647	597
		1 352	1 616	1 850	2 113	2 646	3 084
		-29	-48	-49	-168	-128	-129
	India	1 323	1 568	1 801	1 945	2 518	2 955
		472	516	560	835	762	813
		620	725	814	950	1 218	1 213
	Indonesia	1 092	1 240	1 375	1 785	1 980	2 026
		9 219	9 152	9 678	10 814	11 294	12 408
		1 680	1 865	1 944	2 185	1 740	1 769
27%	**DDPP-10**	10 875	10 907	11 276	12 616	12 774	13 898
		72	94	115	144	206	240
		0	-1	-1	0	0	0
	United Arab Emirates	72	93	114	144	205	240
		139	155	187	246	275	320
		0	-1	-1	-1	0	0
	Egypt	139	155	186	246	274	319
		283	370	449	577	526	555
		0	0	0	-3	-3	-3
	Iran	283	370	449	574	523	552
		205	262	312	388	493	601
		0	0	0	0	0	0
	Saudi Arabia	205	262	312	388	493	601
		357	243	193	263	317	349
		0	0	0	0	0	0
	Kazakhstan	357	244	194	263	317	349
		93	131	167	226	252	293
		-244	-233	-222	181	146	145
	Malaysia	-151	-102	-55	407	398	438
		137	185	249	290	296	283
		0	0	0	0	0	0
	Taiwan	137	185	249	290	296	283
		224	261	318	350	420	491
		-6	-21	-21	-29	-29	-29
	Turkey	218	240	297	321	391	462
		196	268	276	337	376	427
		18	11	11	5	-2	-2
	Thailand	214	279	286	342	374	425
		945	591	475	445	392	411
		0	-46	-48	-24	-24	-24
	Ukraine	945	545	427	421	368	387
	International Aviation	299	314	361	429	491	524
	International Shipping	378	428	477	533	626	669
		2652	2561	2741	3265	3553	3970
		-232	-291	-282	129	88	87
10%	**Sup400-2012**	3 098	3 012	3 297	4 356	4 758	5 249

		330	280	287	307	354	350
		0	-45	-46	-65	-72	-73
	Other Annex 1 countries	329	235	241	242	283	277
		271	346	424	509	617	680
		41	-65	-60	-22	-23	-22
	Other emerging countries	312	281	364	486	594	658
		81	108	129	174	206	242
		2	2	2	2	2	2
	Other high income oil exporters	83	110	131	176	208	244
		4 575	4 558	4 908	5 440	6 253	6 480
		2 226	1 970	1 979	1 873	1 811	1 885
19%	Rest of World	6 802	6 529	6 887	7 314	8 064	8 365
		32 528	33 342	35 162	40 264	44 290	47 629
		3 313	2 551	2 623	3 034	2 562	2 659
	Total (bottom-up)	**36 182**	**36 277**	**38 100**	**43 551**	**47 436**	**50 926**

Table 1- Repartition of historical GHG emissions between the different categories of countries, expressed in $MtCO_{2eq}$ per year, and based on EDGAR and FAO datasets. Note that in this table, emissions are separated into all greenhouse gas emissions except CO_2 emissions for land use (orange), CO_2 emissions or storage from land use (green) and total emissions (blue).

Calculating 2030 emissions derived from INDCs

As already noted above, available INDCs differ significantly in terms of target year (2025 or 2030), base year (1990, 2005, 2010 ...), perimeter (CO_2 or other gases, accounting of land use changes or not...). Therefore they must be converted into a single quantity; after considering several options, we opted for the GHG emissions level (in CO_2eq) in 2030, including emissions from land use changes but excluding carbon sinks from existing ecosystems which are included in the result presented by the UNFCCC secretariat and UNEP, among others.

- For most of the identified countries, the amount of emissions can be directly calculated from a percentage reduction in 2030, applied to a specific base year (in black in Table 2).
- Since many countries indicate two objectives, one unconditional and the other conditional on international financing, or a range, it became necessary to provide two values for those countries in 2030, delimiting the range of possible values.
- Among the countries whose INDC was published, we had to make further assumptions for the USA, China and India (in blue):
  - the USA INDC indicates a reduction in emissions of 26-28% by 2025 compared to 2005; we extrapolate this into a reduction of 30% to 32% in 2030;
  - Some targets are expressed in terms of **carbon intensity of GDP** ($MtCO_2$/GDP unit for China, $MtCO_2$eq/GDP unit for India). The following assumptions are made on future economic growth:
    - China: economic growth from current base level of 7%/year decreasing linearly to 5%/year, or alternatively to 4%/year between 2015 and 2030,
    - India: economic growth from current base level of 6.5%/year decreasing linearly to 5%/year, or alternatively to 4%/year between 2015 and 2030.

  The low growth assumption results in the peaking of Chinese emissions between 2026 (intensity target of -65%) and 2029 (intensity target of -60%), as the yearly decrease rate in carbon intensity (corresponding to an overall 60-65% carbon intensity reduction over the period considered) becomes larger than the economic growth rate before 2030. This is not the case for India, due to a less pronounced reduction in carbon intensity (33-35% over the same period). For China who expressed their target in CO_2, we convert emissions in CO_2eq using a ratio CO_2eq/CO_2 ratio that is fitted on past data, resulting in a 1.2 conversion factor for 2030.

- For countries identified in the INDC counter for which there is no published INDC or for which targets are not expressed in terms of emissions (e.g., renewables share in the electricity mix), we make assumptions that illustrate a cautious best guess, which may be modified at a later stage (in brown in Table 2). This leads to variation in 2030 compared to 2012 of +15% for Malaysia and Taiwan and +30% for Middle-East countries.
- For **international aviation,** we consider a projection showing an increase from 700 $MtCO_2eq$ in 2010 to a range of 900 (ACARE projection) to 1550 $MtCO_2eq$ (BAU) in 2030. For **international shipping**, we considered a Business As Usual trajectory (with a linear extrapolation of the 1990-2012 trend to 2030) for the higher value, and a lower value of -15% compared to this BAU.
- Regarding the **rest of the world**, we considered published INDCs for Annex I countries. For the three other groups, we made assumptions on their GDP carbon intensity, and used the US Department of Agriculture's GDP projections: intensity reduced by 30 to 45% compared to 2005 for emerging countries (corresponding to the Chilean INDC), by 30 to 40% for high-income oil exporters (corresponding to an emissions rise of 20 to 40% compared to 2012, in line with the assumption made for Saudi Arabia and the United Arab Emirates), and by 30 to 40% for the remaining countries.
- **Emissions from land use**: when not otherwise mentioned, mitigation targets are always applied to total emissions (i.e. the sum of EDGAR greenhouse gas emissions and FAO land use CO_2 emissions). However, some countries give an emission target based on a net-net approach. We apply a correction for those countries when carbon sinks from existing ecosystems are significant and may introduce a bias in comparison to emission inventories generally used in climate models. The FAO database, as well as the Integrated Assessment Models used for IPCC reports, do not indeed consider carbon sinks as part of national emissions, but as part of the natural carbon cycle. Therefore, in order to avoid double counting of carbon sinks, we applied for specific countries (USA, Canada, Russia) the emission reduction target to EDGAR emissions plus UNFCCC land use emissions, but then subtracted from the result the carbon sink (difference between UNFCCC and FAO land use emissions) that is assumed constant between now and 2030.

These reasoned assumptions lead to a **2030 emissions level between 55.0 and 63.7 $GtCO_2eq$**, 84% of which corresponding to the published INDCs and the rest from assumptions made on remaining countries.

INDCs		***2030***		***2030/référence***				***2030/2012***	
MtCO2e GHG		***inconditionnel/ min***	***conditionnel/ max***	***inconditionnel /min***	***conditionnel /max***	***référence***	***economic growth (%/yr, 2012-2030)***	***incondition nel/min***	***conditionnel /max***
		5 477	*4 656*	*-22%*	*-34%*			*-8%*	*-22%*
		-300	*-1000*						
	USA	*4 477*	*4 356*	*-30%*	*-32%*	*/2005*		*-15%*	*-17%*
	EU	*3 280*	*3 170*	*-40%*	*-42%*	*/1990*		*-24%*	*-27%*
		12 900	*10 461*	*-60%*	*-65%*	*carbon*	*7 to 5 or 7*		
		15 357	*12 912*				*to 4*		
		-139	*-139*				*between*		
	China	*15 219*	*12 774*				*2015 and*	*21%*	*1%*
							2030		
44%	**Triad**	*22 975*	*20 301*					*3%*	*-9%*

	Canada	626	626	-30%	-30%	/2005		-20%	-20%
	Mexico	759	623	-22,0%	-36%	/BAU		10%	-10%
	Brazil	1312	1 312	-43%	-43%	/2005		-35%	-35%
	South Africa	614	398	PPD	PPD	/PPD		47%	-5%
	Russia	2 806	2 638	-25%	-30%	/1990		25%	17%
		-37	-37						
	Japan	1 006	1 000	-25%	-25%	/2005		-33%	-34%
	South Korea	536	536	-37%	-37%	/BAU		-21%	-21%
	Australia	484	471	-26%	-28%	/2005		-19%	-21%
		6643	5 972	-33%	-35%	carbon	6,5 to 5 or		
							6,5 to 4		
	India	6643	5972				between	125%	102%
	Indonesia	2046	1700	-29%	-41%	/BAU		1%	-16%
		-37	-37						
27%	**DDPP-10**	16 831	15 275					21%	10%
	United Arab Emirates	312	312	30%	30%	/2012		30%	30%
	Egypt	415	415	30%	30%	/2012		30%	30%
	Iran	717	717	30%	30%	/2012		30%	30%
	Saudi Arabia	781	781	30%	30%	/2012		30%	30%
	Kazakhstan	303	267	-15%	-25%	/1990		-13%	-23%
	Malaysia	503	503	15%	15%	/2012		15%	15%
	Taiwan	283	266	-50%	15%	/BAU		0%	-6%
	Turkey	928	928	-21%	-21%	/BAU		101%	101%
	Thailand	444	416	-20%	-25%	/BAU		4%	-2%
	Ukraine	567	567	-40%	-40%	/1990		46%	46%
	International Aviation	1200	906			/BAU		129%	73%
	International Shipping	866	736	0%	-15%	/BAU		30%	10%
10%	**Sup400-2012**	7 320	6 816					39%	30%
		230	230						
	Other Annex 1 countries	230	230					-17%	-17%
		1 378	1 083	-30%	-45%	carbon	5,27%		
	Other emerging countries	1 378	1 083					109%	65%
		338	290	-30%	-40%	carbon	3,95%		
	Other high income oil exporters	338	290					38%	20%
		12 768	10 032	-30%	-45%	carbon	4,87%		
		1 885	942	0%	-50%				
19%	Rest of World	14 653	10 974					75%	31%
	Total (bottom-up)	**63 726**	**54 969**					25%	8%

Table 2 - Estimate of GHG emissions in 2030 for various countries / groups of countries, according to the published or estimated INDCs, expressed in $MtCO_2eq$.

INDCs and emissions trajectories for a 2°C target

The level of emissions from INDCs estimated as above can then be compared to emission trajectories that are compatible with the 2°C objective. We adopt two methodologies to characterize such trajectories: emissions pathways consistent with a 2°C target as developed in IPCC AR5 report, and pathways derived from a 2°C compatible carbon budget.

Emissions pathways consistent with a 2°C target as developed in IPCC AR5 report

The different scenarios considered by the IPCC are shown in Figure 1. It is noteworthy that a number of them show a peak in global GHG emissions between 2010 and 2015, and are therefore obsolete as they would imply to "reinvent the past". These scenarios have therefore not been considered further in our study. The other scenarios are considered throughout the century (available data on the AR5 database), and served as a first benchmark to compare the estimated global 2030 emission level, as shown in Figure 2. We can see that there are only a few 2°C scenarios passing through the estimated range of 2030 emissions implied by INDCs. Furthermore, these scenarios correspond to a high degree of delayed action, a sharp downturn in 2030 and negative emissions by the end of the century, illustrating the critical importance of the post-2030 dynamics for compliance with the 2°C target.

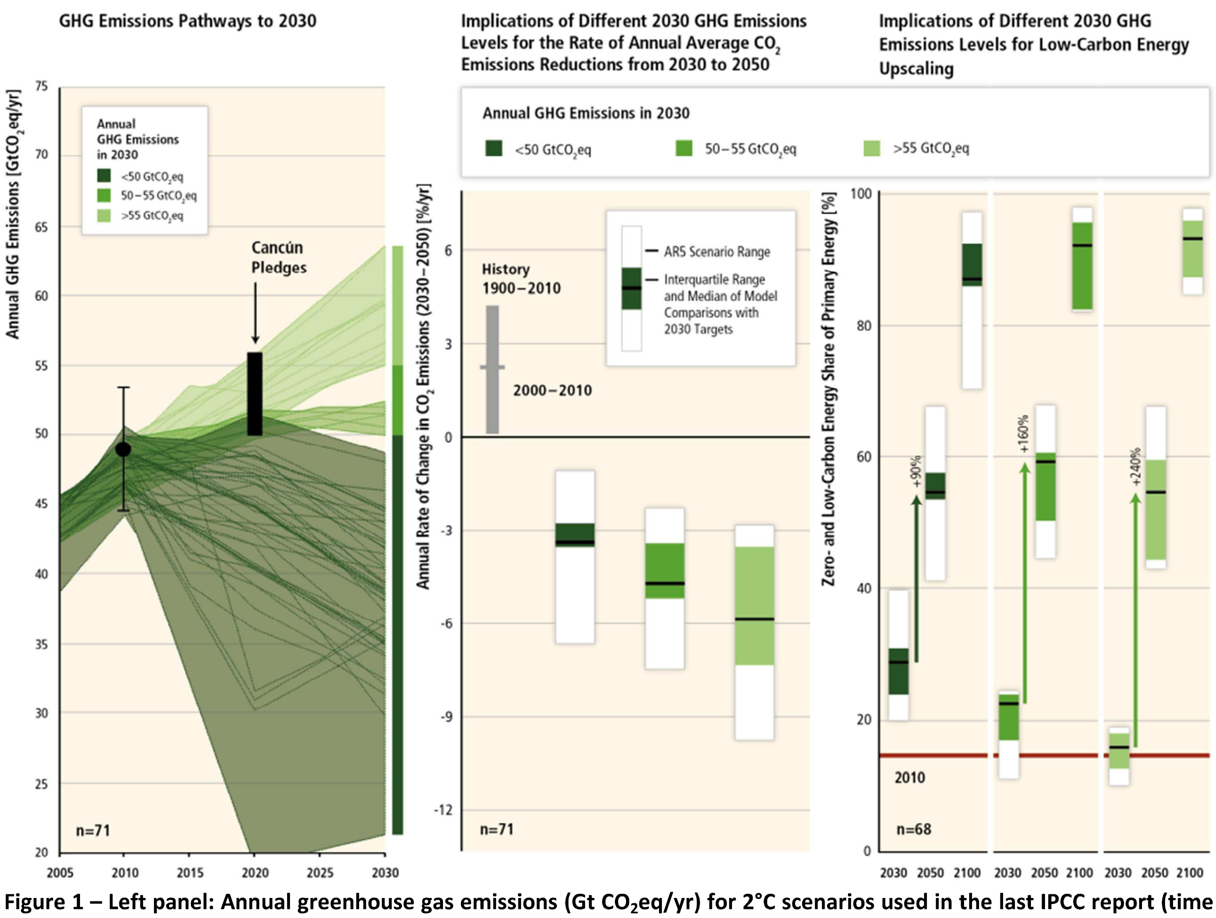


Figure 1 – Left panel: Annual greenhouse gas emissions (Gt CO_2eq/yr) for 2°C scenarios used in the last IPCC report (time period 2005-2030). Right panel: average of CO_2 emission reduction rate from 2030 to 2050. The dark green scenarios imply an average annual emissions reduction rate of 4% from 2030 to 2050, the scenarios in grass green a 5% rate and the ones in light green a 6% rate. Source: IPCC, AR5, WG3, SPM.

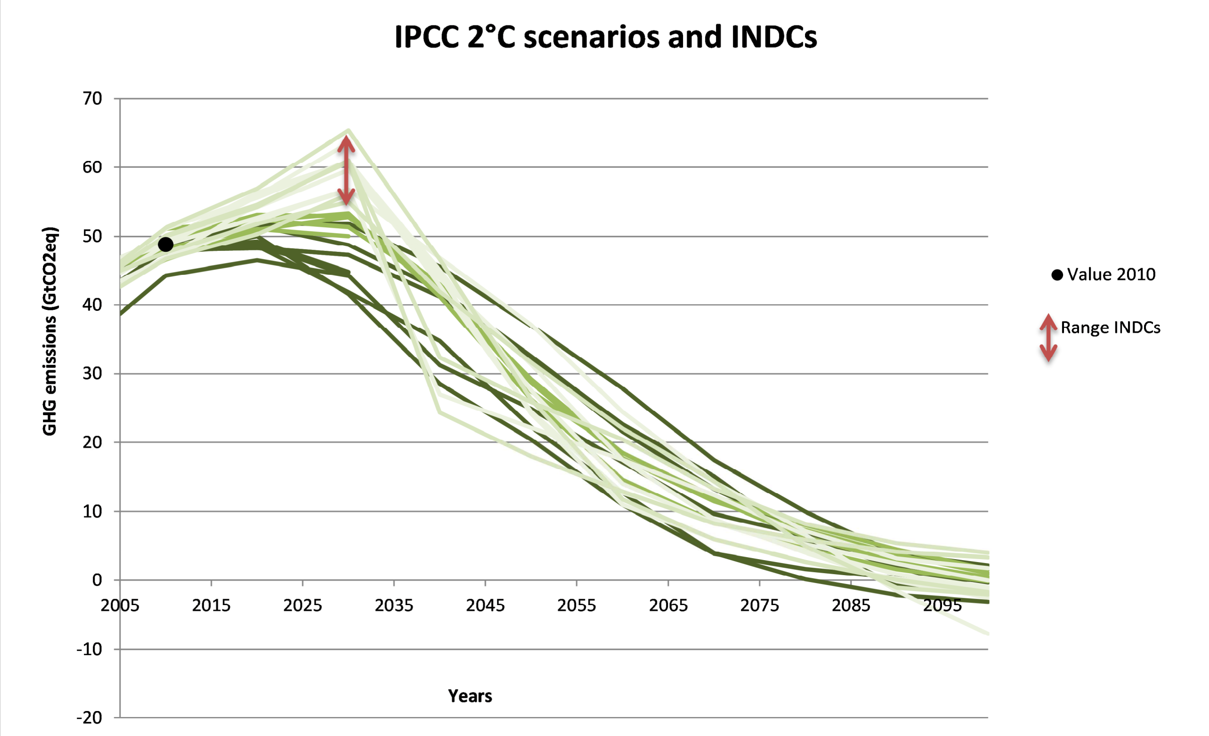


Figure 2 – Selected IPCC 2°C scenarios and aggregated INDCs. Sources: IPCC, WGIII AR5.

Emissions pathways derived from a 2°C compatible carbon budget

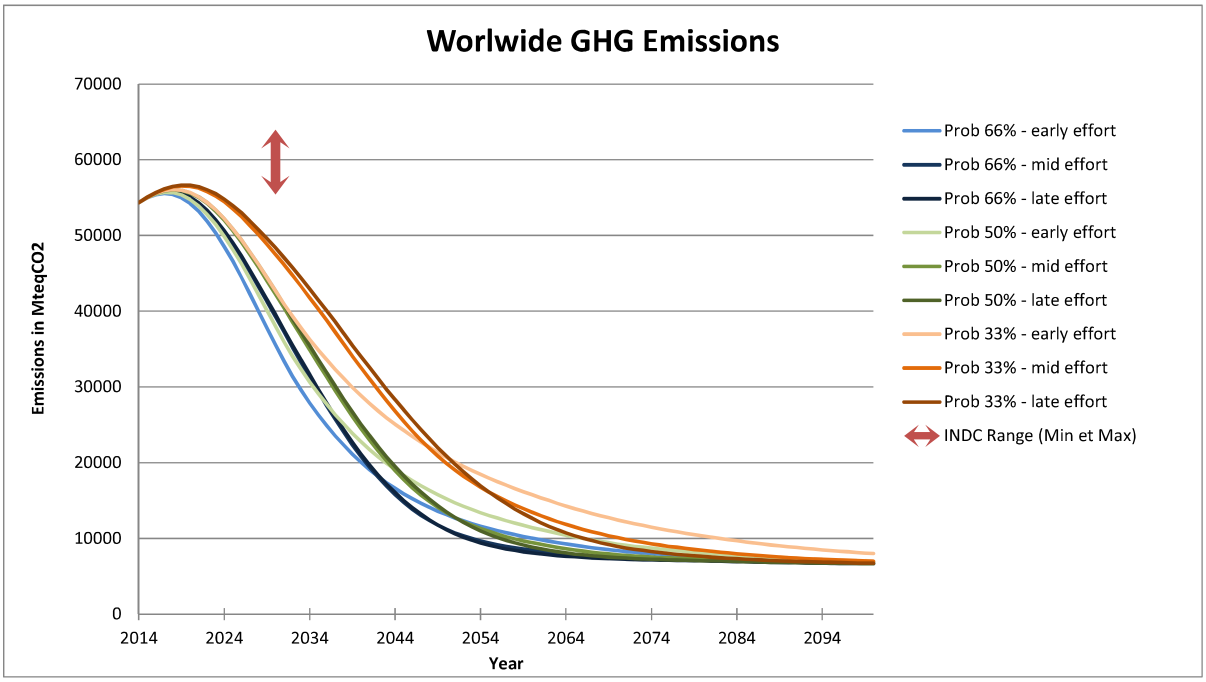
Our second approach is based on the finding that the maximum increase in global mean temperature is directly proportional to the amount of cumulative CO_2 emissions since pre-industrial times. Limiting the warming to 2°C involves considering a permissible carbon budget that should not be exceeded. We therefore took a closer look on carbon budgets associated with the 2°C objective in probabilistic terms, and distributed this budget into the 21st century to derive compatible pathways. This approach was further motivated by the fact that most published studies on the compatibility of the INDCs with the 2°C objective differ on implicit assumptions on the required global emissions to be achieved in 2030.

Pathways without negative emissions

According to IPCC AR5, carbon budgets since pre-industrial times of respectively 790, 820 and 900 GtC (2900, 3000 and 3300 $GtCO_2$) correspond to probabilities of 66%, 50% and 33 % of limiting global warming to 2°C when also accounting for non-CO_2 greenhouse gases. The main idea of our second approach consists in positioning our 2030 INDC emissions range on benchmarking emission trajectories compatible with these budgets. To generate these benchmarking emission trajectories, we use the REDEM[6] model on a worldwide scale, without any differentiation at the country level.

The trajectories performed with the REDEM model are then directly linked to different dates of “maximum effort”, that is to say the highest annual emissions reduction rates occurring after the emissions peak. For carbon budgets associated to a global warming limited to 2°C, the results from these REDEM projections are shown in Figure 3 in terms of emission pathways (all GHG) and associated efforts rates (CO_2).

[6] Developed by EDDEN (CNRS-UGA) and INRIA; E. Prados, P. Criqui, C. Ilasca. A Benchmarking Tool for the International Climate Negotiations. *AAAI-15 Special Track on Computational Sustainability*, Jan 2015, Austin, United States. 2015. <hal-01101210>



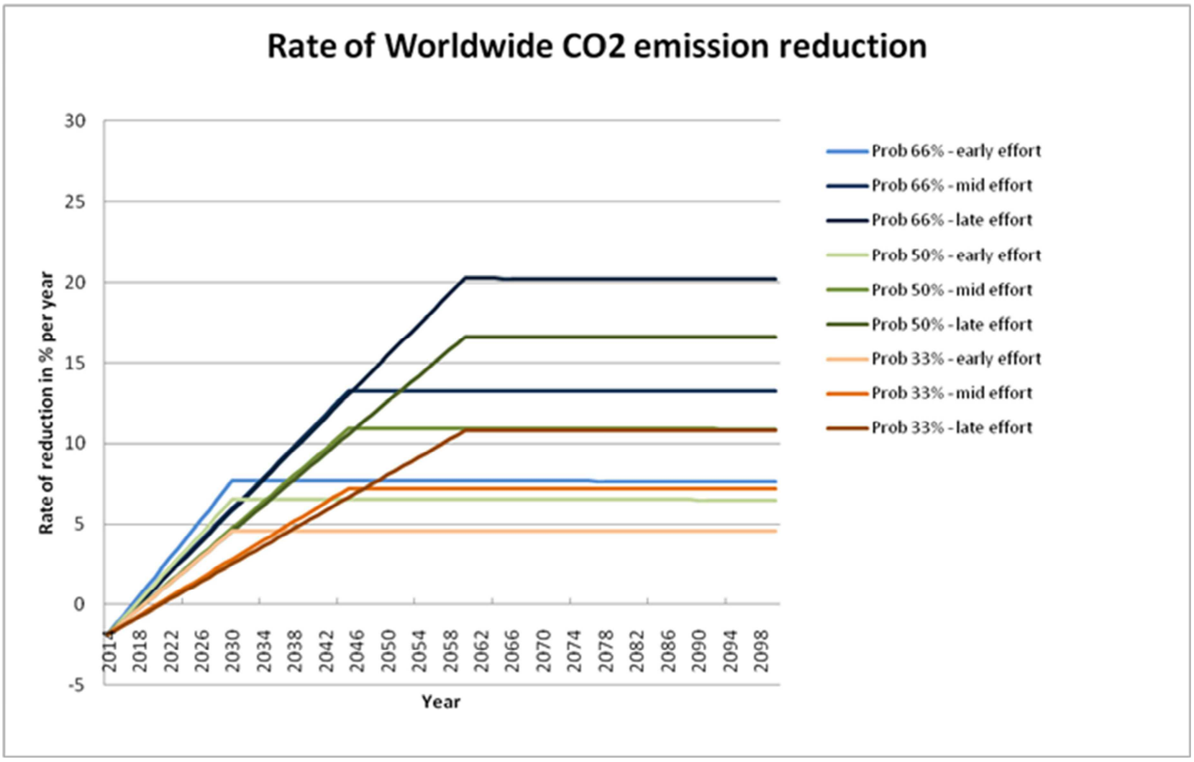
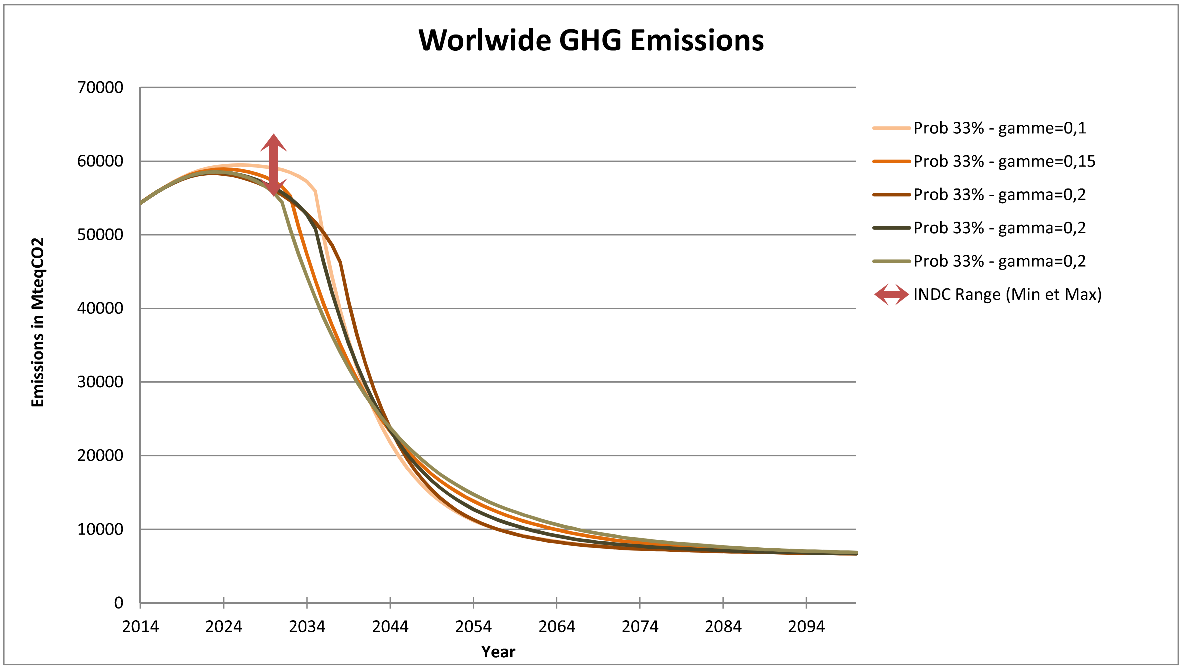


Figure 3 - GHG emission trajectories ($MtCO_2eq$) without negative emissions for different probabilities of reaching the 2°C target and different maximum effort dates; compared with global 2030 emissions from the aggregation of INDCs and "current policies" scenario (top). Associated emissions reduction rate (bottom).

One can note that the longer the mitigation effort is delayed, the larger is the necessary subsequent reduction rate. In addition, we can see that the estimated 2030 emission range implied by the INDCs is well above all considered pathways.

Here, we implicitely assume that the efforts in terms of CO_2 emissions reduction increase regularly. In other words, we assume that the reduction rate increases linearly until it reaches a maximal value. However, if we accept declivities in the reduction rate dynamics, then we can get various trajectories for which the INDC total is consistent with limiting global warming to 2°C with a 33% probability, as shown in Figure 4. Such trajectories require to be able to move from a CO_2 emissions reduction rate of 0% in 2026-2030 to a reduction rate between 8% and 15% only three years later. The feasibility of such a sudden effort remains questionable.



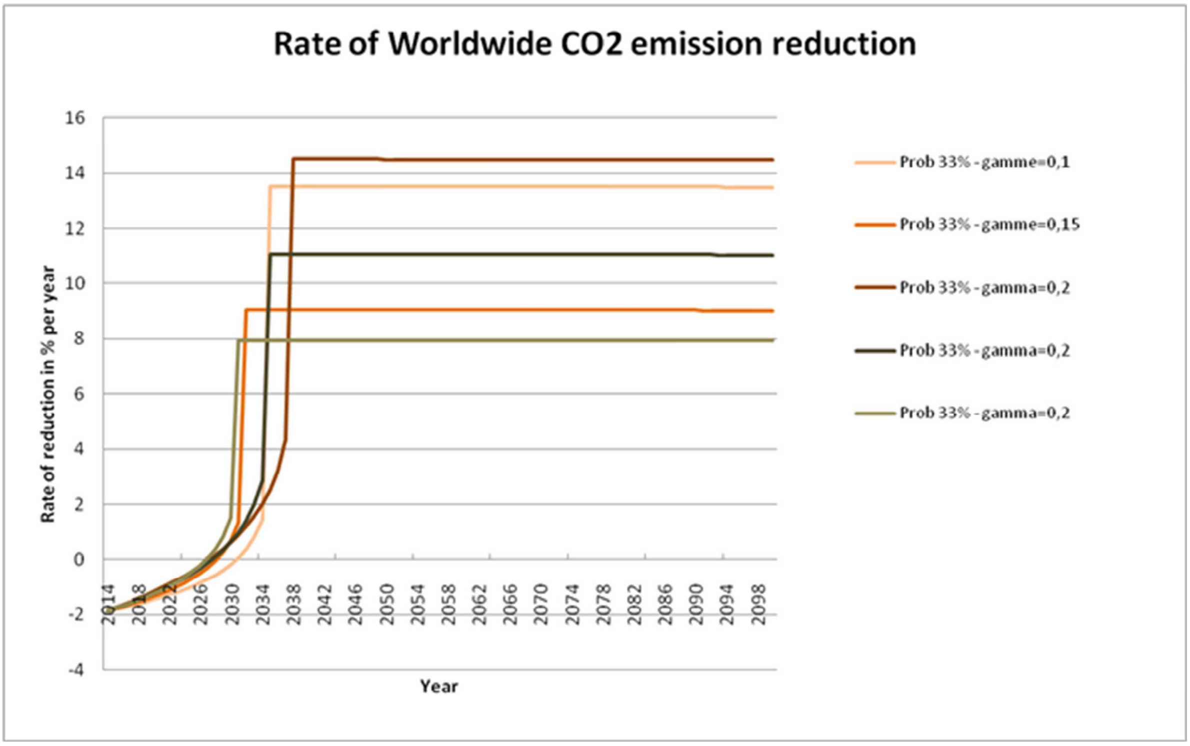


Figure 4 - GHG emission trajectories ($MtCO_2eq$) without negative emissions for a probability of 33% of reaching the 2°C target with different maximum effort dates and different values for parameter γ compared with global 2030 emissions from the aggregation of INDCs and "current policies" scenario (top). Associated CO_2 emissions reduction rate (bottom).

All the above results may seem contradictory with the ones obtained with the first approach. This is explained by the fact that unlike many IPCC scenarios, these trajectories do not consider negative emissions (see chapter on negative emissions) but also because the CO_2 budget approach constrains the peak and not just the 2100 temperature change.

Pathways with negative emissions

To include negative emissions, we first provide a cumulative budget of negative CO_2 emissions until 2100. In the following, let us denote it B_-. We propose to fix this amount to $B_- = 500$ $GtCO_2$ which correspond roughly to the maximum physical potential for afforestation-reforestation, biochar creation and storage in soils according to WGI AR5, see Table 3 (noting that amounts corresponding to various CO_2 removal methods are not necessarily additive).

Table 6.15 | Characteristics of some CDR methods from peer-reviewed literature. Note that a variety of economic, environmental, and other constraints could also limit their implementation and net potential.

Carbon Dioxide Removal Method	Means of Removing CO_2 from Atmosphere	Carbon Storage / Form	Time Scale of Carbon Storage	Physical Potential of CO_2 Removed in a Century[a]	Reference	Unintended Side Effects
Afforestation and reforestation	Biological	Land /organic	Decades to centuries	40–70 PgC	House et al. (2002) Canadell and Raupach (2008)	Alters surface energy budget, depending on location; surface warming will be locally increased or decreased; hydrological cycle will be changed
Bio-energy with carbon-capture and storage (BECCS); biomass energy with carbon capture and storage	Biological	Geological or ocean /inorganic	Effectively permanent for geologic, centuries for ocean	125 PgC	See the footnote[b]	Same as above
Biochar creation and storage in soils	Biological	Land /organic	Decades to centuries	130 PgC	Woolf et al. (2010)	Same as above
Ocean fertilisation by adding nutrients to surface waters	Biological	Ocean / inorganic	Centuries to millennia	15–60 PgC 280 PgC	Aumont and Bopp (2006), Jin and Gruber (2003) Zeebe and Archer (2005) Cao and Caldeira (2010a)	Expanded regions with low oxygen concentration; enhanced N_2O emissions; altered production of dimethyl sulphide and non-CO_2 greenhouse gases; possible disruptions to marine ecosystems and regional carbon cycles
Ocean-enhanced upwelling bringing more nutrients to surface waters	Biological	Ocean / inorganic	Centuries to millennia	90 PgC 1–2 PgC	Oschlies et al. (2010a); Lenton and Vaughan (2009), Zhou and Flynn (2005)	*Likely* to cause changes to regional ocean carbon cycle opposing CO_2 removal, e.g., compensatory downwelling in other regions
Land-based increased weathering	Geochemical	Ocean (and some soils) / inorganic	Centuries to millennia for carbonates, permanent for silicate weathering	No determined limit 100 PgC	Kelemen and Matter (2008), Schuiling and Krijgsman (2006) Köhler et al. (2010)	pH of soils and rivers will increase locally, effects on terrestrial/ freshwater ecosystems
Ocean-based increased weathering	Geochemical	Ocean / inorganic	Centuries to millennia for carbonates, permanent for silicate weathering	No determined limit	Rau (2008), Kheshgi (1995)	Increased alkalinity effects on marine ecosystems
Direct air capture	Chemical	Geological or ocean /inorganic	Effectively permanent for geologic, centuries for ocean	No determined limit	Keith et al. (2006), Shaffer (2010)	Not known

Notes:

[a] Physical potential does not account for economic or environmental constraints of CDR methods; for example, the value of the physical potential for afforestation and reforestation does not consider the conflicts with land needed for agricultural production. Potentials for BECCS and biochar are highly speculative.

[b] If 2.5 tC yr^{-1} per hectare can be harvested on a sustainable basis (Kraxner et al., 2003) on about 4% (~500 million hectares, about one tenth of global agricultural land area) of global land (13.4 billion hectares) for BECCS, approximately 1.25 PgC yr^{-1} could be removed or about 125 PgC in this century. Future CO_2 concentration pathways, especially RCP2.6 and RCP4.5 include some CO_2 removal by BECCS (Chapter 6 of AR5 WGIII) and hence the potentials estimated here cannot add on to existing model results (Section 6.4).

Table 3 - Characteristics of some CDR methods from peer-reviewed litterature. Note that a variety of economic, environmental, and other constraints could also limit their implementation and net potential. Source: IPCC, AR5, WGI, Chapter 6

If we now repeat the above exercise but provide an additional carbon budget, reflecting the use of potential negative emissions technologies, we obtain a new set of curves, displayed in Figure 5.

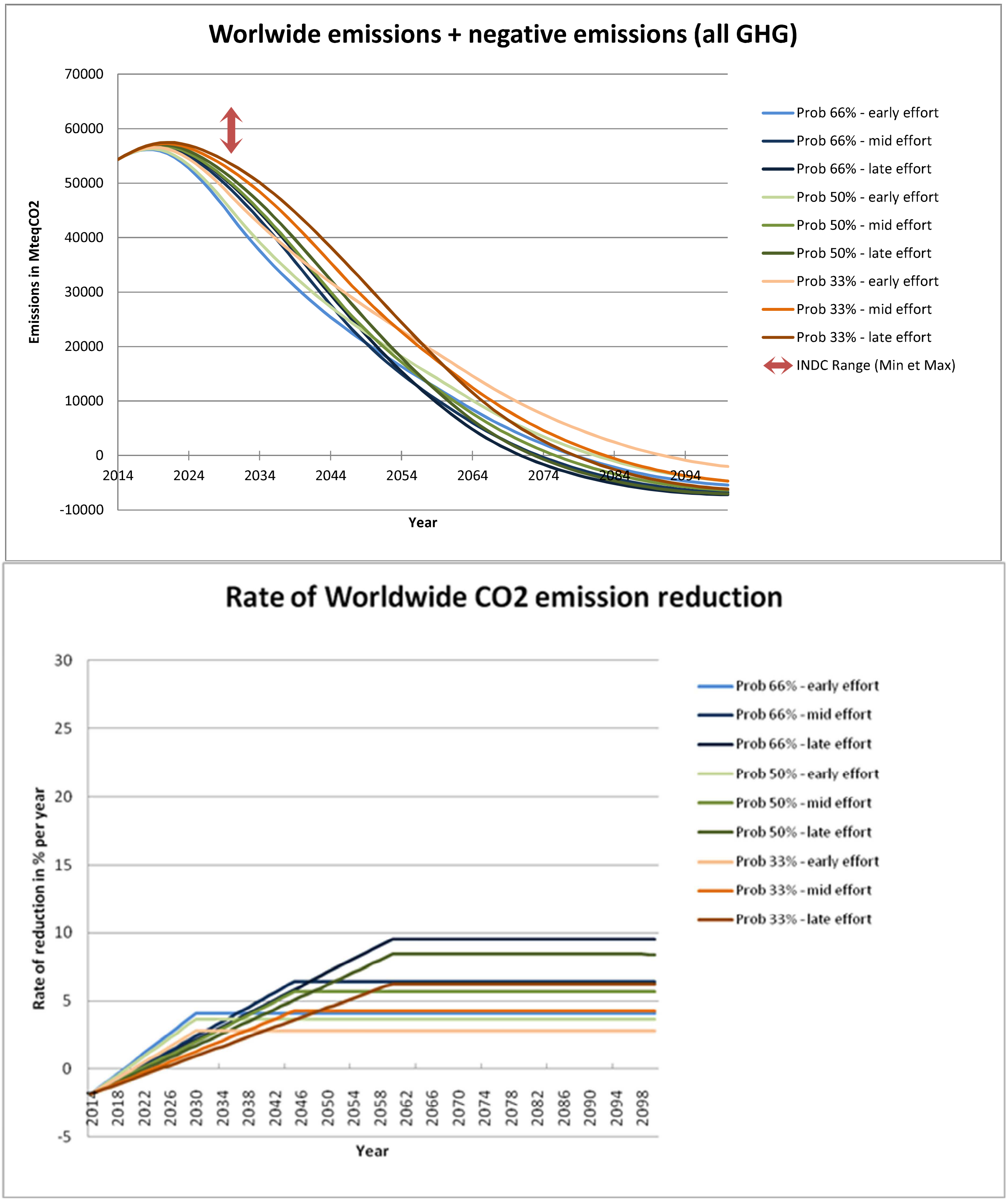


Figure 5 - Same as Figure 3 but with an additional budget of 500 Gt CO_2 accounting for potential negative emissions.

In this case with negative emissions, the range of INDCs is closer to the 2°C compatible trajectories. This makes it highly relevant to have a special focus on negative emissions options and on the associated uncertainties. Note that lower emissions reduction rates are required in these trajectories but that they also imply additional efforts to generate negative emissions, not shown here (more information about this can be found in the Methods section).

INDCs and emissions trajectories for higher temperature targets

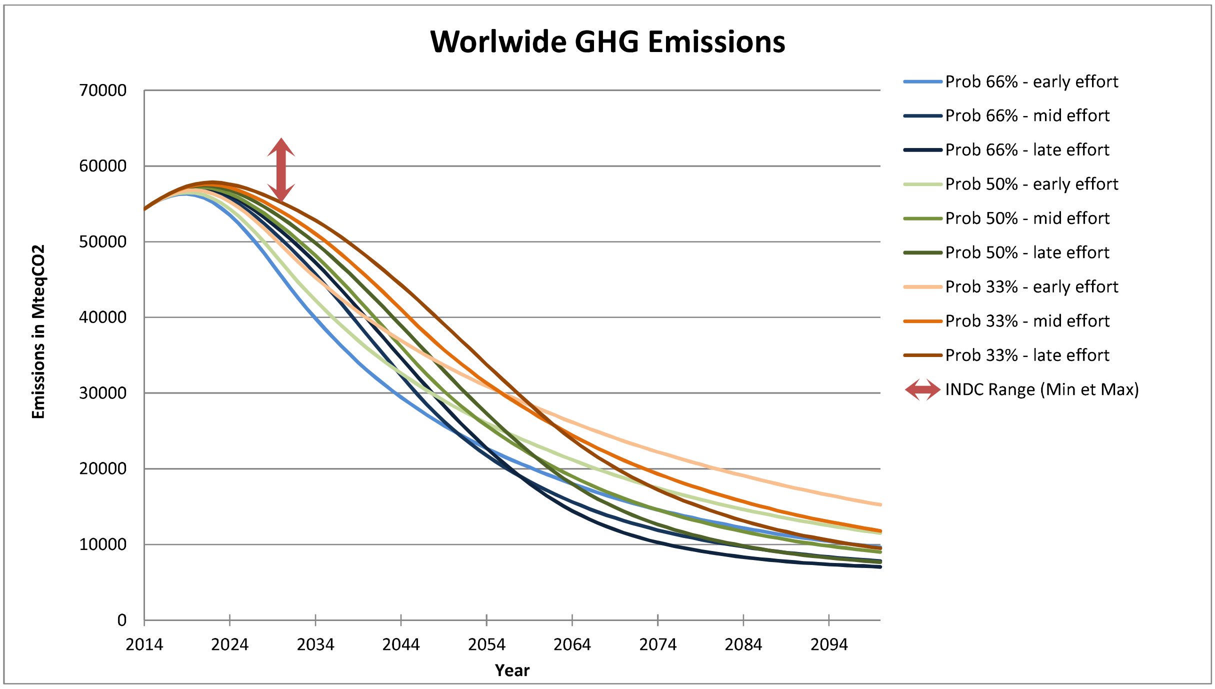
Considering the remaining gap between aggregated INDCs and REDEM 2°C trajectories, we also look at higher temperature targets. The correspondence between budgets, probabilities and warming levels is given in Table 4. Budgets for the 2.5°C global warming is assessed by linear interpolation.

Table 2.2 | Cumulative carbon dioxide (CO_2) emission consistent with limiting warming to less than stated temperature limits at different levels of probability, based on different lines of evidence. *{WGI 12.5.4, WGIII 6}*

Cumulative CO_2 emissions from 1870 in $GtCO_2$									
Net anthropogenic warming [a]	<1.5°C			<2°C			<3°C		
Fraction of simulations meeting goal [b]	66%	50%	33%	66%	50%	33%	66%	50%	33%
Complex models, RCP scenarios only [c]	2250	2250	2550	2900	3000	3300	4200	4500	4850
Simple model, WGIII scenarios [d]	No data	2300 to 2350	2400 to 2950	2550 to 3150	2900 to 3200	2950 to 3800	n.a. [e]	4150 to 5750	5250 to 6000

Table 4 - Cumulative CO2 emission budgets consistent with limiting warming to less than stated temperature limits at different levels of probability, based on different lines of evidence (IPCC AR5 WGI 12.5.4, WGIII 6)

Figure 6 and Figure 7 show the same analyses as Figure 3 and Figure 4 with CO_2 budget associated to a 2.5°C warming. Figure 6 shows that, with a linear increase in the CO_2 emissions reduction rate, aggregated INDCs are only compatible with benchmarking trajectories obtained for a 2.5°C warming with a 33% probability. Figure 7 focuses on trajectories obtained with the budget associated to a 2.5°C warming with a 66% probability. It shows that, if abrupt changes in the emissions reduction rate dynamics are possible, aggregated INDCs could be compatible with a 2.5°C warming with a 66% probability. In this case, the maximal reduction rate in emissions would reach between 5% and 9%.



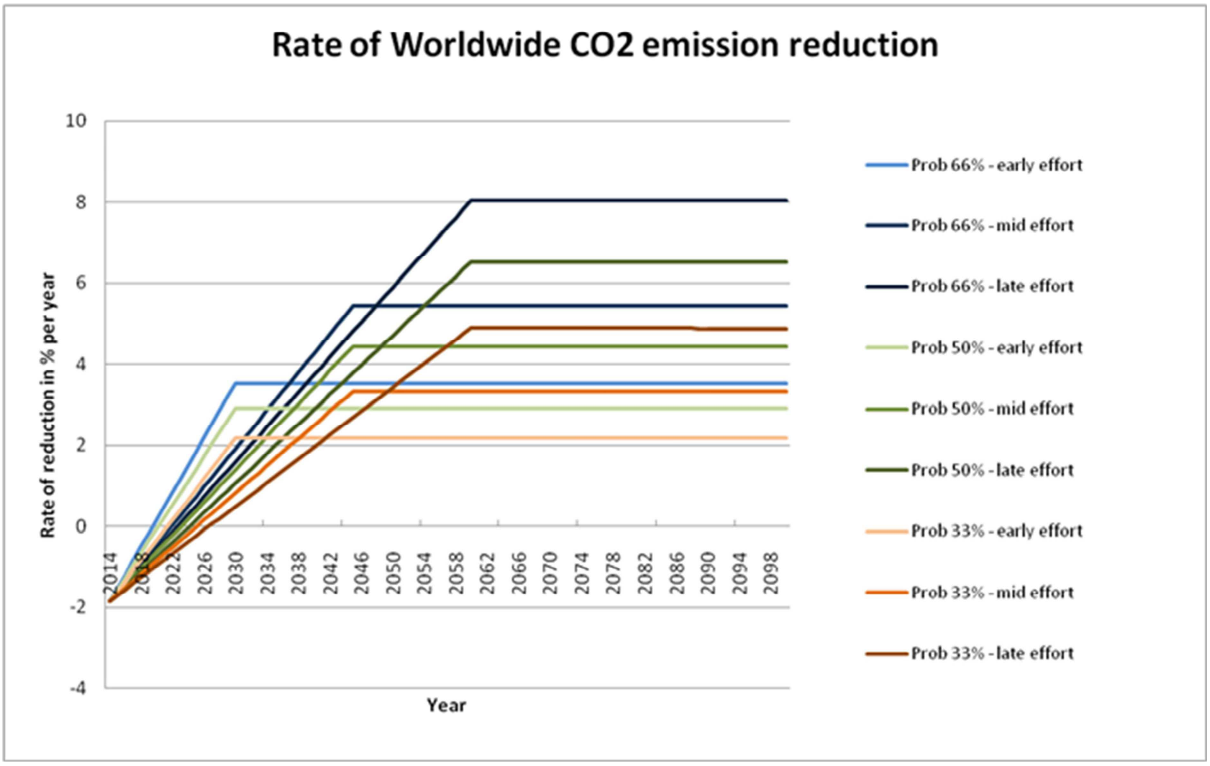


Figure 6 - GHG emission trajectories ($MtCO_2eq$) for different probabilities of reaching the 2.5°C target and different maximum effort dates (top). Associated CO_2 emissions reduction rate (bottom).

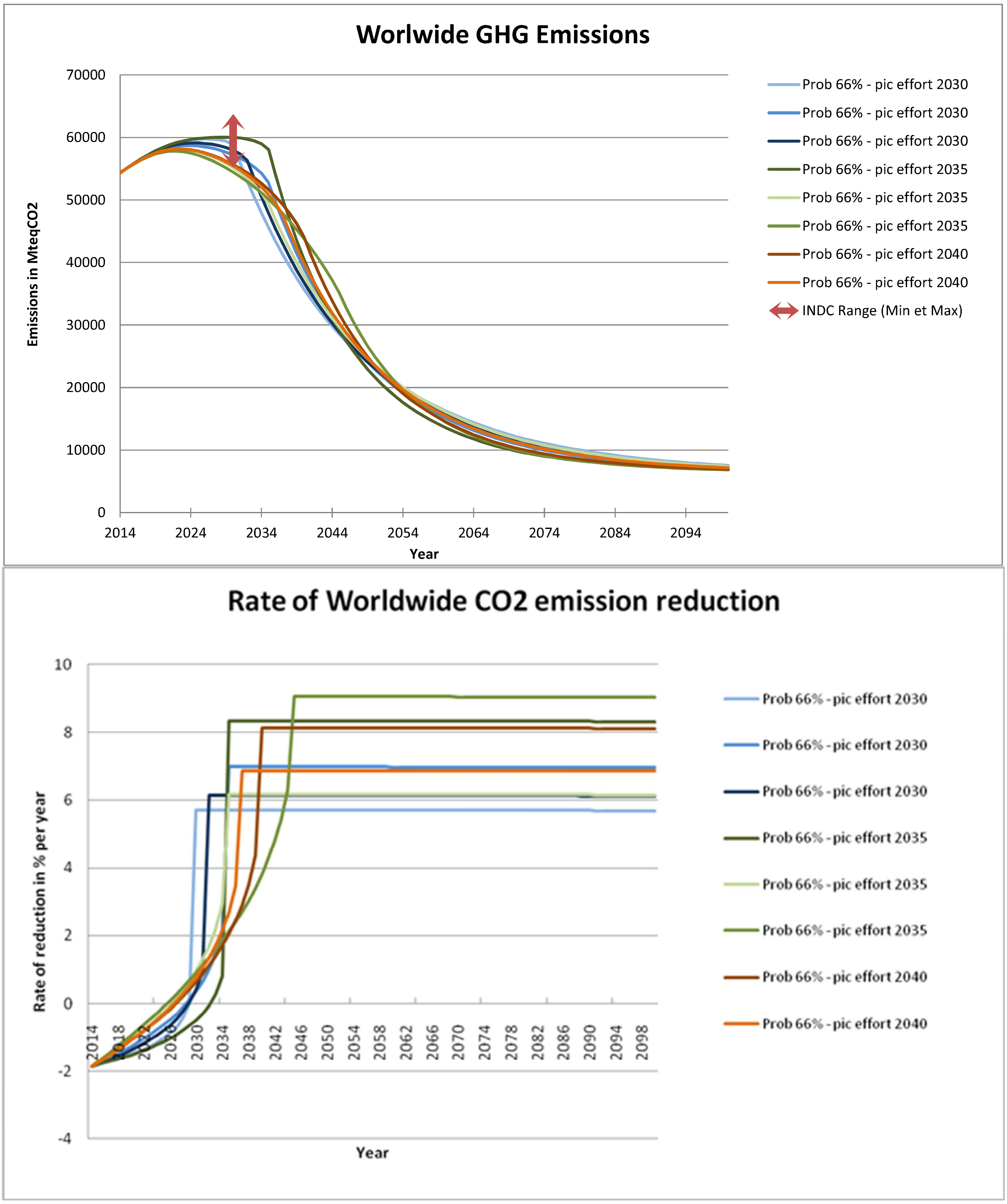
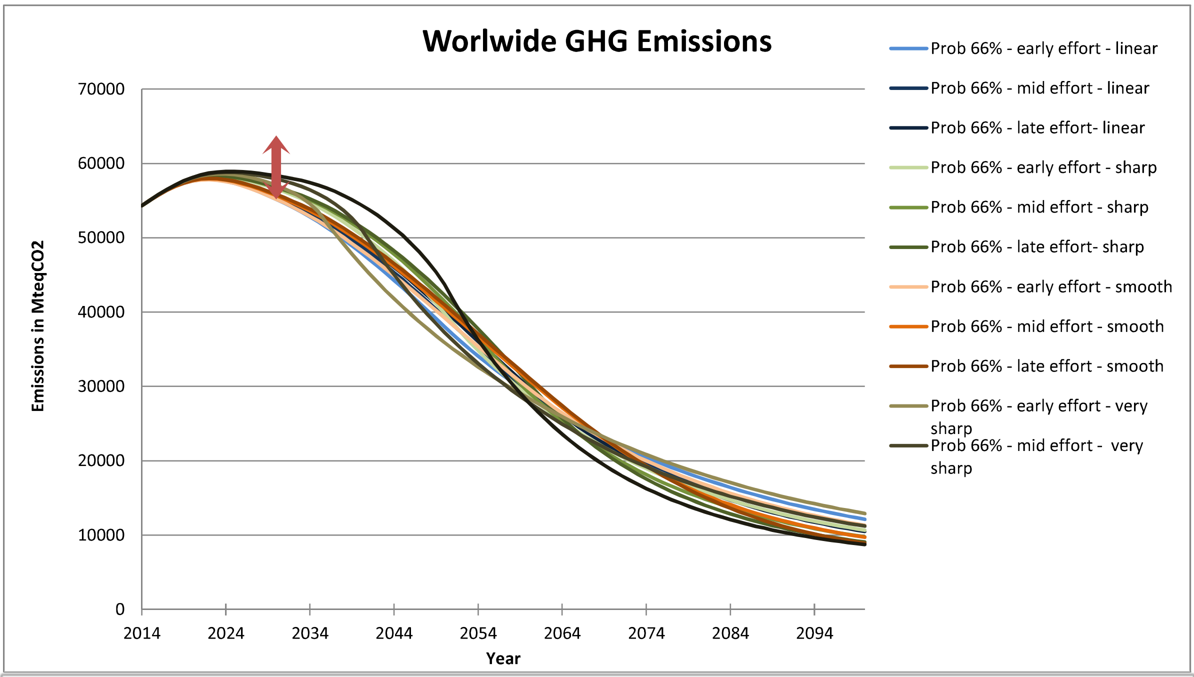


Figure 7 - GHG emission trajectories ($MtCO_2eq$) for a probability of 66% of reaching the 2.5°C target with different maximum effort dates and different values for parameter γ (top). Associated CO2 emissions reduction rate (bottom).

Figure 8 displays similar results for a budget corresponding to a 3°C warming with a 66% probability. In this case, the maximal reduction rate in emissions would reach between 3% and 6%. Abrupt changes in the reduction rate dynamics are not nececessary.



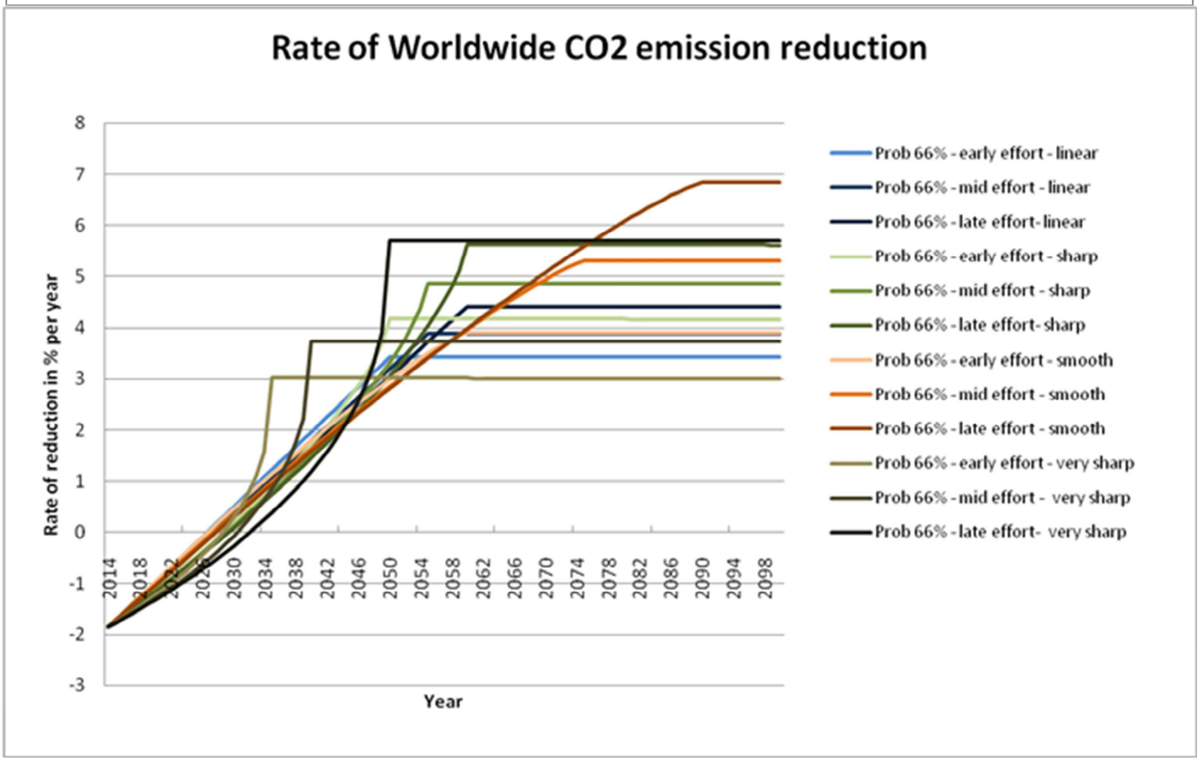


Figure 8 - GHG emission trajectories ($MtCO_2eq$) for a probability of 66% of reaching the 3°C target with different maximum effort dates and different values for parameter γ (top). Associated CO_2 emissions reduction rate (bottom).

Pre – COP21 statements

The analysis and aggregation of INDCs published until mid-November 2015 allow us to draw preliminary conclusions regarding the ongoing process before the COP21:

- Evaluating INDCs against the objective of limiting global warming to 2°C consists of two successive tasks: the aggregation of published and estimated INDCs on the one hand, and the identification of emissions ranges in 2030 that are compatible with 2°C trajectories on the other hand.
- The analysis of the non-obsolete IPCC 2°C trajectories indicates a range of permissible emissions in 2030 around 40-65 $GtCO_2eq$. However, pathways exceeding 53 $GtCO_2eq$ in 2030 involve very large emission reductions rates over the 2030-2050 period.
- The 2°C target is most rigorously interpreted through a carbon budget for the period spanning from today to the end of the century. On the basis of assumptions regarding the date of maximum reduction effort, this budget is described with the REDEM tool in terms of emission trajectories over the century, with different probabilities of meeting the 2°C target.
- These trajectories indicate a range of permissible emissions in 2030 of 30 to 50 $GtCO_2eq$ in 2030 without negative emissions, and 40 to 55 $GtCO_{2eq}$ with negative emissions. It is clear that the more we approach the lower level and the greater the chance of meeting the 2°C target, given the climatic uncertainties.
- Regarding the aggregation of INDCs, current estimates based on published INDCs and on conservative assumptions (particularly in terms of economic growth for China, India and countries without any INDC published yet) lead to an emission level of 55 to 64 $GtCO_2eq$ in 2030. This means that they are larger than the range of permissible emissions with negative emissions, and significantly larger than the range of permissible emissions without negative emissions. They are also compatible with some IPCC 2°C trajectories, but only those with very significant emission reduction efforts in the 2030-2050 period and in the presence of negative emissions at the end of the century.
- Further emissions reductions for the period up to 2030 would significantly increase the probability to achieve the 2°C target, make the necessary emissions reduction rate post-2030 more within reach and reduce the need for negative emissions towards the second half of the century.

Methods

Dataset

The EDGAR database (*Emissions Database for Global Atmospheric Research*) is the result of a collaborative project between the Joint Research Center (JRC) of the European Commission and the Netherlands Environmental Assessment Agency (PBL). Data are presented for aggregate greenhouse gases by country over the period 1990-2012.

Since it was not clear to us whether the raw GHG data from EDGAR available on the EDGAR website include biomass burning or not (inconsistencies for Indonesia and Malaysia notably), we reconstructed a GHG dataset from EDGAR global grid maps, including CO_2 emissions related to fossil fuels and industrial processes and all CH_4, N_2O and F-gases emissions. Global Warming Potentials from the SAR were used[7]. We then needed to add the CO_2 emissions related to land use.

Regarding Chinese emissions, considering a recent paper revising the actual emission data in China[8] and the ongoing debate on this topic, we chose to use CO_2 emission data consisting of the average values between EDGAR data and those same data corrected according to the previously mentioned paper.

CO_2 emissions data related to land use are issued from the database of the Food and Agriculture Organization of the United Nations (FAOSTAT), also available by country over the period 1961-2012.

2°C trajectories

REDEM pathways

The REDEM algorithm computes emission trajectories *E(t)* associated to a decarbonization rate curve $R(t) = -100\frac{E'(t)}{E(t)}$ (*t* being the year) which is parameterized by three parameters:

- The date of the "peak of effort" (the first date for which the decarbonization rate is maximal) [parameter t_{max}],
- The convexity of the curve *R(t)* before and after the "peak of effort" [parameters γ and θ, respectively].

The parameters t_{max}, γ and θ have to be set by the user. The decarbonization rate curves *R(t)* are also characterized by their maximal value R_{max} which is automatically computed by the algorithm, in order to enforce the carbon budget to be equal to the desired value.

On the interval $[t_0, t_{max}]$, *R* is given by

$$R(t) = (R_0 - R_{\max}) \left(\frac{t_{\max} - t}{t_{\max} - t_0}\right)^{\gamma} + R_{\max}.$$

On the interval $[t_{max}, 2100]$, *R* is a Gaussian curve

$$R(t) = R_{\max}\, e^{\frac{-(t_{\max} - t)^2}{2\theta^2}}.$$

[7] If we use GWP from the AR4, our estimated INDC range in 2030 is translated 2 $GtCO_2eq$ higher, reaching 56.7-65.5 $GtCO_2eq$.

[8] Zhu Liu *et al*., Reduced carbone mission estimates from fossil fuel combustion and cement production in China. *Nature*, doi:10.1038/nature14677, 2015.

Finally, the benchmarking trajectories built via the REDEM algorithm also verify fundamental continuity assumptions on the emissions curves and their derivatives. In particular, the values of the emissions and their derivatives at t_0 ($E(t_0)$ and $E'(t_0)$) are taken from a well-established database[9] which is consistent with IPCC AR5 carbon budgets data. In practice, we fix t_0=*2014.* $R_0 = -100\frac{E'(t_0)}{E(t_0)}$ and we simply approximate $E'(t_0)$ by $E(t_0)$-$E(t_0$-1). In the experiments below, we have fixed θ=1000. In other words, for $t > t_{max}$, $R(t)$ is almost a constant. So the only parameters we tune are t_{max} and γ.

From a CO_2 budget to CO_2eq emissions

In this analysis we converted CO_2 emissions (in $MtCO_2$) into greenhouse gas emissions (in $MtCO_2$eq). Indeed, the considered IPCC AR5 carbon budgets and emissions data are expressed in $MtCO_2$. The REDEM algorithm, which computes benchmarking trajectories compatible with these budgets and data, generates CO_2 emission trajectories. Therefore, in order to get all GHG emission trajectories (in $MtCO_2$eq), we add the emissions of all greenhouse gases other than CO_2. These emissions are fixed *a priori*. In practice, throughout the 21st century, we fix these emissions $E_{otherGHG}(t)$ as the mean of the differences between all GHG emissions (in $MtCO_2$eq) and CO_2 emissions (in $MtCO_2$) for a subset of IPCC 2°C scenarios from the RCP 2.6 family, from which we have removed all outliers (i.e. scenarios peaking on or before 2015). However, INDC aggregates are based on EDGAR database and REDEM uses data from Le Quéré et al. For data reconciliation purpose, we also add a small adjustment term equal to $E_{EDGAR}(2012)$- $E_{Le\ Quérré}(2012)$ - $E_{otherGHG}(2012)$ *(= 1300 MtCO2eq).* Figure 9 shows the “other GHG” emissions trajectory we add to CO_2 trajectories computed by REDEM.

[9] C. Le Quéré, G. P. Peters, *et al.*. Global carbon budget 2013. *Earth System Science Data*, 6(1):235–263, 2014. C. Le Quéré, R. Moriarty *et al.*. Global carbon budget 2014. *Earth System Science Data*, 7(1):47–85, 2015. These data are also used to compute the carbon budgets on the period 2013-2100 associated to the IPCC AR5 carbon budgets since pre-industrial times.

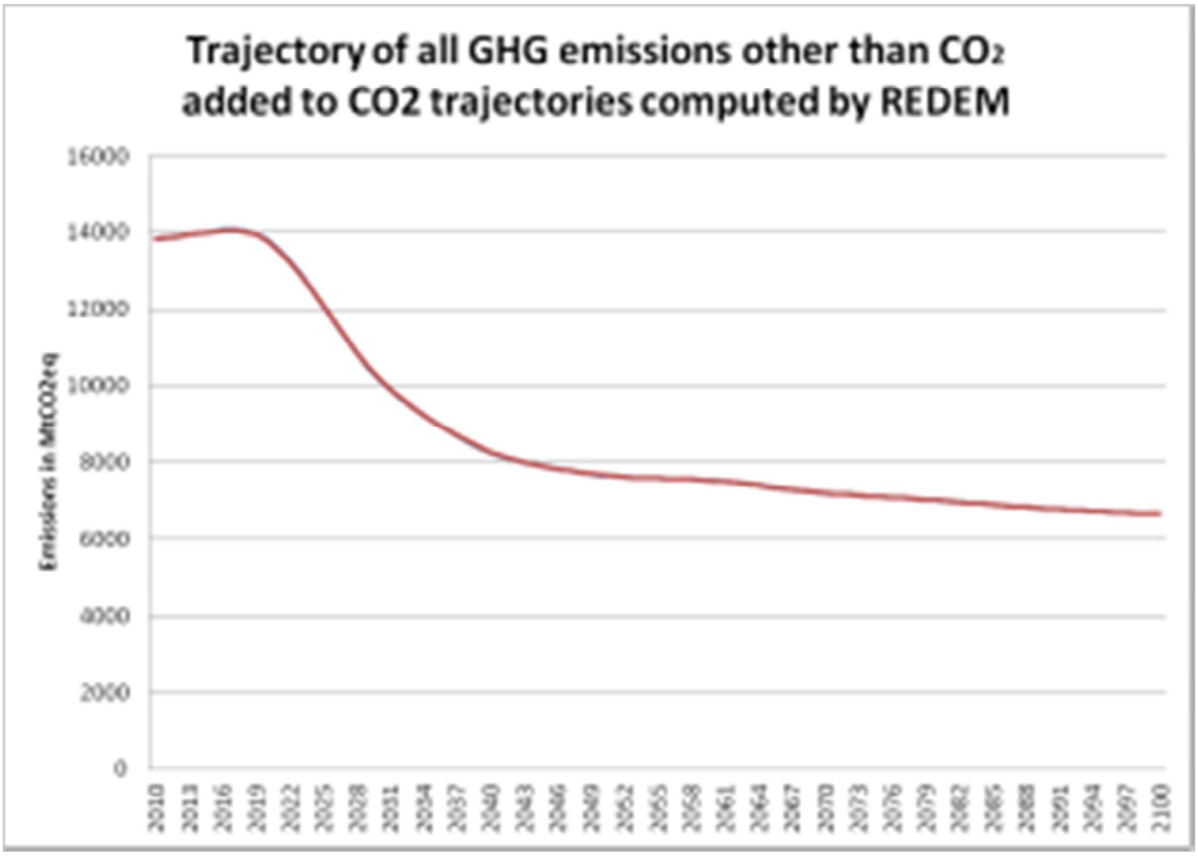


Figure 9 - Worldwide GHG emissions other than CO_2 added to CO_2 emissions trajectories computed by REDEM.

Negative emissions

To include negative emissions, we first provide a cumulative budget of negative CO_2 emissions until 2100. In the following, let us denote it B_{-}. In our analyses, we have only considered the following CO_2 removal methods: afforestation, reforestation, biochar creation and storage in soils. According to WGI AR5, see Table 3, we propose to fix this amount to $B_{-} = 500$ $GtCO_2$ (noting that amounts corresponding to various CO_2 removal methods are not necessarily additive).

The fact that we only consider emissions budgets with the REDEM approach significantly simplifies the problem formulation and allows to assume that one ton of removed CO_2 makes up for one ton of emitted CO_2, whenever they are removed and emitted, respectively. So the cumulative negative emissions budget can be directly added to the cumulative CO_2 emissions corresponding to the chosen probability level (66%, 50% or 33%) and warming level (2°C, 2.5°C, 3°C). We then apply the REDEM algorithm with the obtained budget $B_s = B_{-} + B_{+}$, instead of the "positive" emission budget B_{+} used previously. Note that we call "positive" emissions, the CO_2 emissions physically emitted by anthropogenic activities.

For the same probability and warming level, the benchmarking trajectories thus obtained are higher than those obtained without adding the negative emission budget B_{-}.The mitigation effort now depends on both the rate of decrease of positive emissions and the rate of implementation of negative emissions.

To this aim, we need to consider a negative emission scenario compatible with the associated budget B_{-}. In practice we use a curve $N(t)$, whose value is zero before the date t_{-} (the starting date of the implementation of negative emission technologies) and then reaches a minimal value M at t_{∞}= 2100, and which is symmetric with respect to the point $(t_i, N(t_i))$, where t_i is the middle of t_- and t_∞. It immediately follows that the associated negative emission budget is $B_- = M\,(t_\infty - t_-)\,/2$, see Figure 10.

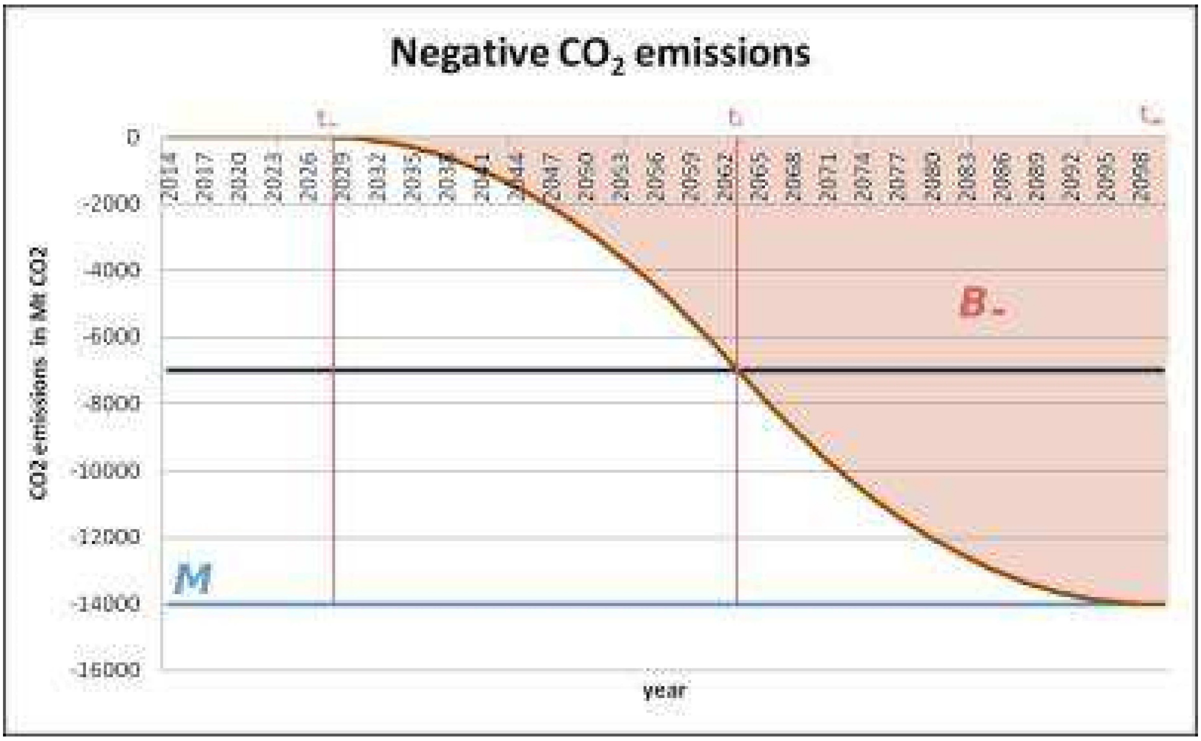


Figure 10 - Proposed negative emission trajectories.

In our implementation, the negative emission curve $N(t)$ is fixed by the following equations:

- for $t < t_-$, $\quad N(t) = 0$
- for $t_- \le t \le t_i$, $\quad N(t) = a\,(t - t_-)^2$
- for $t_i \le t \le t_\infty$, $\quad N(t) = -a\,(t - t_\infty)^2 + 2a\,(t_i - t_\infty)^2$
- for $t \ge t_\infty$, $\quad N(t) = 2a\,(t_i - t_\infty)^2$.

For fixed values of B_- and M, adequate values for a and t_- are given by equations:

- $t_- = t_\infty - 2\,B_- / M$,
- $a = -2\,M / (t_- - t_\infty)^2$.

A summary of INDC assessment studies

Prepared by Sandrine Mathy (EDDEN, CNRS), Laëtita Chevallet (EDDEN), Laureline Coindoz (EDDEN) and Hélène Benveniste (IPSL), based on contributions from teams involved in the considered studies.
Reviewed by Olivier Boucher (LMD, IPSL, CNRS), Patrick Criqui (EDDEN, CNRS, UGA) and Hervé Le Treut (IPSL, UPMC).

A summary of INDC assessment studies

Summary

Eleven studies focusing on INDCs assessment were presented at the INDC workshop on November 3rd 2015 organized in Paris by the GICN. Among them, ten studies estimate the global emission level in 2030 resulting from INDCs aggregation. The emissions range is between 53 and 64 $GtCO_2eq$. A significant part of this range is due to uncertainties regarding the Chinese and Indian growth rates, as these two countries have formulated their INDCs in terms of carbon intensity reduction.

Several studies also assess the global warming level that INDCs would induce. This can only be done by extending INDC efforts beyond 2030 until 2100. The range of temperature change increase reaches between 2.7 and 3.5°C. Two studies build 2°C-pathways compatible with the INDC emission level in 2030, in order to show the magnitude of the effort required after 2030 and until 2100.

Introduction

Several studies assess the progress induced by INDCs on the way to the overall objective of limiting global warming to 2°C. In the following note we describe the methodology and data used in each study in order to understand their commonalities and differences. The following assessments have been considered:

- **UNEP Gap Report**, 2014. As such, only partially taken into account.
- **ESRC Centre for Climate Change Economics and Policy Grantham Research Institute on Climate Change and the Environment**. Boyd R., Cranston Turner J. and Ward B., "Tracking intended nationally determined contributions: what are the implications for greenhouse gas emissions in 2030?", August 2015.
- **PBL Climate Pledge INDC tool** from the PBL Netherlands Environmental Assessment Agency.
- **Danish Energy Agency**. Available results take into account INDCs published up until September 22nd. This means 37 INDCs representing 64 countries and 61% of GHG in 2012.
- **Climate Action Tracker**: consortium gathering PIK, Climate Analytics, NewClimate Institute and Ecofys. "INDCs lower projected warming to 2.7°C: significant progress but still above 2°C", October 1st 2015; "How close are INDCs to 2 and 1.5°C pathways?", September 2nd 2015.
- **Climate Interactive and MIT Sloan**. A. Jones, J. Sterman, "Current INDCs strictly interpreted deliver 3.6°C[10] (6.5°F), missing the goal of 2.0°C (3.6°F)", September 28th 2015.
- **EC-JRC-IPTS**, European Commission Joint Research Center Institute for Prospective Technological Studies. A. Kitous, K. Keramidas "Analysis of scenarios integrating the INDCs", October 2015.
- **Fondation Nicolas Hulot**, "Thermometer of commitments and financing". Last update from October 9th. FNH is a French environmental NGO.
- **International Energy Agency**, Energy and Climate Change Special Briefing for COP 21, World Energy Outlook Special Report, October 2015; Energy and Climate Change, World Energy Outlook Special Report, June 2015.
- **MILES project:** consortium gathering IDDRI, PIK, PBL, E3M Lab, NIES, RITE, PNLL, Tsinghua University, Remnin University, ERI NRDC, COPPE/UFRJ, TERI, IIASA, IIMA. "Beyond the Numbers: Understanding the Transformation Induced by INDCs".

[10] This estimate has been revised to be 3,5°c since the publication has been published,

- **World Resources International.** CAIT Climate Data Explorer; "Climate Plans in the Lead-Up to Paris: Where Do We Stand?", August 4th, 2015. To the best of our knowledge, WRI does not assess the aggregated INDCs in terms of global emissions or temperature change.
- **GICN:** interdisciplinary group of French experts, led by Hervé Le Treut and Olivier Boucher.
- **PNNL.** H. McJeon will present PNNL's so far unpublished work on INDCs on workshop day.
- **National Institute for Environmental Studies and Mizuho Information Research Institute:** "Assessment of INDCs using AIM/CGE[Global] (Ver.1)", October 9th 2015. Given the fact that our colleagues from NIES are not able to join this workshop, this study is not presented in details here.
- **UNFCCC:** Synthesis report on the aggregate effect of the intended nationally determined contributions, October 10th 2015.

Sources

Studies	Web links	Last version
Grantham	http://www.lse.ac.uk/GranthamInstitute/the-road-to-paris-cop-21/	August
PBL	http://infographics.pbl.nl/indc/	Sept. 3rd
DEA	http://www.ens.dk/en/node/6332	Oct. 29th
FNH	http://www.fondation-nicolas-hulot.org/magazine/paris-climat-2015-le-thermometre-des-engagements	Oct. 9th
CAT	http://climateactiontracker.org/global.html	Oct. 1st
CI-MIT	https://www.climateinteractive.org/tools/scoreboard/	Oct. 17th
MILES	http://www.iddri.org/Publications/Beyond-the-numbers-Understanding-the-transformation-induced-by-INDCs	Oct. 27th
JRC	http://www.indcforum.org/wp-content/uploads/2015/10/Analysis-of-scenarios-integrating-the-INDCs_201510_JRC97845.pdf	October
IEA	http://www.iea.org/newsroomandevents/pressreleases/2015/october/climate-pledges-for-cop21-slow-energy-sector-emissions-growth-dramatically.html	Oct. 15th
GICN	http://icmc.ipsl.fr/images/publications/scientific_notes/note_GICN_nov2015.pdf	Dec. 3rd
UNFCCC	http://unfccc.int/resource/docs/2015/cop21/eng/07.pdf	Oct. 30th

Analysis

Several types of assessment are performed in the 11 studies (see Table 5).

- Some calculate the emissions gap in 2030 between aggregated INDCs and a diagnosed intermediate point of 2°C pathways presented in the scientific literature.
- Some build 2°C pathways passing by the 2030 INDC level.
- Some compute the warming path resulting from INDCs. In order to do so, assumptions are made for what happens after 2030.

	INDC resulting emissions in 2030	Emission gap INDC/2°C in 2030	Extending INDCs after 2030	Resulting warming	2°C pathway built from INDCs
Grantham	X	X			
PBL	X	X			
DEA	X	X			
CAT	X	X	X	X	
CI-MIT	X	X	X	X	X
MILES	X (PBL)	X (PBL)	X		X
JRC	X	X	X (2050)	X[11]	X
FNH	X	X	(X)	X	
IEA	X	X	(X)	X	X (2030)
GICN	X	X			
UNFCCC	X	X			X

Table 5 - Types of assessments performed in studies. (X) means that the methodology is not described in the published study.

[11] By comparison with the IPCC WG3.

Table 6 – Worldwide GHG emissions projections for BaU or Current Policies scenarios, INDC levels in 2030, comparing to 2°C pathways, resulting emissions reductions from reference, emission gap with 2°C pathway, induced warming. *N.A.= not available*; data with a * are approximations from graphic reading.

				Type of reference scenarios		2030 level for reference scenarios (GtCO2eq)			2030 level for the considered 2°C pathway (GtCO2eq)			INDC emissions in 2030 (GtCO2eq)			Emission gap INDC-2°C in 2030 (GtCO2eq)		Including emissions from international transport	Including LULUCF
	T (°C)	2010	2012	Current policy	No policy	median	min	max	median	min	max	median	min	max	min	max		
UNEP	**(2)**	**49**	**54**	**X**		**68**	**63**	**72**	**42**	**29**	**44**						N.A.	Yes
Grantham		44		X		64				36	42		57	59	14,9	17,1	Yes	Yes
PBL		49		X		66			42	30	44	56	54	62	10	18	Yes	Yes
DEA			48	X		61			42				53*	55*	12		N.A.	Yes
CAT	**2,7**	47	48	X			58	61		36	40		54	54	14	18	Yes	Yes
CI-MIT	**3,5**	50	53		X	72			54				56	57	2,8		Yes	Yes
MILES		49	50		X		58*	63*	42*	40*	48*	54	52	60			N.A.	Yes
JRC	**3**	48,2	49,9	X		60,1			45,5				54*	56,6	11,1	8,5	Yes	Yes
FNH	**3**	49							47	30	50	60[12]			30	10	Yes	Yes
IEA[13]	**2,7**	46		X		59			40			52			12		Yes	Yes
GICN					X[14]					30[15]	55		55	64	25	8	Yes	Yes
UNFCCC		48		X		60.8	60.7	60.8	38	30	45	57	53	59	23	14	N.A.	Yes

Results presented here come from studies updates up to October 20th 2015.

[12] FNH assessment considered as more realistic: 56 $GtCO_2eq$ in 2030.

[13] Only energy emissions (without industrial processes)

[14] Use of the UNEP BaU scenarios: absence of climate mitigation policies after the 2005–2010 period (such as recent country pledges and policies).

[15] Includes trajectories with and without negative emissions, and with different probabilities of staying below 2°C.

1. Evaluating the 2030 global emissions level resulting from INDCs

The estimated INDC emission range in 2030 for all studies is between 52 and 57 $GtCO_2eq$ for the most ambitious INDC interpretations (INDC max), and between 54 and 64 $GtCO_2eq$ for the least ambitious INDC interpretations (INDC max).

For China alone, uncertainties and assumptions on GDP growth until 2030 and on carbon intensity reduction (-60 or -65% in 2030) lead to a gap of several $GtCO_2eq$ in 2030. The emissions peak date for China depends on it. For India, the range induced by different assumptions on GDP growth and carbon intensity reduction is lower (less than 1 $GtCO_2eq$ in 2030). None of the assessments assume that GHG emissions in India will have peaked by 2030. GHG emission reductions induced by conditional objectives in addition to unconditional objectives can reach 1GtCO2eq but not more (UNFCCC, PBL).

Most studies estimate INDC benefits relative to a baseline (that can be either a no policy scenario, a current-policy scenario or a Cancun pledge scenario) in 2030 within a range of up to 7 $GtCO_2eq$. Some plan benefits above 10 $GtCO_2eq$.

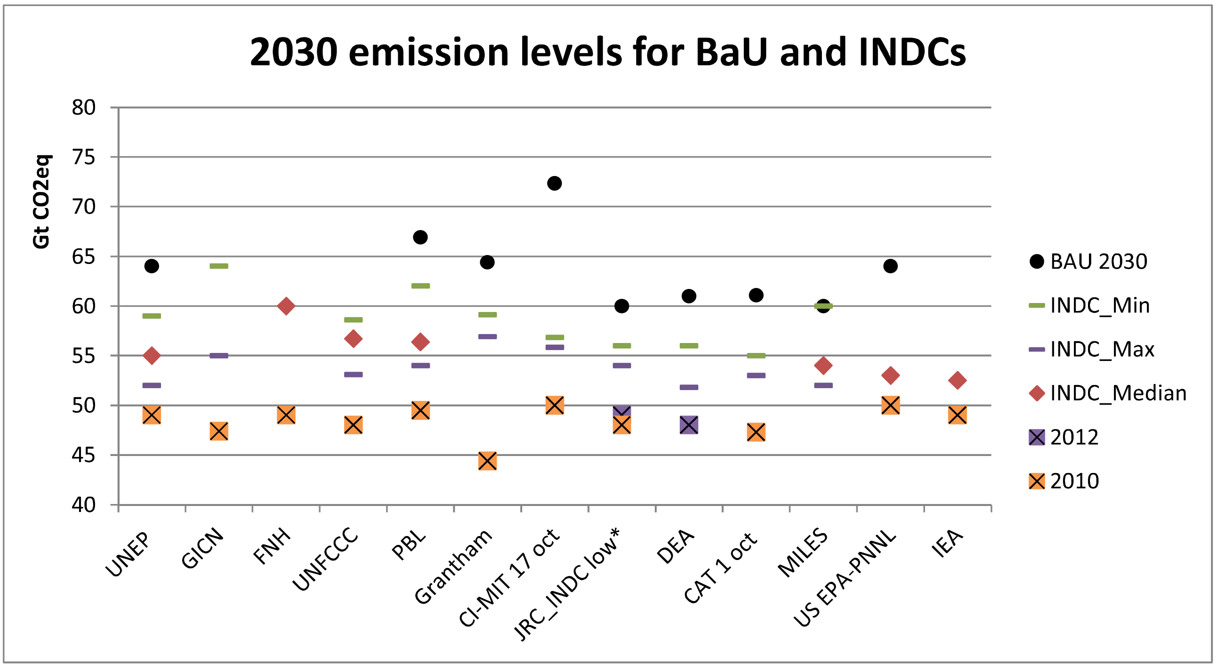


Figure 11 - 2030 emission levels for baseline and INDC scenarios.

2. Evaluating the emission gap in 2030 compared to a 2°C pathway

Calculating the emission gap in 2030 compared to a 2°C pathway requires referring to a 2°C pathway. Several studies (Grantham, PBL, CAT, JRC, DEA, CI - MIT) refer to one of the UNEP Gap Report 2°C pathways (66% chance of staying below 2°C). Some refer to the trajectory with an emission peak in 2010 (Grantham, CAT, JRC, CI - MIT), others to the one with a peak in 2020 and including negative emissions (Grantham, PBL, DEA, CI - MIT). The baseline taken by FNH is not clear. IEA refers to the WEO 2014 450ppm scenario (50% chance of staying below 2°c).

	2°C trajectories for emission gap
Grantham	2 UNEP pathways
PBL	UNEP peak 2020 including net negative emissions
DEA	UNEP peak 2020 including net negative emissions
CAT	UNEP peak 2010
JRC	Enhanced GECO 2015 Global Mitigation Scenario
FNH	Range derived from IPCC/WG3
IEA	450 ppm scenario WEO 2014
CI - MIT	2 UNEP pathways
GICN	IPCC scenarios, probability levels
UNFCCC	IPCC scenarios

Table 7 - 2°C trajectories used to assess the emission gap.

3. Extending INDCs past 2030 to determine the resulting warming

This part focuses on the four following studies: CI-MIT, CAT, JRC and MILES. The FNH study is not considered here because the methodology is not described.

Several methodologies are used to extend INDCs emission trajectories beyond 2030:

- **CAT**: The methodology is based on the idea that the level of mitigation effort corresponds to the relative position of an emissions pathway in a set of pathways. CAT uses the AR5 database and takes into account all AR5 emission pathways from models that simulate all sectors and gases. Scenarios with too high level of negative emissions and scenarios where climate action only starts after 2030 were excluded. The INDC emissions level in 2030 is placed among the scenarios crossing points in 2030 (the nth percentile). A trajectory is built: for each year post-2030, emissions are equal to the nth percentile of the distribution of AR5 scenarios database for that year.
- **CI-MIT**: four extended INDC scenarios beyond 2030 are considered. Two of them are designed to assess the compatibility of INDCs with a 2°C trajectory
    - - « INDC strict »: no change after the national commitment period. This means that for instance, if a country agrees to reduce its energy intensity by x% in 2030, it is considered that the energy intensity remains constant afterwards;
    - - « INDC Ratchet 1 »: same as « INDC strict » with a continuation of reductions after the commitment ends. This means that for instance, if a country agrees to reduce its

energy intensity by x% in 2030, it is considered that the energy intensity continues to decrease at the same rate thereafter.

- « INDC Ratchet 2 »: same as « INDC Ratchet 1 » with the integration of two more assumptions for China: the integration of other GHGs and emissions reduction assumption after the peak in 2030 at up to 2% per year.
- « INDC Ratchet 3 »: same as « INDC Ratchet 2 » with one more assumption regarding other developing countries without commitment which are expected to peak by 2035.

The three « Ratchet » scenarios clearly assume actions beyond the pledges.

- **JRC** considers that beyond 2030 (up until 2050, end of the study), regional carbon prices increase and gradually converge at a speed depending on their GDP/capita. The global energy intensity decreases between 2030 and 2050 at the same rate as between 2020 and 2030. Using the POLES model.
- **MILES** uses an "INDC-extended" scenario, in which INDCs are extended beyond 2030 by an extrapolation of the regional carbon prices that emerged under the INDCs as well as technology targets for selected regions. Trajectories are shown until 2050. MILES does not compute a resulting warming.
- **IEA:** to assess the impact on global average temperature increase, IEA uses MAGICC with an emissions pathway in between the representative concentration pathways (RCP) 4.5 and 6 from the IPCC's Fifth Assessment Report. This was considered as the long-term emissions trajectory most closely aligned with this INDC analysis. However, the extension beyond 2030 is not presented in the paper, therefore the IEA study is not represented on Figure 12.

This analysis shows a diversity of understanding of what is a « constant effort ».

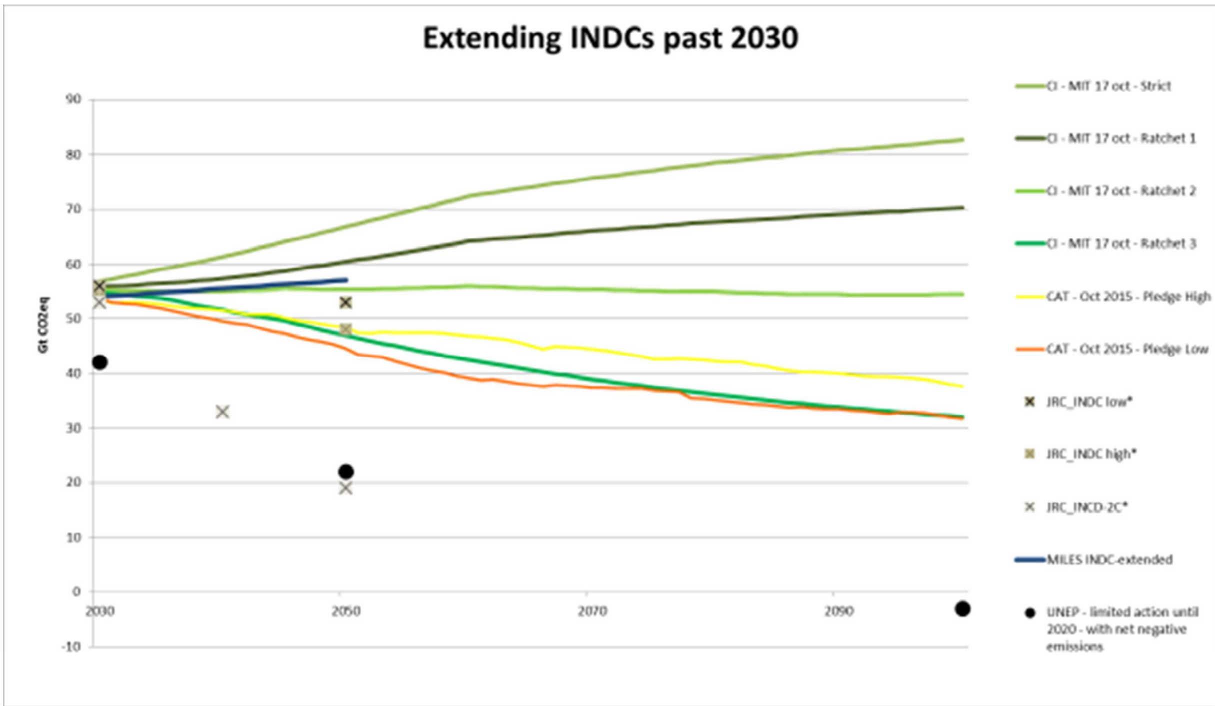


Figure 12 - Pathways extending INDCs beyond 2030.

4. Building 2°C trajectories passing by the INDC level in 2030

Two studies build 2°C trajectories passing by the estimated level of INDC emissions in 2030.

CI-MIT: The 2°C pathway comes from the "INDC Ratchet 3" trajectory with a global emissions peak in 2020 and emission reductions of 3.5% per year. The pathway does not include negative emissions and has emissions above 50GtCO_2eq in 2030. There is no mention of the probability for the 2°C goal.

MILES: Several scenarios are developed in this study. The "INDC-2°C" scenario has been designed as follows: the model represents the INDC scenario until 2030. After 2030, a global carbon price that increases with the marginal cost of abatement is implemented in the model in order to be consistent with the 2°C target. The "Bridge-2°C" scenario was designed considering investors anticipate the significant strengthening of post-2030 climate policies, and therefore can prepare with additional measures in the period 2020-2030 to allow for a more continuous transition. The driver of this scenario is strengthened policies and targets by 2020 for the period before 2030 and after 2030. Finally, in the "Immediate-2°C" scenario, the 2°C goal is imposed immediately in 2015 (in terms of a radiative forcing target of 2.6 W/m²) and implemented in the model with a globally uniform carbon price that increases over time with the marginal cost of abatement.

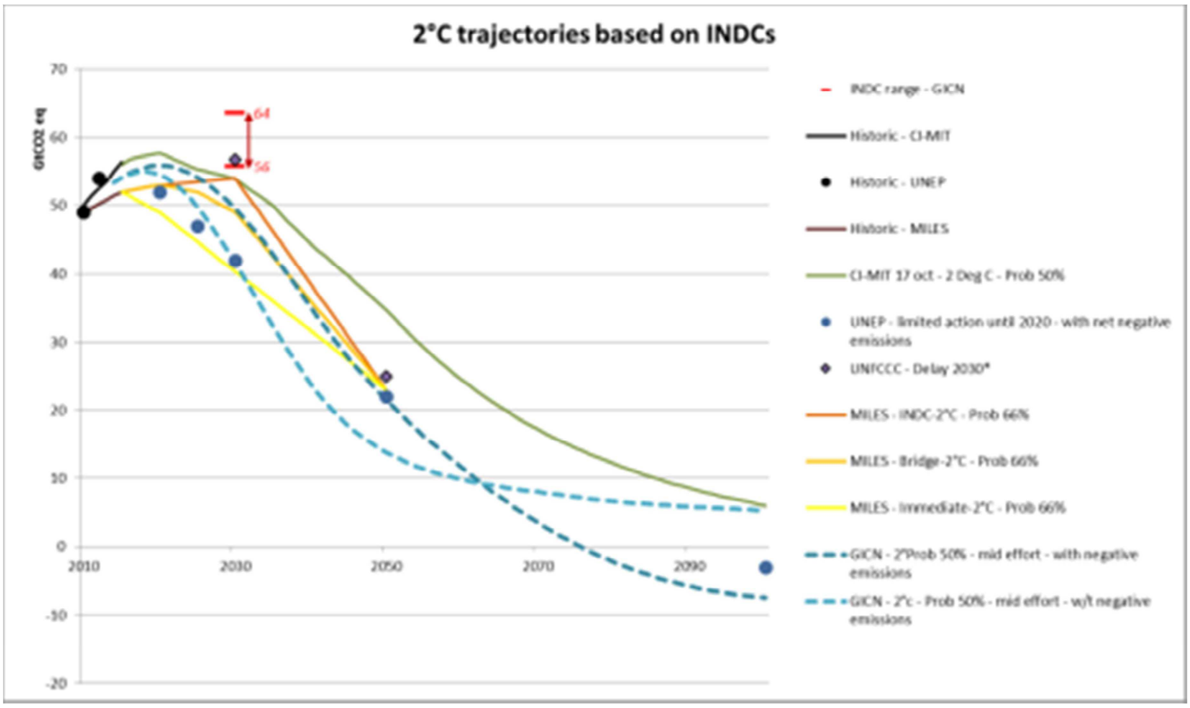


Figure 13 - 2°C trajectories based on INDCs.

As an illustration, the 2030 and 2050 levels of the UNFCCC Delay-2030 scenarios with > 50% likelihood of staying below 2°C were added to this graphic. Note that the 2°C trajectories of JRC and IEA are not included in this part because:

- The JRC 2°C trajectory does not pass through the INDC level in 2030: The JRC considers more ambitious political measures from 2015, which allows reaching an emission peak by 2020. A gradual convergence of carbon prices after 2030 based on GDP/capita allows staying on a path consistent with the 2°C objective by 2050.
- The IEA Bridge scenario is not a 2°C scenario; the 450ppm scenario of WEO 2014 does not pass through the INDC in 2030.

Groupe Interdisciplinaire sur les Contributions Nationales

INDCs and long term trajectories for countries in the Deep Decarbonization Pathways Project

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Reviewed by GICN.

INDCs and long term trajectories for countries in the Deep Decarbonization Pathways Project

Introduction

This work describes the INDCs of different countries in comparison to various prospective exercises. This allows evaluating the contributions of the Parties relative to several long-term trajectories (2050), according to the level of ambition of climate policies (2°C trajectory and baseline).

The analyzed countries correspond to the 16 countries that were part of the Deep Decarbonization Pathway Project (DDPP), whose aggregated CO_2 emissions from energy account for 74% of current global CO_2 emissions (source DDPP):

- France, United Kingdom, Germany and Italy (given the common INDC for EU members , the analysis covers the European Union and consider its overall objectives for its 28 members)
- United States
- China
- Australia
- Brazil
- Canada
- India
- Japan
- Mexico
- The Russian Federation
- South Africa
- South Korea
- Indonesia

Synthesis

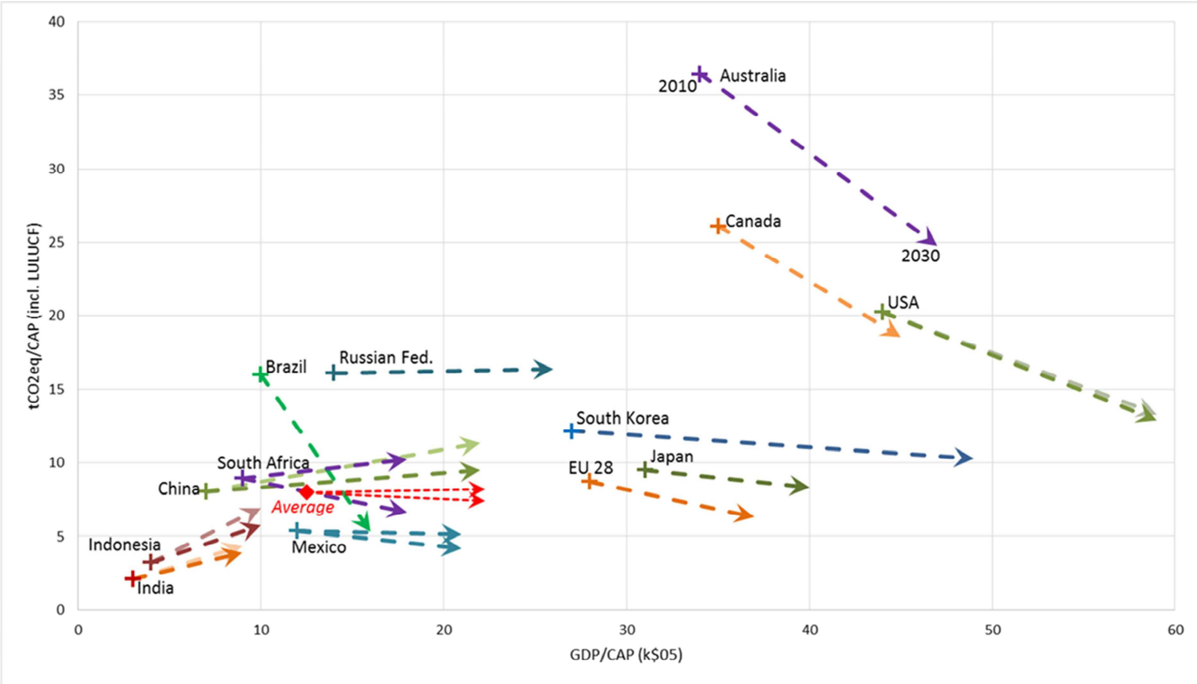


Figure 14 - 2010-2030 pathways resulting from INDCs for DDPP countries. Source: GICN for GHG emissions (2010 data are based on EDGAR database), UNPOP (median scenario) for population, GECO for GDP/capita.

Parties	Base year	GHG 2012	INDC 2030		2030/2012 reduction		% Global GHG			
			Min. / Uncond.	Max / Cond.	Min / Uncond.	Max / Cond.	2012	2030[1]	2030[2]	Cumul[1]
EU 28	1990	4 342	3 280	3 170	-24%	-27%	9%	5%	6%	5%
USA	2005	5 268	4 477	4 356	-15%	-17%	10%	7%	8%	12%
China	2005[3]	12 625	15 219	12 774	+21%	+1%	25%	24%	23%	36%
Australia	2005	597	484	471	-19%	-21%	1%	1%	1%	37%
Brazil	2005	2 003	1 312		-35%		4%	2%	2%	39%
Canada	2005	778	626		-20%		2%	1%	1%	40%
India	2005[3]	2 955	6 643	5 972	+125%	+102%	6%	10%	11%	50%
Indonesia	BAU	2026	2 046	1 700	+1%	-16%	4%	3%	3%	53%
Japan	2005	1 506	1 006	1 000	-33%	-34%	3%	2%	2%	55%
Mexico	BAU	691	759	623	+10%	-10%	1%	1%	1%	56%
Russia	1990	2 249	2 806	2 638	+25%	+17%	4%	4%	5%	60%
South Africa	PPD[4]	418	614	398	+47%	-5%	1%	1%	1%	61%
South Korea	BAU	676	536		-21%		1%	1%	1%	62%
Total		36 133	39 806	35 575	+10%	-1%	71%	62%	65%	62%

Table 8 - GHG emissions (incl. LULUCF) for the considered countries. [1] % for INDC min or unconditional. [2] % for INDC max or conditional. [3] INDCs expressed in terms of GDP carbon intensity reduction. [4] Peak-plateau-decline

Methodology

Historical data come from CAIT (WRI) and EDGAR (EU-JRC / PBL) databases[16]. The trajectories used in this study come from the scenarios described in Table 9.

Scenarios	Sources	Gas	Scenarios hypotheses
GECO – *baseline scenario*	Global Energy and Climate Outlook 2015 (JRC-IPTS)	GHG	*"The Baseline scenario represents the effects of the current pre-2020 mitigation pledges on global emission levels up to 2050, without new additional policies by 2020 or beyond. The Baseline scenario represents the evolution of the energy markets, as driven by its own dynamic of production, supply and demand. This representation is consistent with other international energy projections. In the absence of new policies, economic and emission growth are not decoupled. Large-scale additional investments are required to cope with the growing energy demand, as the energy sources are not used very efficiently. In this Baseline scenario, global emissions would increase to unsustainable levels: by more than 10% above 2010 levels by 2020, by at least 30% above 2010 levels by 2030, and around 50% above 2010 levels by 2050. Along such trajectories, the world is at risk to experience a global temperature increase of +4°C, with sizeable impacts on sustainable growth and on vulnerable groups in all regions."*
GECO – *mitigation scenario*	Global Energy and Climate Outlook 2015 (JRC-IPTS)	GHG	*"The Global Mitigation scenario is meant to represent the effects of possible new mitigation commitments beyond 2020. This scenario requires global participation by all countries and all sectors and greenhouse gases to be addressed; yet it is differentiated according to the countries' capabilities, especially giving time and flexibility to the lowest income countries to join the global mitigation efforts and sustain their growth potentials. This Global Mitigation scenario is illustrating how all countries can set milestones for action by 2025 or 2030 in relation to the common goal to stay below 2°C and integrating their national circumstances. In this Global Mitigation scenario, global emissions (excluding land use sinks) would peak in 2020 at about 10% above 2010 levels, then decrease to 10% below 2010 levels by 2030 and by 60% below 2010 levels by 2050. This trajectory leaves space to countries to gradually embark on realising emission reductions. At the same time, it keeps global emissions on a path consistent with securing a 60-80% probability of staying below 2°C according to the latest IPCC report. […]"*
WEO – *450 scenario*	World Energy Outlook 2014 (IEA)	CO2	*"The **450 Scenario** sets out an energy pathway that is consistent with a 50% chance of meeting the goal of limiting the long-term increase in average global temperature to 2 °C compared with pre-industrial levels. »*
WEO – *current policies scenario*	World Energy Outlook 2014 (IEA)	CO2	*"The **Current Policies Scenario** is based on those government policies and implementing measures that had been formally adopted as of mid-2014."*
WEO – *bridge scenario*	WEO Special Report on Energy and Climate Change 2014 (IEA)	CO2	*"The **Bridge Scenario** puts a brake on growth in oil and coal use within the next five years: oil demand rises to 95 mb/d by around 2020 and then plateaus, while coal demand peaks before 2020. The shift towards renewables increases their share in power generation to 37% in 2030, 6 percentage points above that in the INDC Scenario."*

Table 9 – Scenarios used for assessing INDCs. EE: Energy Efficiency, KP: Kyoto Protocol, NAP: National Adaptation Plan, REN: Renewable Energy

The scenarios used in this study refer to various hypotheses regarding the sectoral scope, especially the LULUCF sector and considered GHG emissions. In order to facilitate the comparison, each country analysis presents values for GHG emissions and for CO_2 emissions only.

The 2030 emissions levels estimation resulting from INDCs refers to the GICN counter. As most INDCs targets are mentioned in terms of GHG emissions, we can compare INDCs to the scenarios previously presented. China is the only country that proposes a CO_2 target. In this case, a conversion process (a proportionality rule based on historical emissions) is used by the GICN counter to translate this target into a GHG target. Some other countries have defined 2025 as the target year, and in these cases 2030 emission levels were determined by extrapolation.

The terms « INDC min. » and « INDC max. » are used throughout the document. This refers to an emission level range for the year 2030. The terms « conditional INDC» and « unconditional INDC » are also used. « Conditional INDC » refers to a mitigation target whose achievement is subjected to exogenous conditions, e.g. funds or technology transfers from Annex I Parties to emerging countries. The term « unconditional INDC » then refers to targets without any exogenous requirement.

In order to evaluate the ambition of the INDC compared to previous commitments, Copenhagen pledges are positioned on each GHG emission trajectory graph.

[16] The dataset called « EDGAR (manual) - GHG excl.LULUCF » refer to EDGAR data which have been processed to completely exclude the LULUCF sector.

INDCs analysis

Parties	Gas	Period	Typology of target	Use of international credits	LULUCF	Adaptation plan
EU 28	7 GHG*	1/01/2021 - 21/12/2030	Absolute (/1990)	No	Will be subject to a subsequent decision	N.D.
The United States	7 GHG*	- / 2025	Absolute (/2005)	No, at this time	Integrated Consistent with IPCC guidance. Net-net approach for the land sector + « production approach » to account for harvested wood products + exclusion of natural disturbances.	N.D.
China	CO_2 (all sectors) HCFC-22 and HFC-23 (industry)	- / 2030	Relative, based on GDP growth (/2005)	N.D.	Integrated Accounting methodology N.D.	Highlights the requirement to make a NAP for all the Parties
Australia	7 GHG*	2021 - 2030	Absolute (/2005)	N.D.	Integrated Net-net approach	Adaptation strategy underway
Brazil	6 GHG All 7 GHG except NF3	- / 2025	Absolute (/2005)	Maybe Only for mechanisms under the Convention	Integrated Especially reforestation. Accounting methodology N.D.	Important NAP underway (final stage)
Canada	7 GHG*	- / 2030	Absolute (/2005)	Maybe	Integrated Consistent with IPCC guidance. « Production approach » and « net approach » + exclusion of natural disturbances.	N.D.
India	N.D. Mention of « *GHG* », without more details.	2021 – 2030	Relative, based on GDP growth (/2005)	N.D.	Integrated With a focus on carbon sinks increase.	Important Several actions implemented and a national plan underway
Japan	7 GHG*	01/04/2021 - 31/03/2031	Absolute (/2013)	Yes No clear detail on what kind of credits could be used	Integrated *« Removals by LULUCF sector are accounted in line with approaches equivalent to those under the Kyoto Protocol »*	N.D.
Mexico	7 GHG CO_2, CH_4, N_2O, HFCs, PFCs, SF6 + *black carbon* (SLCP)	- / 2030	Relative to a BaU scenario (/2013)	Yes For the conditional target	Integrated With a focus on deforestation reduction.	Important Measures already implemented.
Russian Fed.	7 GHG	01/01/2020 - 31/12/2030	Absolute (/1990)	No	Integrated *« […] forest management is one of the most important elements […] »*	N.D.
South Africa	6 GHG No more details on which GHG, only a reference to a focus on CO_2, CH_4 and N_2O	- / 2030	Relative to a BaU scenario (no detail on the methodology)	N.D.	Integrated (AFOLU)	Important Identification of 6 adaptation targets.
South Korea	6 GHG CO_2, CH_4, N_2O, HFCs, PFCs, SF6	- / 2030	Relative to a BaU scenario (base year N.D.)	Yes Partially	Will be subject to a subsequent decision	Important *National Climate Change Adaptation Plan under way* (2010) + willingness to strengthen their adaptation abilities
Indonesia	3 GHG CO_2, CH_4, N_2O,	- / 2030	Relative to a BaU scenario (/2010)	Yes	Integrated IPCC guidance.	Important *Significant efforts towards developing a « National Action Plan on Climate Change Adaptation »*

Table 10 - Summary of the INDCs analysis. 7 GHG are considered: CO_2, CH_4, N_2O, HFCs, PFCs, SF6, NF3.

Parties	2012 emissions (MtCO2eq)		LULUCF in the INDC	
	GHG emissions, excl. LULUCF (source : GICN counter based EDGAR)	LULUCF (source : FAO)	Typology of LULUCF INDC objective	Quantified target (when given)
EU 28	4 619	- 277	Will be subject to a subsequent decision	N.D.
The United-States	5 963	- 420	Integrated Net-net approach for the land sector + « production approach » to account for harvested wood products + exclusion of natural disturbances	N.D.
China	12 916	- 292	Integrated Accounting methodology N.D.	*« […] by 2030 […] to increase the forest stock volume by around 4.5 billion cubic meters on the 2005 level. »*
Australia	562	+ 35	Integrated Net-Net approach*	N.D.
Brazil	1 211	+ 792	Integrated Especially reforestation. Accounting methodology N.D.	*« - […] zero illegal deforestation by 2030 and compensating for greenhouse gas emissions from legal suppression of vegetation by 2030; - Restoring and reforesting 12 million hectares of forests by 2030, for multiple purposes; - Enhancing sustainable native forest management system, through georeferencing and tracking systems applicable to native forest management, with a view to curbing illegal and unsustainable practices. »*
Canada	703	+ 126	Integrated Consistent with IPCC guidance. « Production approach » and net approach » + exclusion of natural disturbances.	N.D.
India	3 084	- 129	Integrated With a focus on carbon sinks increase	*« […] for the period 2021 to 2030 […] to create an additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent through additional forest and tree cover by 2030 […] »*
Japan	1 643	- 137	Integrated *« Removals by LULUCF sector are accounted in line with approaches equivalent to those under the Kyoto Protocol »*	*« The target for removals is set approximately 37 million tCO2 ((2.6% reduction of total emissions by FY 2013) (corresponding to 2.6% reduction of total emissions in FY 2005)) (approximately 27.8 million tCO2 by forest carbon sinks measures […] and approximately 9.1 million tCO2 by cropland management, grazing land management and revegetation […]»*
Mexico	667	+ 24	Integrated With a focus on deforestation reduction.	*« Reach a rate of 0% deforestation by the year 2030. »*
Russian Fed.	2 600	- 123	Integrated *« […] forest management is one of the most important elements […] »*	N.D.
South Africa	417	≈ 0	Integrated (AFOLU)	N.D.
South Korea	708	- 32	Will be subject to a subsequent decision	N.D.
Indonesia	813	+ 1 213	Integrated. IPCC guidance.	N.D.

Table 11 - LULUCF emissions in INDCs. *The net-net approach is a LULUCF accounting methodology defined as the difference between the total net GHG flow from LULUCF in a given year and that in a defined base year is accounted for in the country's GHG balance. Example: In the base year, LULUCF activities removed 10 million tons of CO_2. In year X these activities remove 11 million tons of CO_2. The country books a credit of 1 million tons of CO_2 for year X. » (cf. art.3.3 of the Kyoto Protocol, and : http://unfccc.int/land_use_and_climate_change/lulucf/items/4129.php - last visit 20/11/15-)

100% emissions

EU 28 INDC

% global GHG (GICN counter) :
2012: 8.5% (8.6 tCO_2eq/cap)
2030: 5.1% (6.4 tCO_2eq/cap)
2030: 5.9% (6.4 tCO_2eq/cap)

INDC : « *The EU and its Member States are committed to a binding target of an* ***at least 40% domestic reduction in greenhouse gas emissions by 2030 compared to 1990***. »

Kind of objective : Absolute, compared to 1990 level

Period : 01/01/2021 – 31/12/203

Perimeter :
◊ 7 GHG
◊ 100% emissions
◊ Economy-wide

International credits : No

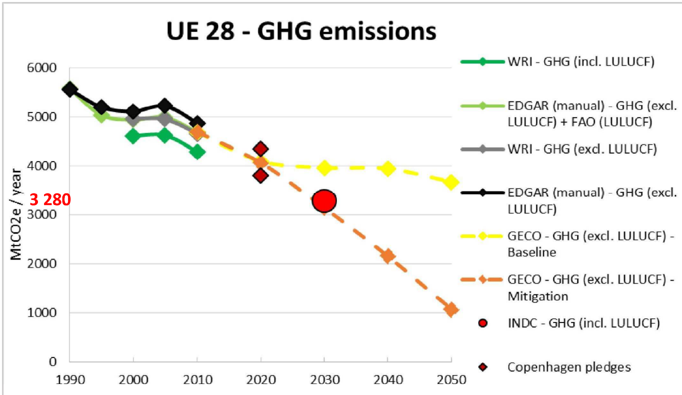
Post-2030 : Reduce GHG emissions consistently with IPCC recommendations to achieve a 80-95% reduction for industrialized countries by the year 2050 compared to 1990 levels

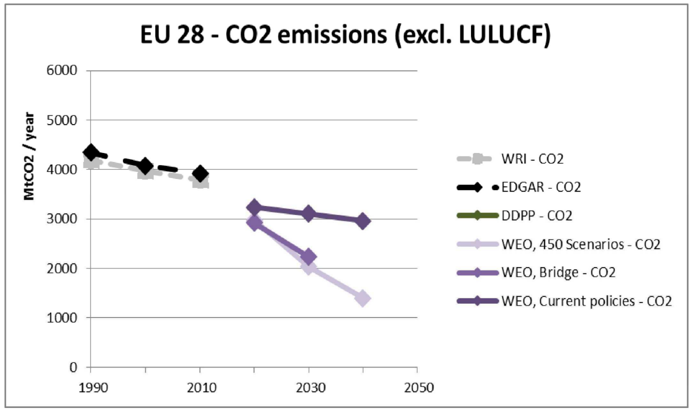
Policies : « *Legislative proposals to implement the 2030 climate and energy framework […] to be submitted by the European Parliament in 2015-2016 on the basis of the general political directions by the European Council […]* »

LULUCF : « *Policy on how to include Land Use, Land Use Change and Forestry into the 2030 greenhouse gas mitigation framework will be established as soon as technical conditions allow and in any case before 2020.*»

Negative emissions from LULUCF (2012) : - 277 MtCO2

INDC 2030 : 3 280 MtCO2eq, incl. LULUCF



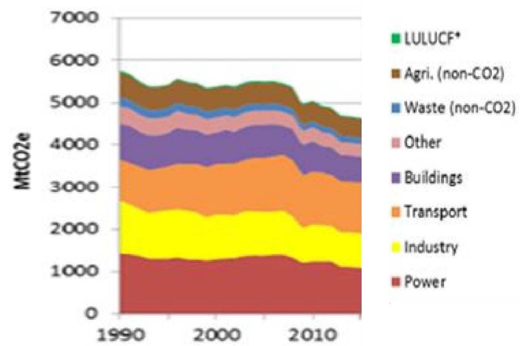


◊ The European INDC is **in line with GECO mitigation path**

◊ The European INDC is consistent with GHG emission trend since 1990.

◊ No mention of adaptation issues in the INDC

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



2025

USA INDC

% global GHG (GICN counter) :
2012: 10.3% (16.7 tCO_2eq/cap)
2030: 7% (12.6 tCO_2eq/cap)
2030: 7.9% (12.2 tCO_2eq/cap)

INDC : « *The United States intends to achieve an economy-wide target of* ***reducing its greenhouse gas emissions by 26% - 28% below its 2005 level in 2025 and to make best efforts to reduce its emissions by 28%.*** »

Kind of objective : Absolute, compared to 2005 level

Period : - / 2025

Perimeter :
◊ 7 GHG
◊ 100% emissions
◊ Economy-wide

International credits : No « *at this time* »

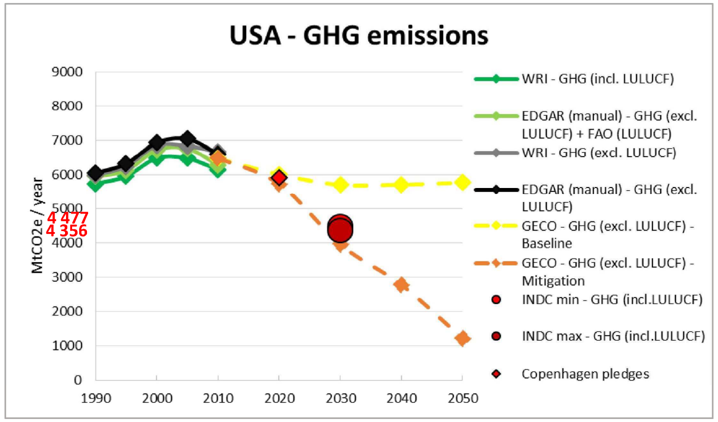
Post-2030 : « *This target is consistent with a straight line emission reduction pathway from 2020 to deep, economy-wide emissions reductions of 80% or more by 2050* »

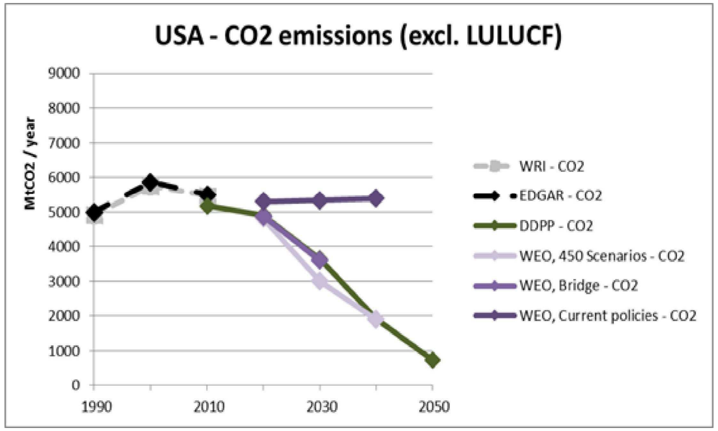
Policies : Continuity of current policies, in particular :
◊ *The Clean Air Act* (standards and regulations in the transportation sector, power plants emissions reduction, development of standards to regulate methane emissions in the oil and gas sectors, etc.)
◊ *The Energy Policy Act,* and *the Energy Independence and Security Act* (measures to address buildings sector emissions, building regulation, energy-saving standards for devices, etc.)

LULUCF : Consistent with IPCC guidance :
◊ « net-net approach » for the land sector
◊ « production approach » to account for harvested wood products
◊ Exclusion of emissions from natural disturbances

Negative emissions from LULUCF (2012) : - 420 MtCO2

INDC 2030: 4 356 - 4 477 MtCO2eq, incl. LULUCF



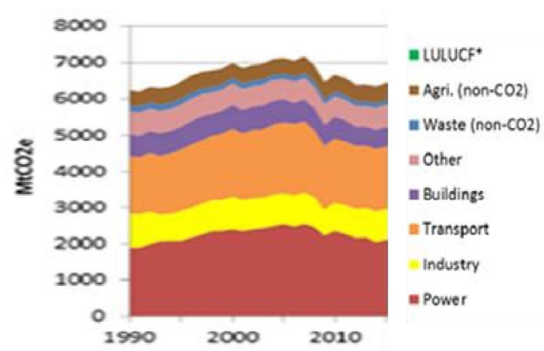


◊ USA INDC path is consistent with the 2020 objective (17% GHG emission reduction compared to 2005 level)

◊ **Speed-up of the emission reduction pace** between 2020 et 2025 (up to - 2.8% per year compared to the 2005-2020 emission reduction pace)

◊ No mention of adaptation issues in the INDC

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



China INDC

Peak – plateau - decline

% global GHG (GICN counter) :
2012: 24.8% (9.3 tCO_2eq/cap)
2030: 23.9% (10.8 tCO_2eq/cap)
2030: 23.2% (9 tCO_2eq/cap)

INDC : « *China has nationally determined its actions by 2030 as follows:*

- ◊ ***To achieve the peaking of carbon dioxide emissions around 2030* and making best efforts to peak early;**
- ◊ ***To lower carbon dioxide emissions per unit of GDP by 60% to 65% from the 2005 level;***
- ◊ ***To increase the share of non-fossil fuels in primary energy consumption to around 20%; and***
- ◊ ***To increase the forest stock volume by around 4.5 billion cubic meters on the 2005 level. »***

Kind of objective: Relative (based on GDP growth, compared to 2005 level)
Peak (2030) – plateau - decline

Period : - / 2030

Perimeter :
◊ CO_2 (+ HCFC-22 and HFC-23 for the industry)
◊ Economy-wide

International credits : N.D.

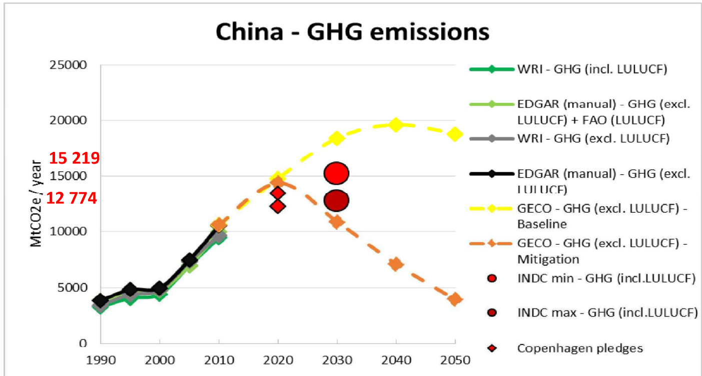
Post-2030 : N.D.

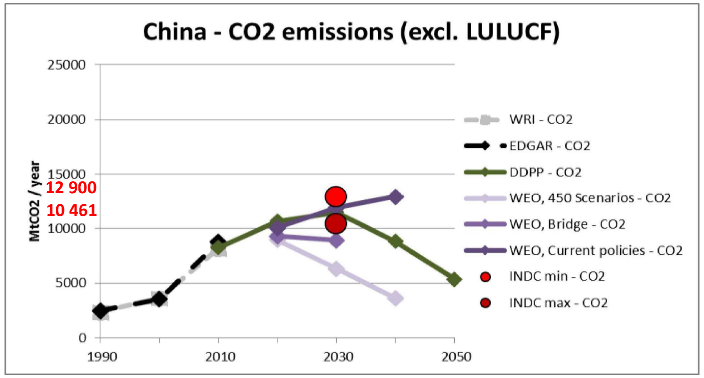
Policies : Identification of several additional measures to be implemented, in particular :
◊ Building a low-carbon energy system
◊ Industry: to build an energy efficient and low-carbon industrial system, to diminish the production and consumption of HCFC-22 (35% reduction from the 2010 level by 2020, and 67.5% by 2025), to achieve effective control on HFC-23 emissions by 2020, etc.
◊ Building and transportation sectors: to control emissions by improving EE of buildings, to promote the share of green buildings, to develop a low-carbon transportation system, etc.
◊ Carbon emission trading market
N.B. 2 pilot projects : « *carbon emissions trading pilots* » & « *low carbon development pilots* »

LULUCF: To increase carbon sinks and to reduce deforestation-related emissions (enhance afforestation, protect and restore forest, strengthen forest disaster prevention, etc.)
Accounting methodology N.D.

Negative emissions from LULUCF (2012) : - 292 MtCO2

INDC 2030 : 12 774 – 15 219 MtCO2eq, incl. LULUCF





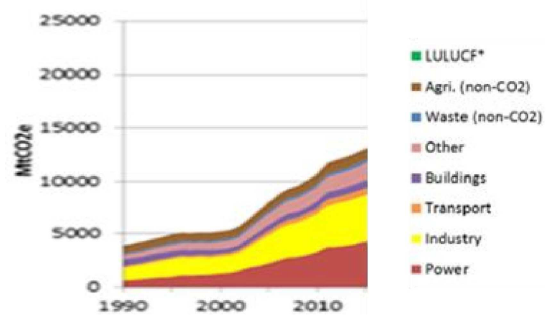
GDP growth rate:
GICN counter : 5-7% (INDC min.) & 4-7% (INDC max.) for the 2015-2030 period
GECO : 6.4% (2010-2030) *WEO : 6% (2012-2040)*

◊ INDC expressed in terms of GDP carbon intensity reduction: **what is the expected growth rate?**
Cf. the box below the graphs for economic growth rate hypotheses

◊ Focus on emerging and industrialized countries differentiation (historical responsibility of developed countries)

◊ Beyond mitigation, a focus is also put on development and adaptation issues

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



Key role of non-CO2 GHG

Australia INDC

% global GHG (GICN counter) :
2012: 1.2% (26.1 tCO_2eq/cap)
2030: 0.8% (17 tCO_2eq/cap)
2030: 0.9% (16.5 tCO_2eq/cap)

INDC: « *Australia will implement an economy-wide target to reduce greenhouse gas emissions by* ***26 to 28 per cent below 2005 levels by 2030.*** »

Kind of objective: Absolute, compared to 2005 level

Period : 2021-2030

Perimeter :
◊ 7 GHG
◊ 100% emissions
◊ Economy-wide

International credits : N.D.

Post-2030 : « *As part of this process* [*nb.* a government consultation planned for 2017-18 to structure post-2020 policy measures], *the government will consider a potential long term emissions reduction goal for Australia, beyond 2030, taking into account international trends and technology developments.* »

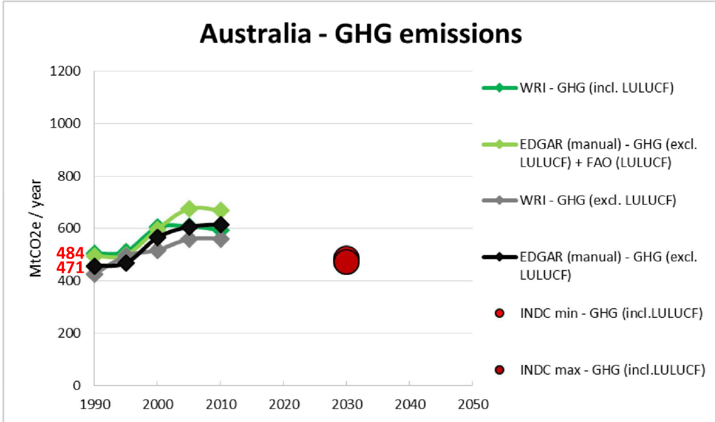
Policies : Continuity and strengthening of current policies, in particular :
◊ *Australia's Emissions Reduction Fund* : emissions reduction while improving productivity (exchanges market, without offset)
◊ *Australia's Renewable Energy Target Scheme* (2020 target : 23% of renewable electricity)

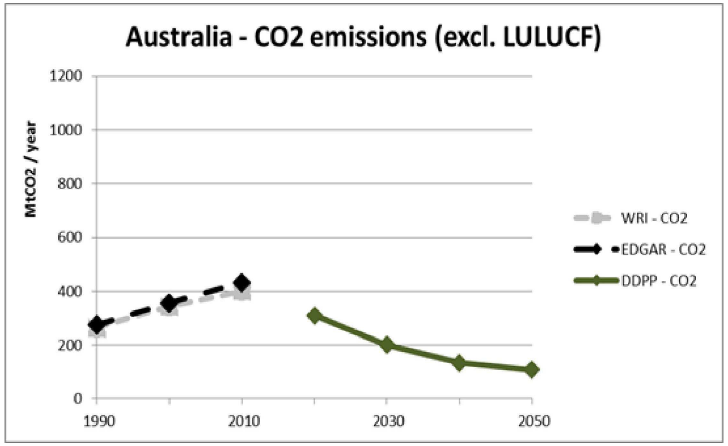
Additional policies :
◊ *National Climate Resilience and Adaptation Strategy* (2015)
◊ The Australian government will undertake a consultation in 2017-18 to determine further post-2020 emissions reduction policies

LULUCF : « net-net approach »

Positive emissions from LULUCF (2012) : + 35 MtCO2

INDC 2030 : 471 - 484 MtCO2eq, incl. LULUCF





◊ Less ambitious commitments compared to the target announced by the *Climate Change Authority* (between -40 to -60 % emissions reduction compared to 2005 level)…

◊ … However, this 2030 target would enable Australia to achieve :
- **A significant decrease in its GHG intensity of GDP** (-64/-65% by 2030 compared to 2005 levels)
- **A decrease in its per capita GHG intensity** (-50/-52% by 2030 compared to 2005 levels)

◊ The INDC refers to its own target as an « *ambitious, fair and responsible contribution* »

◊ **Adaptation strategy underway** by the government

◊ Australia **reserves the right to adjust its target** in the case the new global agreement differs in a way that materially impacts the definition of Australia's target

Brazil INDC

2025

% global GHG (GICN counter) :
2012: 3.9% (9.9 tCO_2eq/cap)
2030: 2.1% (5.7 tCO_2eq/cap)
2030: 2.4% (5.7 tCO_2eq/cap)

INDC : « *Contribution :* *Brazil intends to commit* ***to reduce greenhouse gas emissions by 37% below 2005 levels in 2025****.*
Subsequent indicative contribution: ***reduce greenhouse gas emissions by 43% below 2005 levels in 2030****.* »

Kind of objective: Absolute, compared to 2005 levels

Period : - / 2025 (*« indicative values for 2030 for reference purposes only »*)

Perimeter:
- ◊ 6 GHG (NF3 left out *)
- ◊ Economy-wide

International credits : Possible use, only for mechanisms that may be established under the Paris agreement

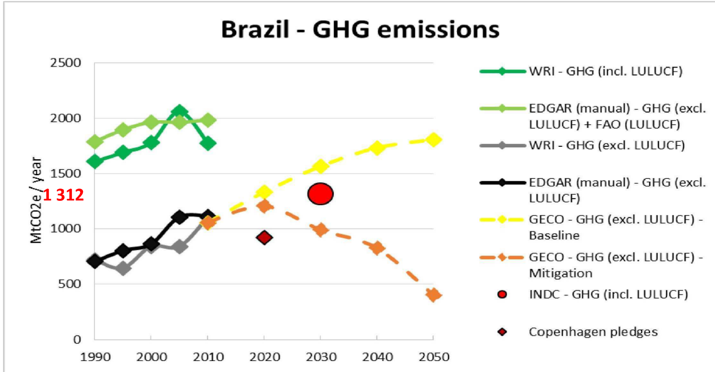
Post-2030 : *« […] Brazil will strive for a transition towards energy systems based on renewable sources and the decarbonisation of the global economy by the end of the century […] »*

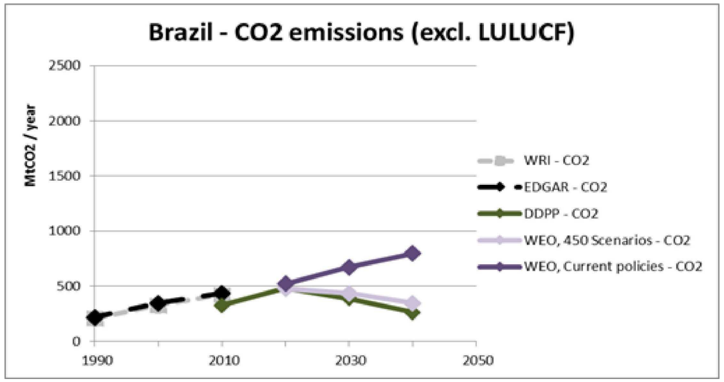
Policies :
- ◊ *National Adaptation Plan (NAP)* in its final development stage (focusing on adaptation strategy)
- ◊ Intention to adopt additional measures focusing on natural resources development and protection (*National Water Security Plan + National Strategic Plan for Protected Areas + Forest Code*)
- ◊ Intention to adopt new measures focusing on the mitigation aspect, in particular :
  - Energy : 45% REN in its energy mix by 2030 (*n.b.* 40% in 2015)
  - Industry : promotion of new standards and clean technologies to improve EE
  - Transportation: efficiency measures, public transportation infrastructure improvement in urban areas, etc.

LULUCF : Several targets, in particular :
- ◊ Deforestation-related emissions reduction by 2030: zero illegal deforestation and compensate GHG from legal suppression of vegetation (*n.b.* deforestation rate reduction between 2004 and 2014: -82%)
- ◊ Restore & reforest 12 million ha of forests by 2030
- ◊ Increase the share of sustainable biofuels : +18% by 2030

Positive emissions from LULUCF (2012): + 792 MtCO2.

INDC 2030 : 1 312 MtCO2eq, incl. LULUCF

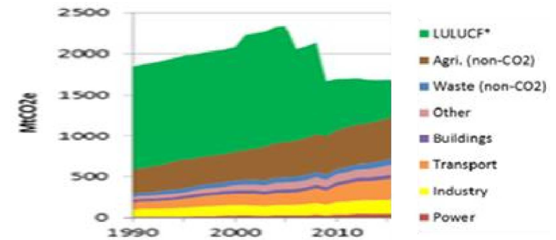




NF3*: a GHG with a warming power 17 000 times more powerful than CO2. This gas is especially used for the thin-film solar panel production.

- ◊ 2012 : emissions reduction by 41% compared to 2005 levels (incl. LULUCF)
- ◊ Low-carbon economy : currently 40% REN in its energy mix, of which 70% for its electricity supply
- ◊ The INDC would lead to 66% GHG emissions reduction per GDP unit in 2025 compared to 2005 (2030: -75%)
- ◊ Strong efforts to reduce deforestation-related emissions (≈ +250 MtC in 2005; +70MtC currently)
- ◊ **Adaptation** : key element of the INDC (strongly inked to social issues + vulnerability mitigation) + *National Adaptation Plan* underway
- ◊ **Development:** poverty eradication, education, access to energy, water management, etc.
- ◊ *« The implementation of Brazil's INDC is not contingent upon international support, yet it welcomes support from developed countries with a view to generate global benefits. »*
- ◊ Recognition of **South-South cooperation** : forest monitoring systems, low carbon and resilient agriculture, restoration and reforestation activities, increasing resilience through social inclusion and protection programmes, etc.

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



Canada INDC

Regulatory approach

% global GHG (GICN counter) :
2012: 1.5% (22.3 tCO_2eq/cap)
2030: 1% (15.2 tCO_2eq/cap)
2030: 1.1% (15.2 tCO_2eq/cap)

INDC: « *Canada intends to achieve an economy-wide target to reduce its greenhouse gas emissions* ***by 30% below 2005 levels by 2030.*** »

Kind of objective: Absolute, compared to 2005 levels

Period : - / 2030

Perimeter:
◊ 7 GHG
◊ 100% emissions
◊ Economy-wide

International credits: Maybe (« *Canada may use international mechanisms to achieve its 2030 target* »)

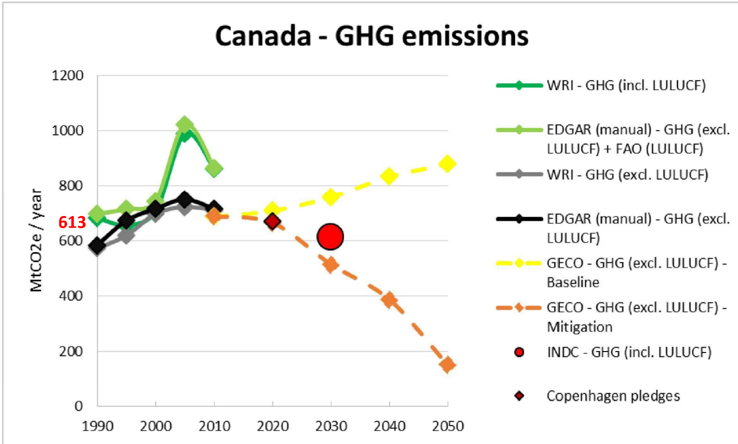
Post-2030: N.D.

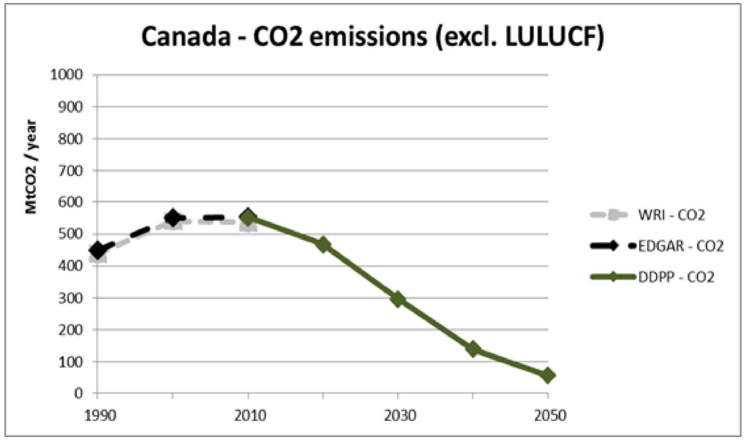
Policies : Strengthening of the Canadian « sector-by-sector regulatory approach », in particular :
◊ To strengthen standards harmonisation with the main partners (USA)
◊ Transportation sector (25% GHG): establish more stringent standards for heavy-duty vehicles of post-2018 model years, etc.
◊ Electricity sector : banishing the construction of traditional coal-fired electricity generating units + intention to progressively phase out the existing coal-fired electricity units without CCS, reduce GHG emissions from natural gas-fired electricity, etc.
◊ Other: gradually phase down HFCs, reduce methane emissions from the oil and gas sector, etc.

LULUCF: Consistent with IPCC guidance :
Net-net approach for the land sector, « production approach » to account for harvested wood products, and exclusion of emissions from natural disturbances

Positive emissions from LULUCF (2012) : + 126 MtCO2

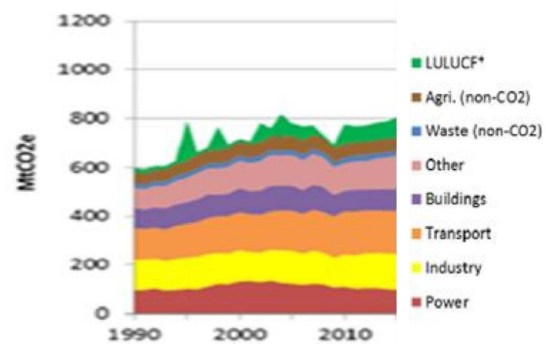
INDC 2030 : 613 MtCO2eq, incl. LULUCF





◊ Almost 80% of electricity supply already emitting no GHG
◊ From 2005 to 2013 : GHG emissions reduction by -3.1% while the economy grew by 12.9%
◊ Regulatory approach coupled to **significant investments** in clean energy technologies ($10 billion since 2006)
◊ **Regional actions** with their own legal and policy frameworks
◊ **No mention of adaptation** issues in the INDC

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



India INDC

« Developement without destruction »

% global GHG (GICN counter) :
2012: 5.8% (2.3 tCO_2eq/cap)
2030: 10.4% (4.3 tCO_2eq/cap)
2030: 10.8% (3.9 tCO_2eq/cap)

INDC: *« […] India hereby communicates its Intended Nationally Determined Contribution (INDC) […] for the period 2021 to 2030 : […]*
*3. To reduce the **emissions intensity of its GPD** by **33 to 35 percent by 2030 from 2005 level**.*
*4. To achieve about **40 percent 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).*
*5. To create an **additional carbon sink of 2.5 to 3 billion tonnes of CO2 equivalent** through additional forest and tree cover by 2030. […] »*

Kind of objective: Relative, based on GDP growth (compared to 2005 levels)

Period : 2021-2030

Perimeter :
◊ No clear details on which GHG and sectors are considered for the monitoring

International credits: N.D. Only a mention of the key role played by international finance mechanisms (such as the *Green Climate Fund*)

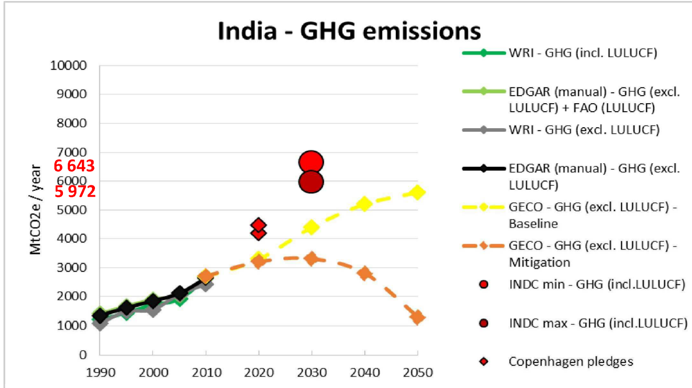
Post-2030: N.D.

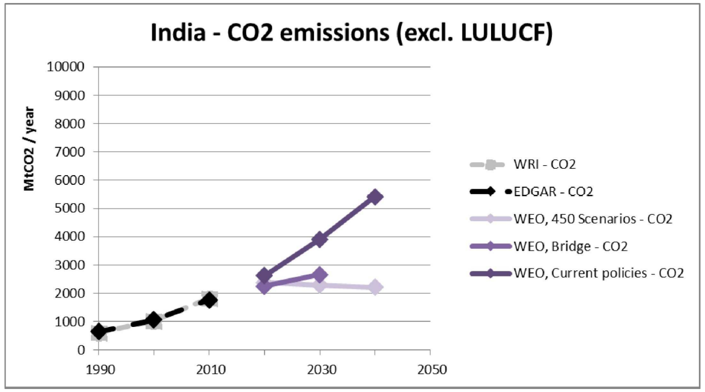
Policies: Absence of quantified target for 2030. Continuity of the currently implemented framework, in particular :
◊ *Mitigation strategies*: efficient and clean energy system, EE improvement in the industry sector, afforestation, waste management, GHG emissions reduction in the transportation sector, etc.
◊ *Adaptation strategies*: focus on agriculture, water, health eau, santé, disasters management, biodiversity, etc.
◊ Financial tools: 2 national funds (*Cess on Coal* et *Nation Adaptation Fund*) , taxes and subsidies on oil products to incite to a low-carbon growth

LULUCF:
◊ Increase of the forest area over the last years (national policies) : net carbon sinks increase
◊ Additional carbon sinks by 2030 : 2.5-3 billion tCO_2eq

Negative emissions from LULUCF (2012) : -129 MtCO2.3

INDC 2030 : 5 972 – 6 643 MtCO2eq, incl. LULUCF





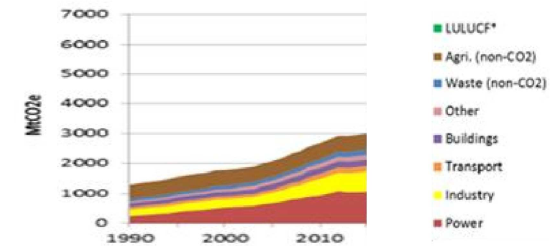
***GDP growth rate**:*
GECO : 6.3% (2010-2030)
GICN counter : 6.5-5 %& 6.5-4 %(2015-2030)
WEO : 6.4% (2012-2040)

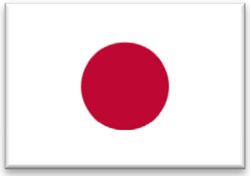
◊ INDC expressed in terms of carbon intensity of GDP reduction : **what is the expected growth rate** ?

Cf. the box below the graphs for economic growth rate hypotheses

◊ 3 quantified targets and various qualitative aspirations
◊ 40% REN target in electric in terms of electric capacity and not in terms of production (currently 24%)
◊ To ensure a reliable, adequate and affordable supply, coal will continue to be highly present. However : initiatives to improve the efficiency of coal power plants
◊ Focus on the key role of financial and technology transfers from industrialized countries
◊ **Development and adaptation issues** are central priorities
◊ From 2012 to 2030 : more urbanization, elec. demand x 3.2, growth rate 7%, GDP/cap x 3

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model





Details for each GHG and each sector

Japan INDC

% global GHG (GICN counter) :
2012: 3% (11.8 tCO_2eq/cap)
2030: 1.6% (8.3 tCO_2eq/cap)
2030: 1.8% (8.4 tCO_2eq/cap)

INDC : « *Japan's INDC towards post 2020 GHG emissions reductions is at the level of a reduction of* ***26.0% by fiscal year (FY) 2030 compared to FY 2013*** *(**25.4% reduction compared to FY 2005**) (approximately 1.042 billion t-CO2eq. as 2030 emissions), ensuring consistency with its energy mix, set as a feasible reduction target by bottom up calculation with concrete policies, measures and individual technologies taking into adequate consideration, inter alia, technological and cost constraints, and set based on the amount of domestic emissions reductions and removals assumed to be obtained.* »

Kind of objective: Absolute, compared to 2013 levels

Period : 01/04/2021 – 31/03/2031

Perimeter :
- ◊ 7 GHG
- ◊ 100% emissions
- ◊ Economy-wide

International credits : No clear details of the relationship between the use of credits and the INDC target achievement: :
- ◊ Mention of the use of the *JCM**
- ◊ Mention of the use of « *other international contributions […] estimated to be at least 1 billion tCO2* »

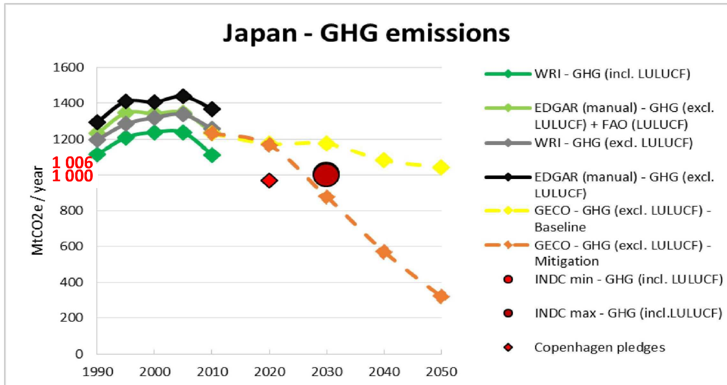
Post-2030: Mention of the INDC consistency with the global 2°c goal « and with the goal the country upholds, namely, « *the goal of achieving at least 50% reduction of global GHG emissions by 2050, and as part of this, the goal of developed countries reducing GHG emissions in aggregate by 80% or more by 2050* ». »

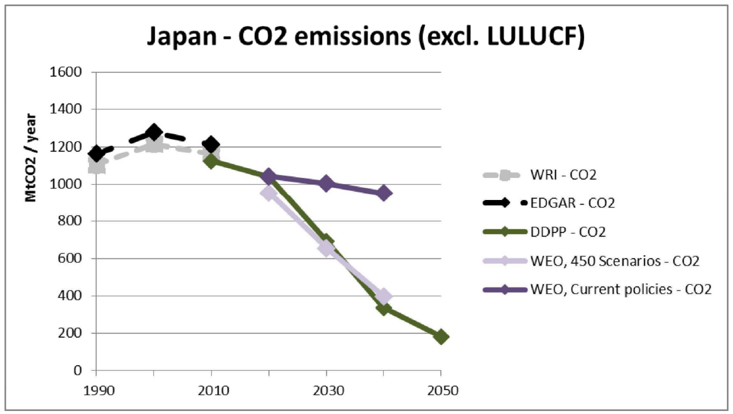
Policies : Details by sector, especially :
- ◊ Industry: details by industry, especially a willingness to improve overall industry EE, etc.
- ◊ Transportation: EE improvement (including aviation), new generation vehicles promotion, etc.
- ◊ Residential: improvement of EE, energy saving standards, etc.
- ◊ Commercial: EE and conservation buildings, etc.

LULUCF: « *The target for removals is set approximately 37 million tCO_2 (26% reduction of total emissions in FY 2013)* » = *27.8$MtCO_2$* by forest management + 9.1*MCO_2* by cropland and grazing land managements, grazing land and revegetation Removals by LULUCF sector accounted in line with « *approaches equivalent to those under the KP* »

Negative emissions from LULUCF (2012) : -137 MtCO2

INDC 2030 : 1 000 – 1 006 MtCO2eq, incl. LULUCF

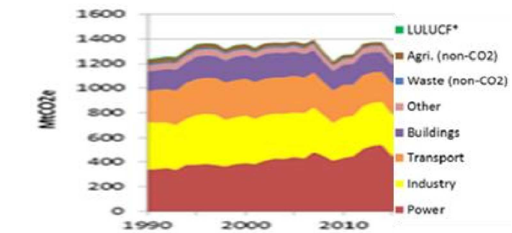




- ◊ Exhaustive and detailed emissions target (details are given for each sector and each GHG, *cf.* table below for GHG details)
- ◊ International contribution will be materialized by a **transfer of low carbon intensity advance technologies** (for more than1 billion tCO_2)
- ◊ Current electricity mix: 26% coal, 27% Gas, 20-22% nuclear, 22-24% REN.
- ◊ **Nothing on adaptation** issues

GHG	/2013	/2005
CO_2 energy (90% GES)	-25%	-24%
Non-energy CO_2	-6.7%	-17%
CH_4	-12.3%	-18.8%
N_2O	-6.1%	17.4%
HFC_s,PFC_s, SF_6, NF_3	-25.1%	+4.5%

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



JCM (Joint Crediting Mechanism): Mechanism similar to the CDM, but not integrated into the UNFCCC.
The INDC refers to the use of this mechanism to achieve the 2030 target for which the « annual budget are estimated to be ranging from 50 to 100 million tCO2 »

Black carbon accounting

Mexico INDC

% global GHG (GICN counter) :
2012: 1.4% (5.7 tCO_2eq/cap)
2030: 1.2% (5.1 tCO_2eq/cap)
2030: 1.1% (4.2 tCO_2eq/cap)

INDC : « *Mexico is committed* ***to reduce unconditionally 25% of its Greenhouse Gases and Short Lived Climate Pollutants emissions*** *(below BAU) for the year* ***2030****. This commitment implies a* ***reduction of 22% of GHG and a reduction of 51% of Black Carbon.*** *This commitment implies a* ***net emissions peak starting from 2026****, decoupling GHG emissions from economic growth:* ***emissions intensity per unit of GDP will reduce by around 40% from 2013 to 2030.*** »
« *The 25% reduction commitment expressed above could increase* ***up to a 40% in a conditionnal manner*** *[…] within the same conditions, GHG reductions could increase up to 36%, and Black Carbon reductions to 70% in 2030.* »

Kind of objective: Relative to a BaU scenario * (BaU = 1110MtCO2 in 2030)

Period : - / 2030

Perimeter:
◊ 7 gas** (GES et **SLCPs*****)
◊ Economy-wide

International credits : Yes for the conditional target « *In order to achieve rapid and cost efficient mitigation, robust global market based mechanism will be essential.* »

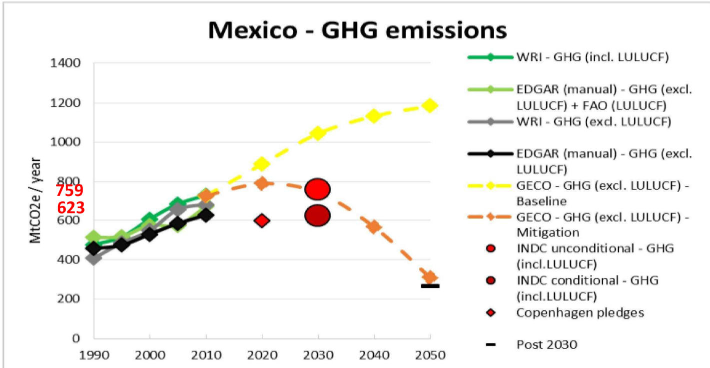
Post-2030: « *The INDC is consistent with Mexico's pathway to reduce 50% of emissions by the year 2050, with respect to the year 2000, as mandated by the LGCC* ». (*n.b.* LGCC :*The General Law on Climate Change*)

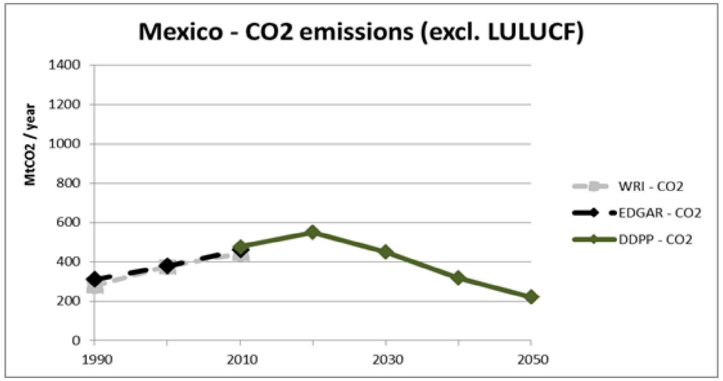
Policies: Current policies instruments strengthening:
◊ *General Climate Change Law* (2012)
◊ *National Strategy on Climate Change*, 10-20-40 years (2013)
◊ *National Emissions and Emissions Reductions Registry* (2014)
◊ *Energy reform (laws and regulations)* (2014)
Processes to implement new standards and regulations underway

LULUCF: Discussed with the « adaptation » side :
◊ 0% deforestation by 2030
◊ Natural carbon sinks increase
◊ Other non-quantified targets for ecosystem management

Positive emissions from LULUCF (2012) : +24 MtCO2

INDC 2030 : 623 - 759 MtCO2eq, incl. LULUCF





◊ Strong interest in co-benefits induced by GHG reductions (**development view**)

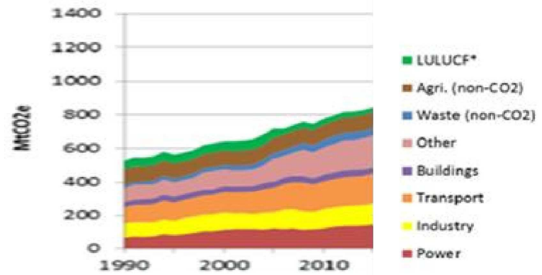
◊ Differentiation between « unconditional targets » and « conditional targets » (*n.b.* conditional : depending on additional resources and technology transfers availability)

◊ **Development approach** focusing on mitigation and adaptation issues (health, gender equality, etc.)

◊ **Adaptation is a key issue** of the INDC, especially: vulnerability reduction, 0% deforestation by 2030, etc.

◊ INDC **in line with GECO mitigation path** for GHG emissions

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



*BaU scenario : « *Business As Usual scenario of emission projections based on economic growth in the absence of climate change policies, from 2013 (first year of implementation of Mexico's General Climate Change Law)* »
gas: CO_2, CH_4, N_2O, HFCs, PFCs, SF6, *Black Carbon* (*n.b. black carbon*** **not integrated into the GICN counter)**
***SLCPs : Short-Lived Climate Pollutants

Russian Fed. INDC

20% of word forests

% global GHG (GICN counter) :
2012: 4.4% (15.7 tCO_2eq/cap)
2030: 4.4% (20.24 tCO_2eq/cap)
2030: 4.8% (19 tCO_2eq/cap)

INDC : « *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 forests.* »

Kind of objective: Absolute, compared to 1990 levels

Period : 1/01/20 – 31/12/30

Perimeter :
- ◊ 7 GHG
- ◊ Economy-wide

International credits : No

Post-2030: « *reducing GHG emissions by 25-30% from 1990 levels by 2030 will allow the Russian Federation to step on the path of low-carbon development compatible with long-term objective of the increase in global temperature below 2 degrees Celsius. This objective can be achieved with efforts of all Parties of the future climate agreement.*».

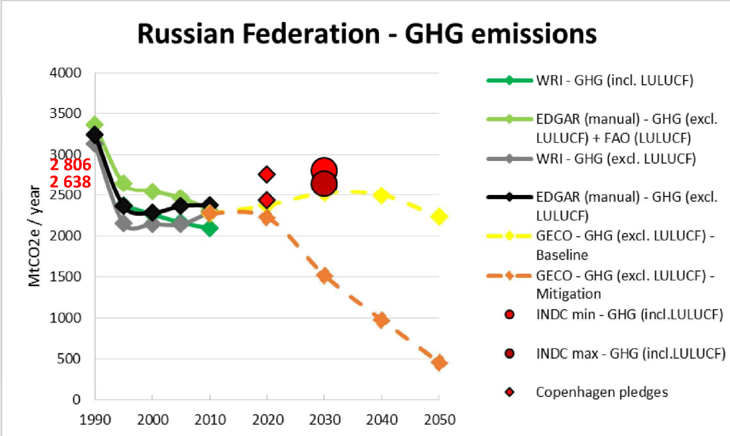
Policies : Already implemented :
- ◊ *Decree of the President of the Russian Federation of 30 September 2013*
- ◊ *Act of the Government of the Russian Federation of 2 April 2014*

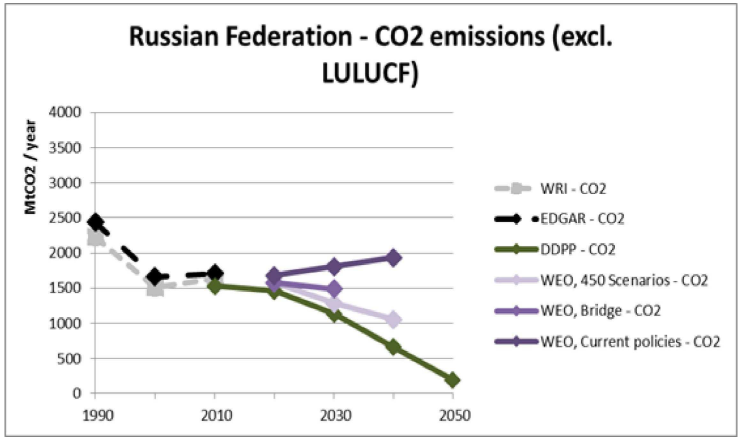
Expected implementation of legislative and regulation acts to achieve the 2030 targets

LULUCF : « *Rational use, protection, maintenance and forest reproduction, i.e. forest management, is one of the most important elements of the Russian policy to reduce GHG emissions* »

Negative emissions from LULUCF (2012) : - 123 MtCO2

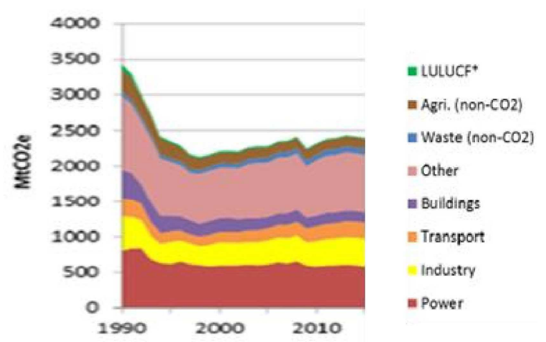
INDC 2030 : 2 638 – 2 806 MtCO2eq, incl. LULUCF





- ◊ Conditional nature of the contribution (« *might be* »)
- ◊ Carbon intensity reduction (nb. 2012 compared to 2000: GDP growth by +172.9%, emissions increase (excl. LULUCF) by +111.8%)
- ◊ **Nothing** in the INDC **on adaptation issues**
- ◊ Key role of biomass and forests to achieve the 2030-target

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



South Africa INDC

Peak – plateau - decline

% global GHG (GICN counter) :
2012: 0.8% (7.9 tCO_2eq/cap)
2030: 1.0% (10.2 tCO_2eq/cap)
2030: 0.7% (6.6 tCO_2eq/cap)

INDC : « *[…] South Africa's mitigation component of its INDC moves from a "deviation from business-as-usual" form of commitment and takes the form of a peak, plateau, deline GHG emissions trajectory range. South Africa's emissions by* ***2025 and 2030 will be in a range between 398 and 614 MtCO2-eq****, as defined in national policy.* »

Kind of objective: Relative to a BaU scenario (methodology N.D. in the INDC)
PPD : Peak (2020-25) – plateau (for approx. a decade) - decline

Period : - / 2030

Perimeter :
- ◊ 6 GHG (no more details, except a focus on CO_2, CH_4, N_2O)
- ◊ Economy-wide

International credits: N.D.

Post-2030 : No specific target, but refer to the consistency of the INDC with a global 2°C target

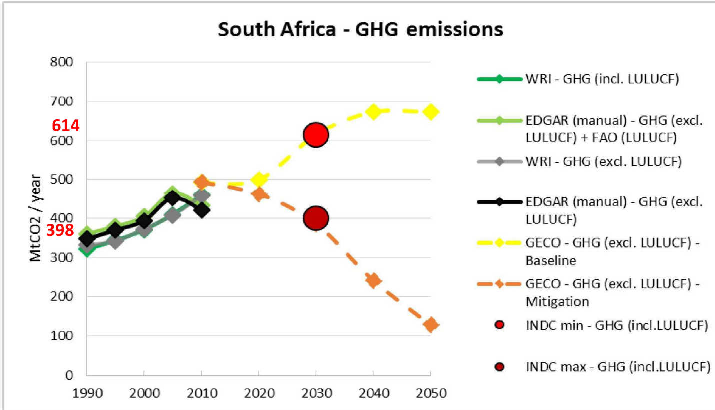
Policies : Various policies instruments underway for both adaptation and mitigation sides, especially:
- ◊ A *National Adaptation Plan*
- ◊ Carbon tax
- ◊ Company-level carbon budgets + regulatory standards and controls

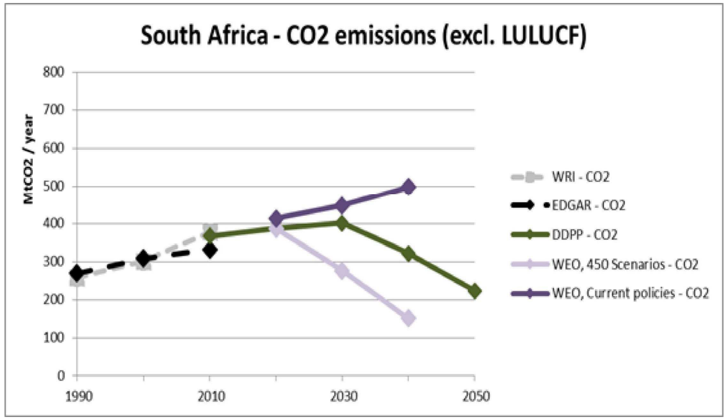
LULUCF: AFOLU* + « *The greater uncertainty in AFOLU emissions should be noted, as well as the intention to reduce uncertainty over time.* »

Zero emissions from LULUCF in 2012

AFOLU*: Agriculture + LULUCF

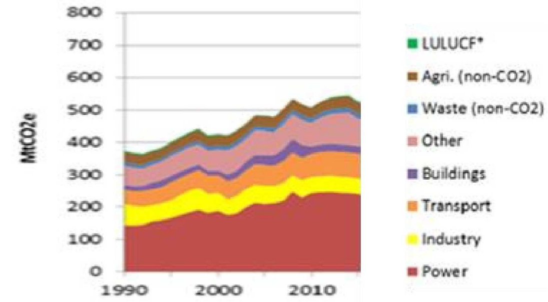
INDC 2030 : 398 - 614 MtCO2eq, incl. LULUCF





- ◊ INDC in 2 parts : « adaptation » and « mitigation »
- ◊ PDD trajectory starting from 2020 : Peak (2020-25) then Plateau (for approx. a decade), then Decline
- ◊ Focus on **development and equity** (« *eliminate poverty and inequity, promote inclusive economic growth and reduce unemployment* »)
- ◊ Conditional INDC target depends on financial and technology transfers
- ◊ **Adaptation as a key issue** + identification of 6 adaptation targets with details on specific investments needs for each one
- ◊ **INDC min. in line with GECO mitigation path for GHG emissions**

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



Exclusion of NF3* gas

South Korea INDC

% global GHG (GICN counter) :
2012: 1.3% (13.6 tCO_2eq/cap)
2030: 0.8% (10.2 tCO_2eq/cap)
2030: 1.0% (10.2 tCO_2eq/cap)

INDC : « *Korea plans to reduce its greenhouse gas emissions* ***by 37% from the business-as-usual*** ***(BAU, 850.6 MtCO2eq)*** ***level by 2030*** *across all economic sectors.* »

Kind of objective: Relative to a BaU scenario * (850.6MtCO2eq in 2030) / base year N.D.

Period : - / 2030

Perimeter :
- ◊ 6 GHG**: CO_2, CH_4, N_2O, HFCs, PFCs, SF6
- ◊ Economy-wide

Post-2030: « *Despite the challenges, Korea has set a target for 2030, which is expected to be in line with the recommendations of the IPCC Fifth Assessment Report to reduce global greenhouse gas emissions by 40-70% from 2010 levels by 2050.* »

International credits: yes for a partial use

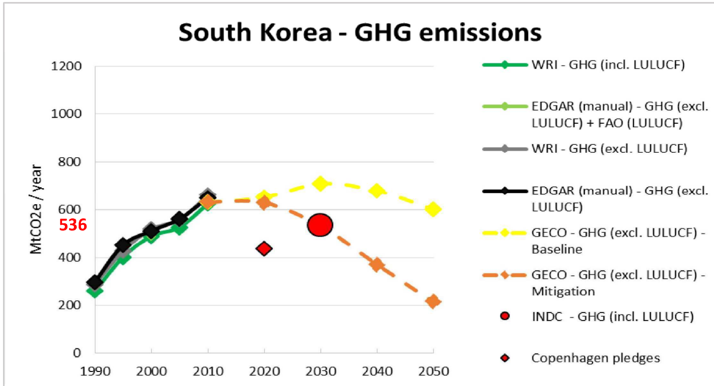
Policies : A detailed plan to implement 2030-target measures will be developed once the mitigation target is finalized at the international level

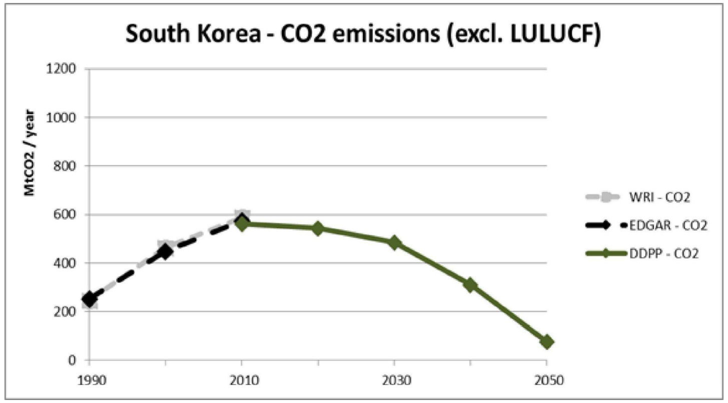
N.b. Already implemented framework:
- ◊ Industry : ETS since 2015 covering 525 entities (67.7% of national emissions)
- ◊ Electricity sector : REN share increase in the mix
- ◊ Building sector : EE improvement
- ◊ Transportation: infrastructure for environmental-friendly public transportation, low-carbon standards for automobiles (140g/km in 2015, 97g/km in 2020), tax reduction for electric and hybrid vehicles, etc.

LULUCF: « *A decision on whether to include land use, land-use change and forestry (LULUCF) will be made at a later stage* »

Negative emissions from LULUCF (2012) : -32 MtCO2

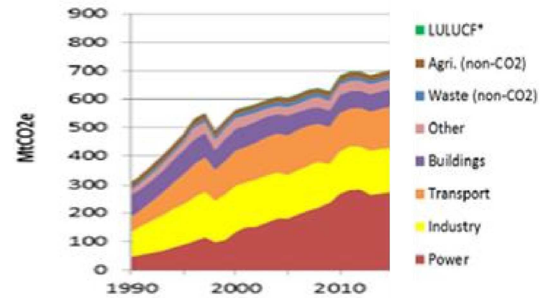
INDC 2030 : 536 MtCO2eq, incl. LULUCF





- ◊ 2020-target : GHG emissions reduction by 30% compared to BaU path
- ◊ Sectorial level of mitigation policies
- ◊ **Adaptation:** Development of the *National Climate Change Adaptation Plan* (2010) + Government's willingness to strengthen its adaptation abilities by implementing various actions, such as: systematic transition to a « climate-resilient social and economic structure »; strengthening infrastructure for climate change monitoring, forecasting and analysis; developing a management system for disaster prevention and stable water supply, etc.
- ◊ INDC **in line with GECO mitigation path** for GHG emissions

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



BaU : « The scenario is based on the BAU projection of KEEI-EGMS (the Korea Energy Economics Institute Energy and GHG Modeling System), taking into account projections for key economic variables, including population, GDP, industrial structure and oil price »
***NF3 is left out the GHG scope. This gas is linked to the production of : computers, solar panels, flat-screen TVs, touch screens, electronic processors, etc.*

Integrated vision « mitigation – adaptation »

Indonesia INDC

% global GHG (GICN counter) :
2012: 4% (8.2 tCO_2eq /cap)
2030: 3.2% (6.9 tCO_2eq /cap)
2030: 3.1% (5.8 tCO_2eq/cap)

INDC : Unconditional : « *[…] Indonesia is committed* ***to reducing emissions by 29%*** ***compared to the business as usual (BAU) scenario by 2030*** *[…]* »
Conditional : « *Indonesia's target should encourage support from* ***international cooperation, which is expected to help Indonesia to increase its contribution up to 41% reduction in emissions by 2030****.* »

Kind of objective: Relative to BaU scenario (« *[…] scenario based on the country's most recent assessment of the 2010's National Action Plan on GHG Reduction. The BaU scenario is projected approximately 2 881GtCO2e in 2030* ») / base year : 2010

Period : - / 2030

Perimeter :
- ◊ 3 GHG: CO_2, CH_4, N_2O.
- ◊ Economy-wide

International credits : Yes for the conditional target (unconditional target achievement will be met regardless of international market mechanism)

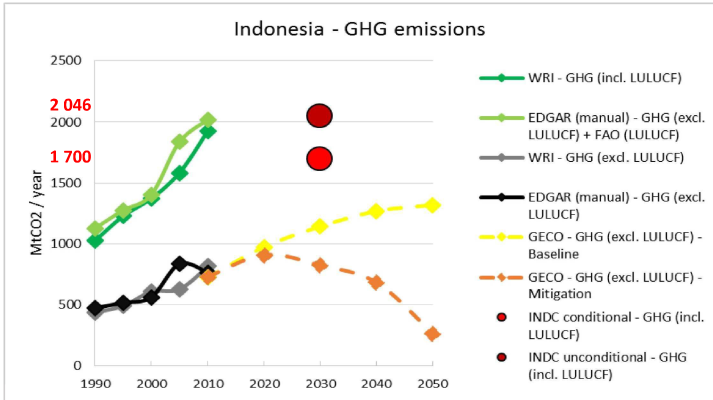
Post-2030 : « *Indonesia's INDC outlines the country's transition to a low carbon future […] that will lay the foundation for more ambitious goals beyond 2020, contributing to the concerted effort to prevent 2°c increase in global temperature.* »

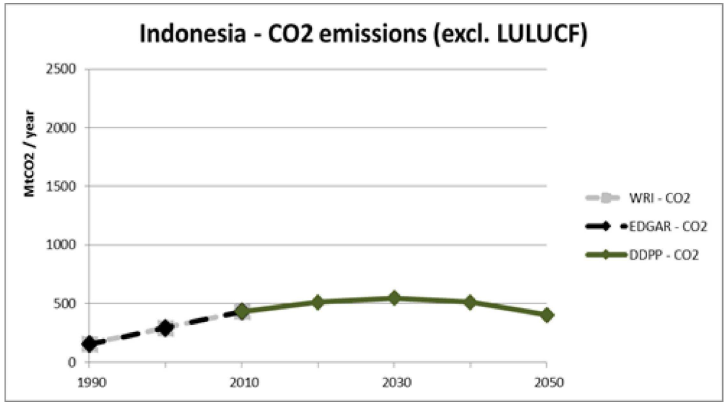
Policies :
- ◊ Electricity sector : at least 23% REN in 2025
- ◊ Waste sector: « *Reduce, Reuse, Recycle* » approach
- ◊ *National Action Plan on Climate Change Adaptation*

LULUCF : IPCC guidance
- ◊ Implementation of a moratorium on the clearing of primary forests, peat land conversion ban from 2010-2016
- ◊ Improvement of land and forestry managements (deforestation, restoration, etc.) + ocean-based climate change adaptation and mitigation + ecosystem protection
- ◊ 2005 : most emissions (63%) result from land use change and peat and forest fires

Negative emissions from LULUCF (2012) : +1 213 MtCO2

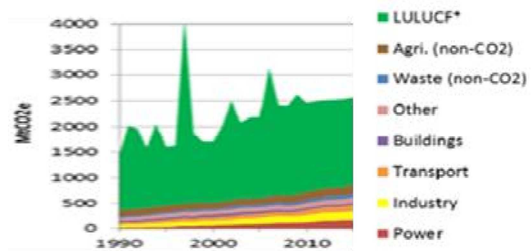
INDC 2030 : 1 700 – 2 046 MtCO2eq, incl. LULUCF





- ◊ Baseline scenario used is a BaU scenario of emissions projections starting, based on 2000-2010 historical trajectory, with increase projections in the energy sector and the absence of mitigation actions.
- ◊ **GHG peak, but no given date**
- ◊ **Adaptation and mitigation** are integrated as cross-cutting priorities
- ◊ Vulnerable country and so, especially focusing on adaptation issues :
  - Climate change is a significant risk for natural resources (food, water, energy, etc.)
  - *« innovative climate mitigation and adaptation efforts by government, the private sector, and communities »* (regional subdivision)
- ◊ **Development**: climate issues are integrated into development plans (*poverty, water, education, gender equality, food security, energy access*, etc.)
- ◊ Key-role for **the international cooperation**

Sectoral GHG emissions, incl. LULUCF.
IPTS-GECO 2015 projections
Source : JRC POLES model



Groupe Interdisciplinaire sur les Contributions Nationales

Negative emissions generate significant uncertainty when assessing INDCs relative to 2°C pathways

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Reviewed by Hervé Le Treut (IPSL, UPMC).

Negative emissions generate significant uncertainty when assessing INDCs relative to 2°C pathways.

Summary

The 2°C objective requires a rapid and substantial reduction in emissions over the next decades; otherwise it only remains possible when "removing" CO_2 from the atmosphere: this is called negative emissions. However, methods to produce negative emissions currently are only at very early stages of development, if any; their potentials for large scale deployment are still unknown (they could be none for some) and they involve risks still poorly known but potentially important. These methods cannot be considered as substantial complements to mitigation measures in the coming decades, and generate significant uncertainty for scenarios covering the second half of the 21st century.

Conclusions

- To limit global warming to 2°C, zero or slightly negative net emissions will have to be reached by the end of this century. The negative emissions technologies - if viable on a large scale - would remove CO_2 from the atmosphere, and thus make the goal of carbon neutrality at the end of the century more easily attainable.
- Large-scale deployment of negative emissions technologies remains highly speculative. Even if these technologies become viable, they are in no way an alternative to mitigation policies or a possibility to defer them.
- Among the various options discussed to provide these negative emissions, reforestation and forest management are already known and relatively mastered. However their overall potential remains limited and uncertain.
- The Carbon Capture and Storage technology, often coupled with bioenergy, is the one favored by the IPCC scenarios consistent with the 2°C objective, most of which do not reach this goal without using this technique substantially (net negative emissions). Yet nothing ensures the actual feasibility of this technique to the scale suggested by models.
- Each of the techniques considered to provide these negative emissions can be limited in terms of potential, including difficult scaling, costs, energy consumption, and possible competition with other resource uses.
- In addition, there are major uncertainties on these techniques, particularly on their actual carbon footprints, environmental impacts, the availability of biomass for bioenergy due to changing agricultural yields and the acceptance of the population.
- The possibility of deploying negative emissions by the end of the century, as well as uncertainties about the potential and limitations of these, make it particularly uncertain to assess INDCs compared to the 2°C target.

Definition

Negative emissions refer to different techniques or technologies leading to deliberate removal of CO_2 from the atmosphere. However, the exact scope of the concept is not fixed and varies according to studies (see Figure 5). The techniques considered are called "Carbon Dioxide Removal" (CDR). We talk about **net negative emissions** when global gross negative CO_2 emissions exceed gross positive emissions from all sources.

Technologies

Technologies most seriously considered are[17] :

- The **development of wooded areas**, thereafter called reforestation. Tree growth transfers CO_2 from the atmosphere to the biomass and soil, allowing medium term storage. This method, in fact the most mature, has been included for a long time in the original text of the UNFCCC, long before the term negative emissions was used. It has the co-benefit of being a strong element of an adaptation strategy.
- The use of **biomass as an energy source coupled with CO_2 capture** (acronym: BECCS): the point is to use biomass, which growth naturally removes carbon dioxide from the atmosphere, as fuel to generate energy (important co-benefit), while capturing and storing the CO_2 emitted during combustion. This technology is at the demonstration stage of its components. This is a method often used in 2°C scenarios.
- The **direct capture of CO_2 from ambient air**, as opposed to collecting it on industrial sites, using chemical absorbents; CO_2 is then released in concentrated form to be stored or valued. Some prototypes of this technology exist.

Moreover, it makes sense to mention here techniques for **geological carbon storage** (the acronym CCS includes carbon capture), which must be linked to certain methods (BECCS and direct capture) to result in negative emissions. They are designed to permanently store CO_2 captured with various processes in geological reservoirs (oil fields, saline aquifers). These technologies are currently in the demonstration phase for CO_2 capture from industrial sites (oil sites in particular) or plants using fossil fuels; in which case they fall under emission reduction measures and will not result in negative emissions. Nevertheless, the development of these fossil applications is related to that of negative emissions applications, since the same technologies and storage capacities are at stake.

Finally, the captured CO_2 can also be valued as different products, but which often concern niche markets. However, note that methanisation, considered for storing energy from intermittent sources (wind, solar), requires a CO_2 supply.

[17] Also worth mentioning is the **manufacturing and burying of biochar** (type of charcoal) in soils in order to increase their carbon content and fertility. This technique involves producing biomass and turning it into biochar, which residence time is longer than that of biomass. It is not a negative emission in the long term but rather an improvement of carbon sequestration in the continental biosphere.

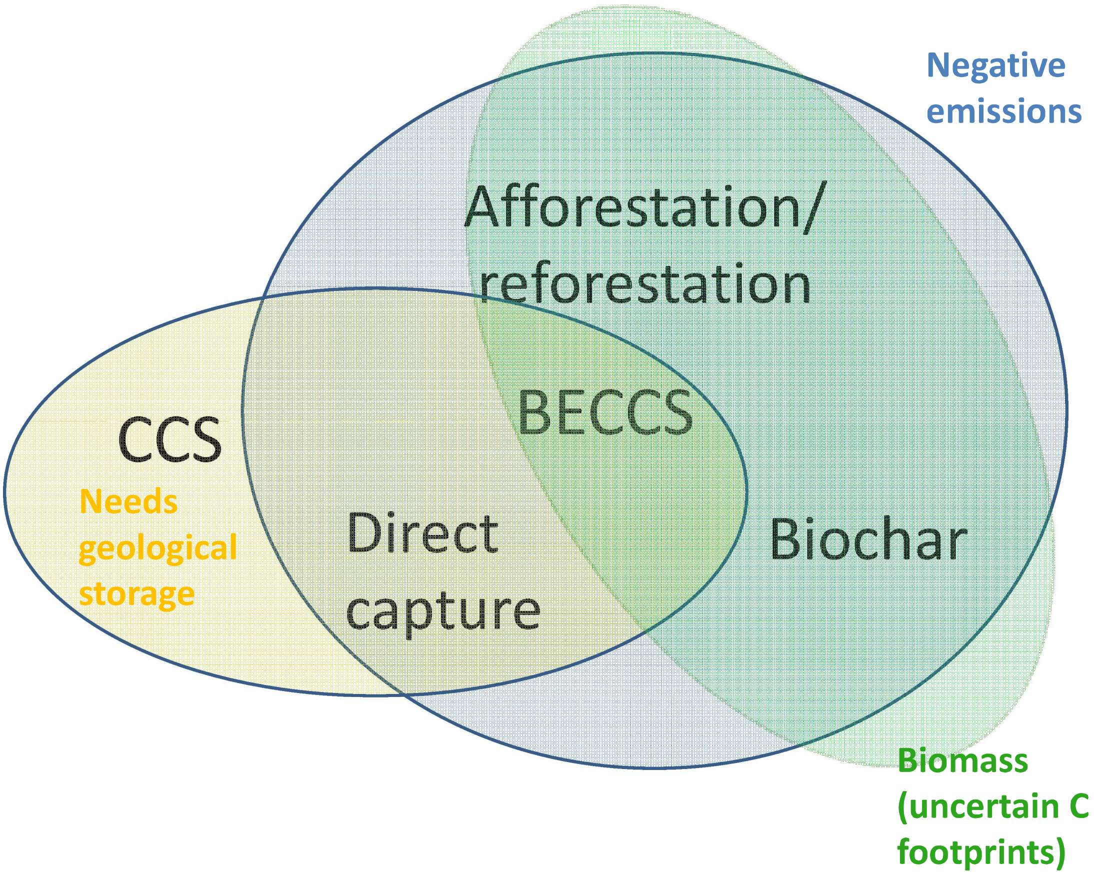

Figure 15 - Les émissions négatives, une définition pas vraiment arrêtée.

Limitations and uncertainties

Negative emissions techniques have a number of limitations and uncertainties, common or specific to the technologies. In particular should be mentioned:

- The difficulty to **reach required upscaling**: our ability to implement these techniques on a scale sufficient to limit warming remains very uncertain. For instance, the size and geographical accessibility of geological reservoirs that could store CO_2 over long periods are far from being established, and would involve for some methods building very important infrastructure, e.g. for transporting CO_2 between capture and storage sites, which could also cause leaks that would limit the technology efficiency.
- The **costs and financing** issue, crucial for a large scale deployment: investment and maintenance costs required, although varying according to the methods and still not stabilized due to their immaturity, are very substantial and could be the limiting factor for the technology deployment. In this context, a high carbon price would prove necessary; one study estimated 40-110 $ / tCO2 for BECCS, and 450-550 $ / tCO2 for direct capture (Smith-et-al, 2015).
- The **very long timescale** associated with some of these methods, especially those based on photosynthesis, a biological process with a very low yield, limiting CO_2 capture speed. They should be widely deployed for at least half a century to significantly decrease atmospheric CO_2 content (IPCC, 2014).
- The **maturity** of these techniques, which have significant needs in R&D before they can be deployed, especially for assessing their efficacy and risks, their potential in a context of global warming, as well as economic, political and ethical aspects.

- The **difficulty to test or validate** some methods on a significant scale, since the planet has no 'alternative' atmosphere or oceans, which makes it all the more risky to deploy certain techniques.
- In general, the financing of these methods is fully dependent on a **reliable verification system** of actual quantities of CO_2 removed (for details, see the fact sheet on MRV).
- **High energy requirements** for some methods; for instance direct capture, which takes place on an air flow very poorly concentrated in CO_2, is very energy consuming: to reduce the atmospheric CO_2 concentration from 400 to 360 ppm, using this technology would require the equivalent of 10 years of our current primary energy consumption (Boucher, 2012) ; which, besides the associated cost, impacts the carbon footprint that is only viable through carbon-free energy sources.
- The **carbon footprint** of these methods, which is not guaranteed to be negative.
  - BECCS: Strong uncertainties relate to the **feedstock sustainability**, which depends on the type of biomass used and what it replaces (localization) and on the simple technical feasibility. A BECCS industrial demonstrator will soon enter into operation in England; nevertheless it is today not possible to assess the costs and efficiency of the technology, although it is used conceptually in economic scenarios.
  - Reforestation induces **carbon storage that may not be permanent** (e.g., carbon can return to the atmosphere due to fires) and its magnitude strongly depends on the reforested location. Once the forest has grown to maturity, the storage cannot be increased further and needs to be preserved.
  - As for geological storage, its permanence is not guaranteed (leaks).
  - The **impact of global warming** on the efficiency of some methods is uncertain (especially those related to organic production), as well as the response of the carbon cycle to negative emissions (carbon exchange between atmosphere and natural reservoirs offset in part emissions or withdrawals of CO_2: this is the *Rebound effect*), which may decrease the methods efficiency.
- **Environmental impacts** are uncertain and potentially important. These should be better characterized before deploying these methods to prevent actions potentially more damaging than beneficial for the climate and the environment. Particularly be mentioned are:
  - The biophysical impacts of land use change (BECCS) or reforestation can be particularly strong at the local / regional scale: uncertain effect on temperature and precipitation by changing the albedo, the evapotranspiration and surface roughness.
  - All methods related to organic production potentially generate ecosystem disturbances, and therefore have an impact on biodiversity.
- The development of forests and BECCS involve **direct competition with basic needs**: food security in a context of growing population and therefore increasing demand for food, protection of biodiversity (including preservation of primary forest), protecting subsistence farming and preventing conflicts for access to resources (including water).
- For BECCS, this generates **strong uncertainties about the availability of biomass resources**, related to uncertainties on the availability of surfaces, or water, population growth, diets and global governance modes (biomass resources are widely available in developing countries). Furthermore, evaluating the potential of this technique involves assumptions on **crop yields**, subject to high uncertainty about their evolution with climate change.

A regulatory, political and societal context yet to build

The implementation of large scale negative emissions calls for a **global regulatory framework** in order to regulate the distribution of costs and benefits and compensations for possible damage caused. Regarding the geological storage of carbon, numerous studies point to the utter dependence of this technology to a strict policy of climate mitigation: stringent emission limits, high carbon prices. This regulatory framework will sometimes have to be accompanied by **political decisions** concerning safety and the risk of conflict arising from the implementation of certain techniques.

Moreover, many **ethical issues** remain to be discussed to ensure procedural, intergenerational (these techniques transfer a part of the climate risk in the future) and global justice. Secondly, the moral hazard that implementing these techniques could actually lead to a loss of motivation to reduce emissions will have to be prevented. Finally, the **acceptance** of these technologies by the population is not acquired: they are little known and poorly viewed. In Europe there is strong opposition to BECCS and geological storage.

Implications for a 2°C target

"To limit warming to 2 ° C, emissions must be zero or even negative by the end of the 21st century" (conference Our Common Future under Climate Change, 2015). Indeed, while our **carbon budget** (net cumulative emissions over the period 2015-2100 providing sufficient probability of limiting warming to 2°C) is estimated at 1000-1200 $GtCO_2$ (Fuss-et-al, 2014; UNEP, 2014), the use of negative emissions techniques on a large scale is considered necessary by many studies. This need varies greatly depending on the scenario and can be therefore unattainable if mitigation is performed late and unambitiously (Gasser-et-al, 2015; Ryaboshapko-et-al, 2015). **These methods are implemented in most 2°C IPCC scenarios, even when presenting rapid and ambitious mitigation policies**, as soon as climate sensitivity is in the high end and in all scenarios if reforestation is also considered. As for scenarios with more ambitious climate targets (1.5°C), they are estimated out of reach without significant negative emissions in most models. **However to date, negative emissions stay a concept introduced in models to obtain trajectories compatible with 2°C.**

2°C scenarios mostly plan the use of BECCS, as soon as 2020/2030 and on a gradually large scale. The choice of this technique is the result of an economic optimization between measures to reduce emissions and negative emissions technologies, but which costs are subject to assumptions in models (around 130 €/t) and which **feasibility is assumed possible**. Moreover, models are often based on the assumption that the production of biomass for bioenergy is carbon neutral. This is far from guaranteed, especially when including indirect changes in land use (not included in models; neither is the transport of CO_2 between sites), or energy needs related to the use of biomass. In many cases, biomass for energy creates a carbon debt which takes decades to centuries to be offset by fossil fuel substitution and biomass regrowth (Agostini-Giuntoli-Boulamanti, 2013; Fargione-Hill-Polasky-Hawthorne, 2008).

If this technique is widely considered in the IPCC scenarios for the end of the century, on a short to medium term methods of afforestation/reforestation and soil management seem to be those with lower risks and costs. The different techniques potentials, highly uncertain, are shown next to the carbon budget on the Figure 16.

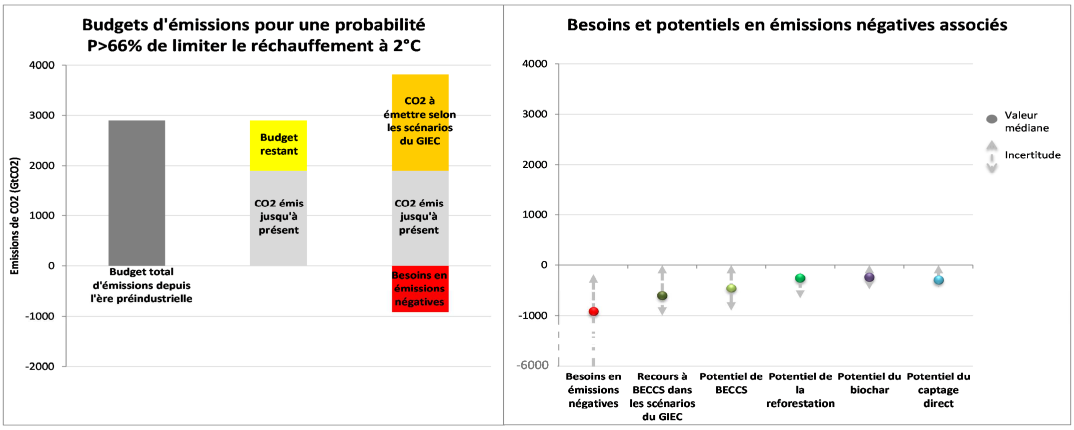

Figure 16 - Emission budgets for a 2°C scenario, associated needs for negative emissions and potentials of the techniques (AVOID2-Wiltshire-et-al, 2015; American Physical Society, 2011; Fuss-et-al, 2014; Gasser-et-al, 2015; UNEP, 2014; IPCC)

In theory, the use of negative emissions technologies would be especially necessary if one grants the right, in order to reach the 2°C goal, to exceed the corresponding CO_2 atmospheric concentrations (*overshooting*): more emissions short-term and/or a later peak of emissions would be possible. However, due to nonlinearities in the system, such overshoots could have significant consequences linked to *tipping points*, such as the melting of Arctic sea ice and the Greenland ice sheet (Lenton-et-al, 2008). Thus, **negative emissions techniques should in no way be considered as an alternative to mitigation policies, or a way to delay them**: any delay in the implementation of mitigation measures increases the required amount of negative emissions and the likelihood of serious consequences poorly anticipated.

Negative emissions in the INDCs

Some of the countries that have already submitted their INDC mention the implementation of negative emissions methods (though never named so) to achieve their 2030 and longer-term goals. Those only include afforestation / reforestation and land use management, since other techniques are not considered feasible by 2030. Among countries referring to such techniques are the following:

- China mentions several measures to strengthen its carbon sinks, including afforestation, reducing deforestation and restoring forests, meadows and wetlands; without giving other quantitative objectives than the ones announced in 2009, to increase its forest cover by 40 million hectares compared to 2005.
- Japan plans negative emissions of 27.8 $MtCO_2$ in 2030 compared to 2013 by forest management, 7.9 $MtCO_2$ by land use management and 1.2 $MtCO_2$ by revegetation.
- Russia, home to 70% of boreal forests and 25% of global forest resources, does not indicate any quantitative target on this, mentioning only the importance of forest management to achieve its emissions reductions goals.
- Mexico's objective is the reforestation of watersheds and the restoration of coastal ecosystems, as well as the total elimination of deforestation in 2030.
- The United States account for land use and associated carbon sinks in their GHG accounting, but without specific quantitative target.
- Brazil's goal is to restore and reforest 12 million hectares of forests by 2030. The country also has a view to achieve, in the Brazilian Amazonia, zero illegal deforestation by 2030 and compensating for greenhouse gas emissions from legal suppression of vegetation by 2030.
- Indonesia plans to reduce deforestation and forest degradation and increase sustainable forest management, but without any specific quantitative target.

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Groupe Interdisciplinaire sur les Contributions Nationales

Benefits of a binding clause on Monitoring / Reporting / Verification in the Paris Agreement

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Reviewed by Hervé Le Treut (IPSL, UPMC).

Benefits of a binding clause on Monitoring / Reporting / Verification in the Paris Agreement

Summary

Reliable Monitoring, Reporting, Verification (MRV) and internationally harmonized accounting of greenhouse gases emissions is the cornerstone of any climate agreement. An agreement on a binding MRV for all parties is desirable, right from the COP21.

MRV is the cornerstone of any climate agreement or regulation

MRV - Monitoring, Reporting, Verification - for greenhouse gas emissions is a **prerequisite for any climate agreement or regulation**, whether the commitments on emissions are binding or not, it is important for the parties to agree on how to count emissions and to trust the reliability of these accounts.

What already exists

Annex I countries already submit an annual greenhouse gas inventories for all sectors of the economy (energy, industrial processes, agriculture, land use change, waste) excluding international transport which is reported outside national totals. This is done based on the "Guidelines" for domestic greenhouse gas inventories made by the IPCC (latest publications are from 2006). The authorities in charge in the different Parties lead a monitoring of their emissions, and notify them to the UNFCCC, which collects them and manages their verification by independent experts (including researchers). Non-Annex I countries submit their emissions in a non-binding way as national communications at different time intervals (typically three to ten years) and biennial reports update. These submissions are not subject to methodological requirements. In particular, they are not required to abide by the IPCC monitoring and reporting guidelines and the UNFCCC principles of transparency, accuracy, consistency, comparability and completeness.

An agreement on principles of MRV is desirable and possible in Paris

MRV can provide a reliable and inter-comparable database on each country's emissions levels. In the spirit of a "positive agenda", there is hope for a virtuous cycle: each country strengthens gradually its mitigation policies while being assured, through this shared and reliable MRV, on efforts made by others. The emission reductions achieved by a country in a given sector may result in further ambition in other countries. Thus, an agreement on MRV in Paris could be based on three principles: trust, transparency and lead by example.

Furthermore, **MRV rules can be relatively respectful of the sovereignty of States**: methods chosen by countries, highlighting the didactic nature of the verification, etc. Note that China, initially recalcitrant on MRV, seems to be more inclined to the idea.

Finally, unlike other negotiations stakes (reduction commitments, financing ...), **MRV is a small cost for the Parties**: the rules for developed countries under the United Nations are applied for under a million euros per country per year[18].

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[18] Bellassen, V., Stephan, N. (Eds.), 2015. Accounting for Carbon: Monitoring, Reporting and Verifying Emissions in the Climate Economy. Cambridge University Press, Cambridge, UK.

Some principles that can be included in the agreement

MRV is not a new subject in the negotiations: binding rules are already in place for Annex I countries, and work relatively well. However, several improvements are needed for a broader agreement that would include emerging countries in particular. Here are some principles that could be included in the Paris agreement and then applied in rules:

- **Including all countries**: it is important that the MRV obligation be extended to emerging countries, like the rest of the Agreement; indeed, non-Annex 1 countries are currently responsible for 59% of global CO_2 emissions from energy and industrial processes (BP 2014), and will potentially represent 71% by 2030 (REDEM projections). Technical support may be envisaged for some developing countries.
- **Incitement**: like all rules, MRV rules must be accompanied by "carrots" or "sticks" to be respected. However, as MRV rules are not a heavy burden, modest incentives may be sufficient. The MRV obligation could also affect access to green financing as it is already the case for result-based REDD+[19].
- **Modulation**: the point is to adapt the requirement level to the emissions level of the country (materiality principle). As an illustration, it is important to remember that the fifty least emitting countries, mostly small island countries, represent only 0.1% of greenhouse gas emissions (EDGAR 2012 data). Thus, a somewhat greater uncertainty will be tolerated for a country or a sector with low emissions. On the other hand, a country or sector with high emissions will have to be more precise but will benefit from significant economies of scale in the implementation of MRV;
- **Securing funding**: centralizing the budget at the UNFCCC would ensure verification regardless of national circumstances[20] ;
- **Comparability of accounting rules**;
- **Bias detection**: the use of several accounting methods should be encouraged for the main sources of emissions, but also the development of methods for independent verification by observing CO_2 streams, which remains the only way to detect bias.

To go further: the science questions on the MRV issue

By convention, current **emissions inventories** include only emissions occurring within the national territory. They thus exclude emissions related to trade in goods, as well as emissions from international aviation and shipping, which are not linked to any country. Other accounting methods have been developed to overcome these deficiencies and thereby strengthen the political relevance of inventories. The COP could decide to add one of these methods to existing inventories.

Furthermore, **climate financing** for developing countries are another mechanism that could be subject to MRV in the context of an overall agreement. This is also the case for **mitigation policies** implemented by each Party. The experience of the scientific community on these points (national communications, etc.) exists but is less rich than for emissions. It is therefore to be built.

[19] Reduction of Emissions from Deforestation, forest Degradation and enhancement of forest carbon stocks.

[20] All countries must appoint auditors and Annex 1 countries must finance their nominees (13/CP.20). The reports of the Secretariat and Lead Reviewers point to the failure to do so as the main source of verification dysfunction (eg. FCCC/SBSTA/2014/INF.1). In 2014, on a total of 59 recruited auditors for Annex I, 10 were unable to participate due to lack of funding from the country that had nominated them.

Groupe Interdisciplinaire sur les Contributions Nationales

National contributions and carbon prices: we need carbon prices, but as a result of the COP21 and not prior to the agreement

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Reviewed by all experts from GICN.

National contributions and carbon prices: we need carbon prices, but as a result of the COP21 and not prior to the agreement

Summary

The introduction of carbon pricing systems is essential to reduce greenhouse gases (GHGs) emissions. However, to negotiate ex ante an international carbon price applicable to all countries poses once again the serious risk of negotiation failure.

In contrast, we must ensure that:

- Carbon-pricing schemes are emerging at subnational, national and regional levels to support the implementation of INDCs;
- At some point, a social cost of carbon[21] - established internationally to reflect the economic damages associated with a small increase in carbon dioxide and the value of damages avoided for an emission reduction – should allow estimating the climate benefits of rulemakings, calibrating national instruments for carbon pricing, guiding consumer choice, investment and R&D choices.

National contributions with initially differentiated national carbon prices that will eventually converge to a reference carbon price

Since the Warsaw Conference in 2013, international negotiations were redirected to a negotiation focused on voluntary contributions (INDCs) that States should submit for COP21. Based on the sovereignty of States and providing *a priori* no international instrumental device, this solution constitutes the initial stage of the new forming climate regime. The non-binding and non-incentive device is probably his first weakness. It does not guarantee that the sum of the national contributions will be consistent with the overall objectives, for example the 2°C target. The second limit arises from the absence - in principle – of economic mechanism ensuring a fair distribution of efforts and economic efficiency.

It should be noted that if economic systems are not present *ex ante* in the agreement, the achievement of national contributions pledged by the States will require the implementation at national or regional scales, of policy instruments explicitly or implicitly introducing a carbon price, in the form of emissions trading markets, carbon taxes, subsidies for low-carbon technologies, technical regulations (on buildings or vehicles, for example), fiscal incentives, etc. Many such instruments have already started to be implemented (see figures below): several countries have introduced a carbon tax, which ranges from \$1/tCO_2 to nearly \$170/tCO_2, emission trading markets exist in Europe, Japan, China, California, etc., carbon regulations on new vehicles exist in Europe, China, Brazil, the USA, etc. Carbon price levels observed in countries that have implemented such control systems show that we are currently far from a sole international price.

[21] The social cost of carbon is the carbon value set and used by the public authorities to take into account the impact of GHG emissions in evaluating its public investment choices and, more generally, its public policies orientations. In France, this approach was developed in the early work of Mr. Boiteux for the French Plan Commission (CGP) and in those of the commission chaired by A. Quinet in 2008 and 2013. The carbon value is estimated to be the price of carbon required to achieve emission reductions arising from objectives from the Kyoto Protocol (stabilization in 2010/1990), from the European climate and energy package for 2020 (20% reduction in emissions/1990), and from the "Factor 4" objective (reduction of 75% for 2050), part of the NOME law of 2005. The last report (Quinet 2013) sets the social cost of carbon: it follows a path starting from € 32/tCO_2 in 2010 reaching € 56/tCO_2 in 2020 and € 100/tCO_2 in 2030.

However in the longer term, a reference carbon value (or a range of values), defined in the context of international negotiations in line with an international objective of limiting global warming to 2°C, should serve as an attractor for calibrating national instruments for carbon pricing, guiding consumption choices, investment and R&D.

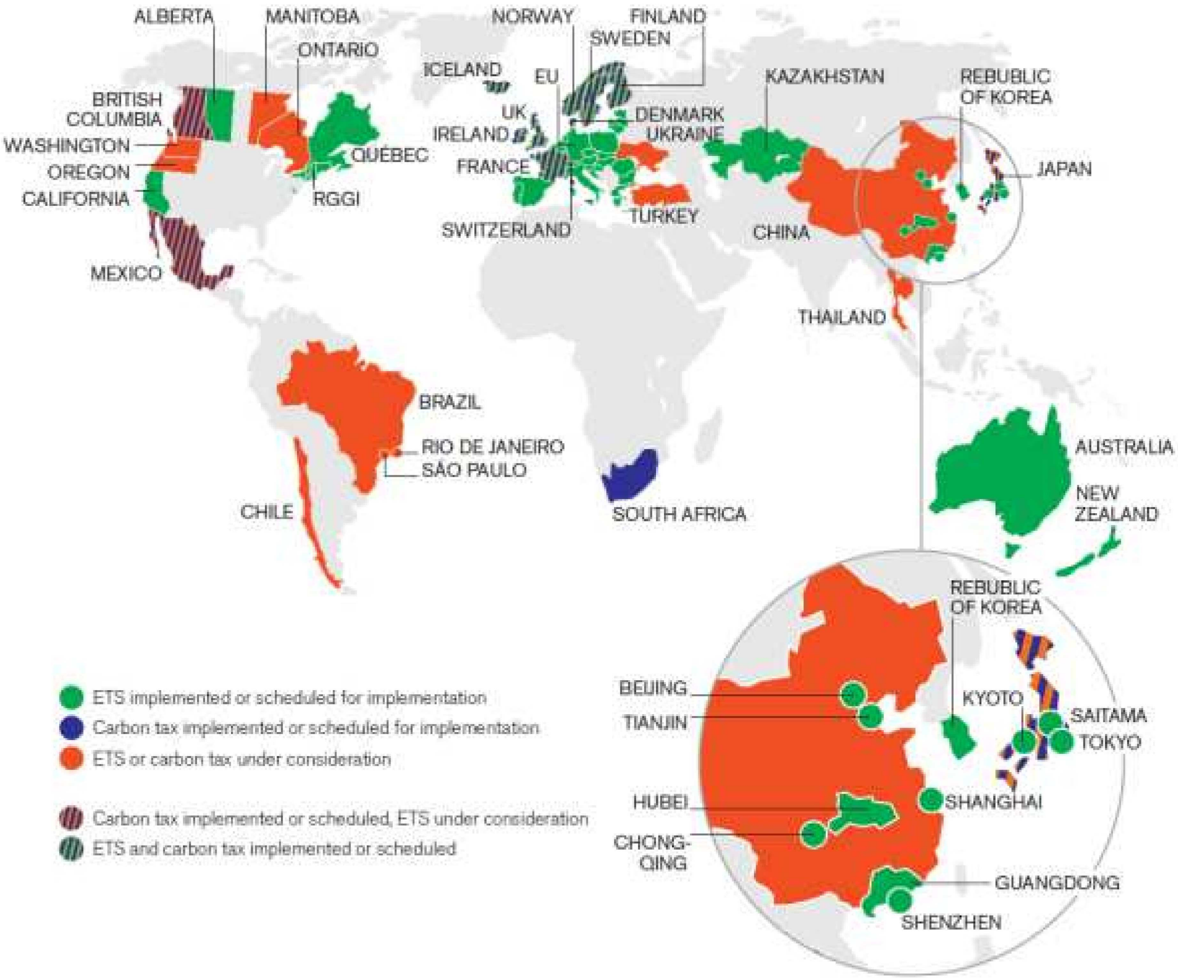

Figure 17 - Mapping of existing, emerging and potential carbon pricing instruments, at regional, national or sub-national levels (quota systems or taxes). Source: World Bank, 2014 State and Trends of Carbon Pricing, Washington DC.

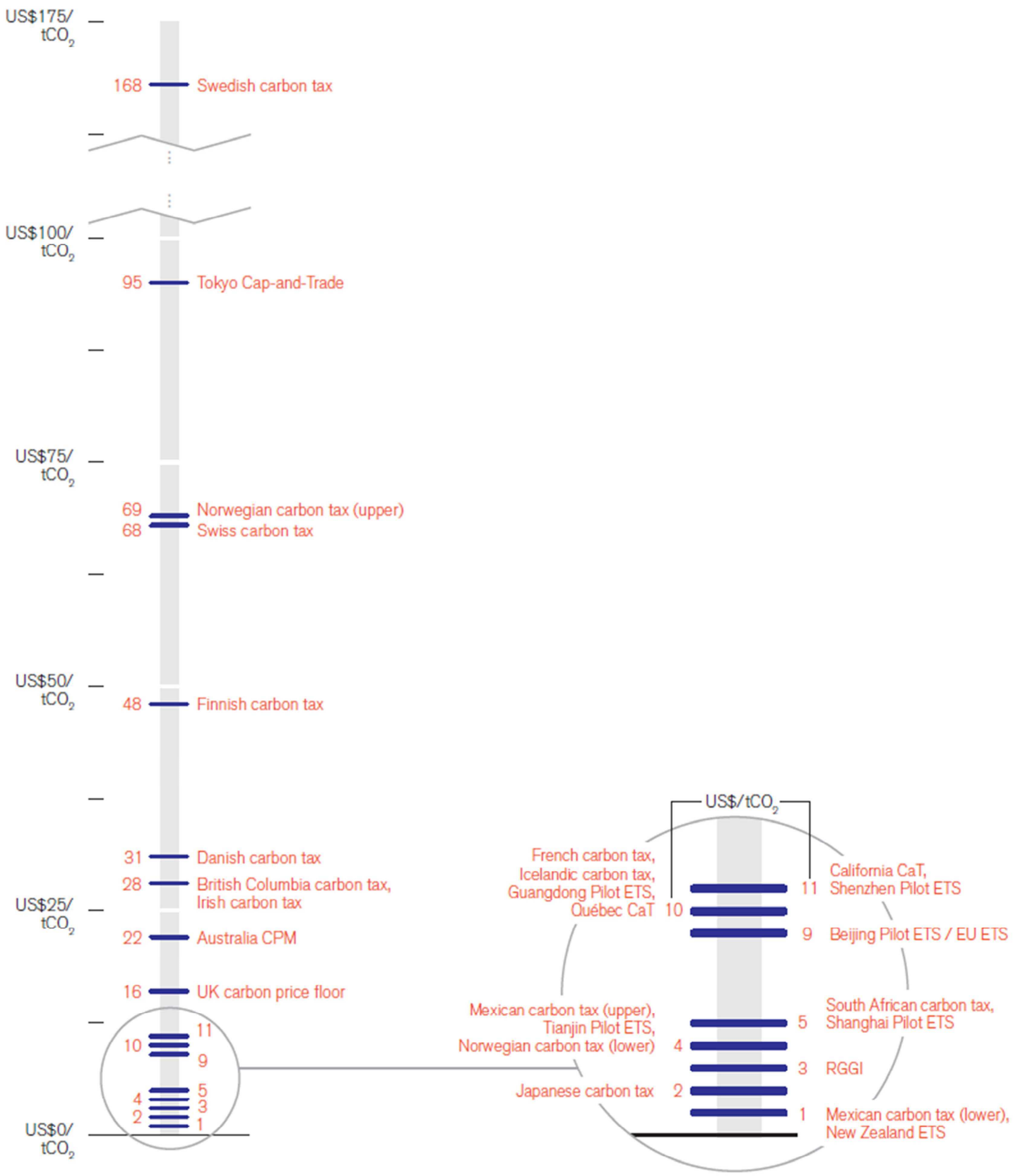

Figure 18 - Carbon price in existing carbon pricing instruments. Source: World Bank, 2014. State and Trends of Carbon Pricing, Washington DC

Why the COP21 negotiations should not focus on setting a single price for carbon

A single international carbon price: a guarantee of economic efficiency?

In theory, minimizing the overall cost of reducing greenhouse gas emissions would result from the equalization of marginal abatement costs[22] (cost of the last reduced ton of GHG) in all countries and all sectors, based on the definition of a single price internationally.

Two architectures are possible to implement a single carbon price: an international carbon tax or a global emissions trading system. If there is no uncertainty in the costs of emission reduction and nor in the concentration target to be achieved to avoid major damage, both instruments are equivalent, but the climate topic is far from fulfilling this condition.

Indeed, each tool mechanically transfers the uncertainty on one variable or the other: in the case of quotas, the environmental objective is set, and the uncertainty relates to the costs required to achieve this objective; in the case of a tax, the marginal abatement cost is fixed, but the level of resulting emissions is unknown. The type of uncertainty (on costs or emissions) considered the most important should then dictate the choice of coordination mode.

But the uniqueness of the price raises equity issues

If the equalization of marginal costs is a guarantee of economic efficiency for technical costs, it neglects the difference between these costs and costs in welfare, a gap that becomes clear once one takes into account the highly heterogeneous preexisting conditions, between countries and between categories of actors. For example, a $1 increase in the fuel or energy price does not have the same impact for an Indian or an American, for a country whose economy is based on heavy industry or one that favors services, or for a country which already has a strong energy taxation and for a country where it is zero. In other words, equalization of technical costs would only be fair if accompanied by significant compensation mechanisms, especially from the richest countries to the poorest countries.

From this point of view, the initial allocation of quotas to countries in a system of tradable emission quotas would generate financial transfers between countries that have received more quotas and those who received fewer allowances, which could allow the necessary compensation mechanisms. Depending on the quotas price levels and the rules for quotas allocation, these transfers could be several percentage points of GDP for some countries (more than official development aid in particular). This is enough to explain why it was impossible in the preparation of the Copenhagen Conference to negotiate such an initial allocation of quotas, each country defending the fairness criteria most benificial for them (historic responsibility or capacity to pay, for the most emblematic criteria) .

An international carbon tax would raise the same distributional problems than an emissions trading quota system. In order to allow redistribution, part of the tax revenues should be used to pay compensation to developing countries.

[22]The marginal cost is the cost of producing one more unit. Regarding greenhouse gas emissions reductions, it is the cost at a given time of the last ton of reduced emissions. Since the emission reductions are implemented in order of increasing marginal cost, that is to say from the cheapest to the most expensive cuts, this is the most expensive reduction action to reach a given target of reducing GHG emissions.

The failure of the Copenhagen conference was partly due to the impossibility of negotiating in a "top-down" approach an architecture that would have led to an international carbon price applied indiscriminately in all countries, because of the impossibility to find an agreement on a "fair" allocation of emissions quotas among countries. In today's globalized world, international governance dimensions (rise of emerging countries, WTO, gas and oil markets, environmental regulations, international financing mechanisms ...) are actually all intertwined with the climate issue. For a State, agreeing to a fixed international carbon price then means abandoning a significant portion of its sovereignty over these different dimensions.

Conclusions

- The implementation of carbon pricing systems is essential in the fight against global warming, but the introduction of economic instruments should be seen as the consequence of the agreement and not as a central component of the agreement, one element *ex post* and not *ex ante*.
- Negotiation is indeed based on an approach focused on intended nationally determined contributions (INDCs). It does not a priori guarantee economic efficiency but if one takes into account the experience gained and the state of the world in 2015 - marked by the economic and political rise of emerging countries - the INDCs solution appears as the only one capable of effective implementation.
- These national contributions will not be met without the implementation at national level of economic instruments, taxes or quotas. In this perspective, the introduction at a future COP at international level with a reference carbon value (or values corridor) is desirable to calibrate the carbon pricing national instruments, guide consumer choices, investment and R&D, in order to limit climate change to 2°C.
- While the emergence of a single carbon price internationally through an international tax or a quota system would allow the equalization of marginal abatement costs and would in theory guarantee economic efficiency, its implementation would generate redistributional impacts and therefore raise questions of equity. Negotiating *ex ante* an international carbon price applicable to all countries would raise again the risk of negotiation failure.
- Whether in an international or national perspective, economic instruments for the environment - taxes and quotas - today appear necessary in the implementation of the right policies, but they call for accompanying measures that improve their acceptability.