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INDCs and carbon budget

Modeling global emissions trajectories compatible with a +2°C carbon budget

Following the adoption of the international climate agreement at the 21st United Nations Framework Convention on Climate Change (UNFCCC) in Paris, The Shift Project has analyzed the Intended Nationally Determined Contributions (INDCs) of signatory countries in relation to the 1000 Gt CO_2 budget that corresponds to the 2°C IPCC scenario.

This analysis report is published in the wake of the COP22 in Marrakech. It presents a modeling (and its methodology) of suitable emissions trajectories in order to limit global warming to a 2°C increase between the beginning of the industrial era and the end of this century.

When it comes to cross-checking the INDCs with the carbon budget, time appears to be of the essence.

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The author would like to thank Nicolas Dorville, Marie Degremont, Aloun Vangkeosay and Maxim Polyavitry, as well Lilian Laurent, Chloé Galiègue, Clémence Vorreux and Laura Dale.

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[1] *The Shift Project*, a non-profit organisation, is a French think-tank dedicated to informing and influencing the debate on energy transition in Europe. *Informing*: we establish working groups on the most sensitive and decisive issues of the transition, with particular attention to appropriately-scaled solutions. *Influencing*: we promote the recommendations of our working groups to political and economic decision-makers. *The Shift Project* is supported by European companies that want to make the energy transition their strategic priority & by French public funding.

I- Humanity's race against time

Despite the diplomatic success of the Paris climate agreement, Intended nationally determined contributions (INDCs) imply a **steady increase of annual greenhouse gas emissions (GHG)** by 2025. At that time, global emissions would be 6% higher than in 2015 and almost 40% greater than in 1990.

The business as usual GHG emissions growth prior to the COP 21 would have been twice as high (about 12% between 2015 and 2025). However, the current INDCs are still insufficient: the current trajectory takes us beyond a +3°C increase in global temperature by the end of the century.

To keep a reasonable chance of remaining under a +2°C temperature increase, cumulated CO_2 emissions between 2011 and the end of the 21st century should not exceed a "carbon budget" of 1000 Gt of CO_2[2]. Furthermore, by 2100, annual GHG emissions must be neutral regardless of the intermediary emission levels of 2025 or 2030.

Reshaping 10% of the global economy every year is unrealistic

Assuming that we will start reducing GHG emissions steadily in 2025 (same yearly abatement); the simulation shows that we must cut our emissions by 10% every year in order to achieve the objective. This scenario incorporates a drop in energy consumption, shifting from CO_2-intensive energy sources to low-carbon alternatives, as well as the deployment of CO_2 storage technologies. The result is a net reduction in CO_2 emissions.

In this case, the 10% average rate of reduction becomes the reference for GHG reduction from 2025 on. This translates to cutting global emissions in half in just 7 years! This is no easy task.

Every political leader or manager is aware that is it extremely difficult, even unrealistic, to transform 10% of one's economic activity year after year. Nevertheless, optimists would argue that this scenario is feasible, thanks on the one hand to a drastic reduction in the cost of renewable energy systems (RES) and, on the other hand, to the deployment of carbon capture and storage technologies (CCS).

Waiting for 2025 means giving up on the objective

The only option in order to meet the Paris climate agreement is to initiate the process in 2017. Even in this case, it is still a monumental task, as emissions have to decrease by a 5% yearly rate starting in 2018[3]. France has achieved one of the highest per capita emissions reductions in history (from 10 tons in 1973 to 5.5 tons in 2015). It took 40 years to halve CO_2 emissions in France. Now, the whole world has only 35 years to divide annual CO_2 emissions by a factor of 3…

Moreover, France achieved more than half of this reduction (around 3 tons out of the achieved 4.5 tons per capita) by resorting to a massive conversion to nuclear power generation, an option which not all major players are willing to consider.

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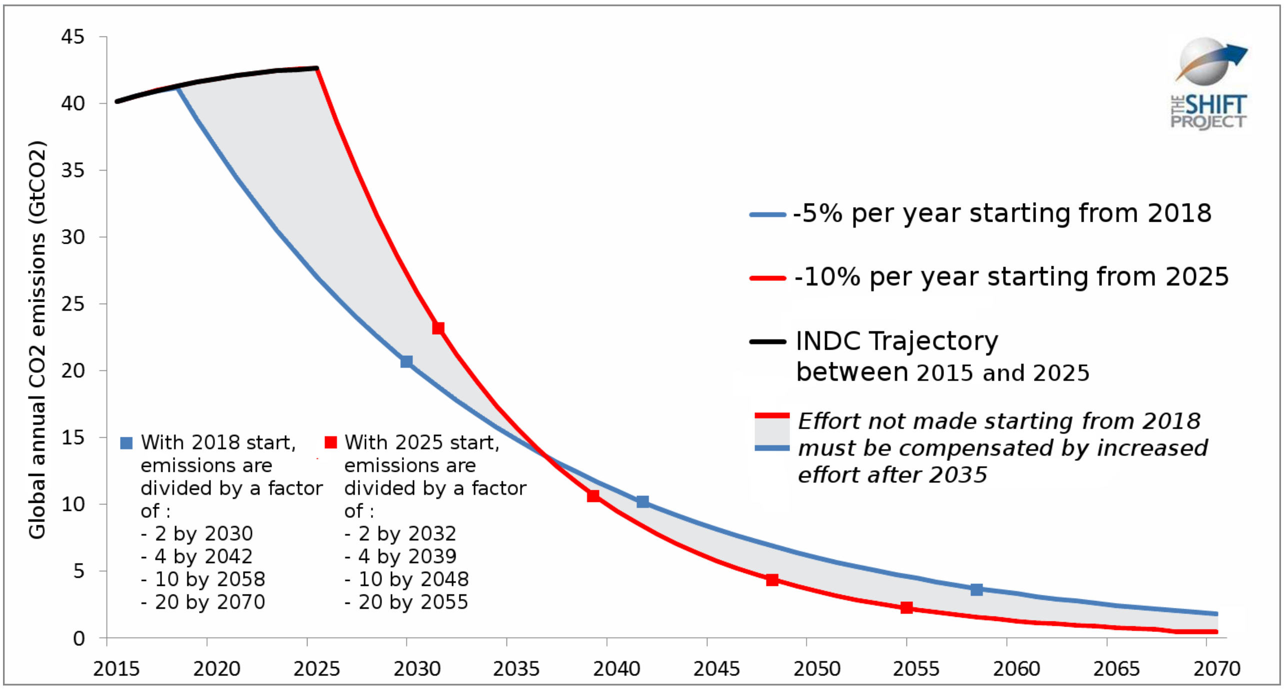
[2] There is a general consensus around this number that has been published by the IPCC in their reports on climate change and more recently by the UNFCCC in the updated synthesis report on the aggregate effect of INDCs - published 2 May 2016 (FCCC/CP/2016/2), p.13 and p.48: http://unfccc.int/focus/indc_portal/items/9240.php.

The 1000 Gt CO_2 carbon budget only covers CO_2 while excluding other GHG and has been defined to likely (i.e. a 66% chance) remain under the +2°C raise in temperature level.

[3] Accurate values are -5.4% from 2018, -6.3 % from 2020 and – 9.4% from 2025, respectively.

There is an urgent need for action. Each year that we postpone the start of global reductions makes the +2°C objective more difficult to attain. Waiting another 10 years without reviewing the INDCs will send the Paris climate agreement to an early grave. "*It will be easier later*" has no validity as an argument for delaying our actions: there is no evidence that the financial and technical context will make us twice as fast and twice as efficient in 10 years. There is considerably more evidence to the contrary.



Graphic I – 2°C compatible emissions trajectories

Nations are ready to shift into transition mode: let's make it happen!

Despite the 932 Gigawatts of coal-fired power plants under development and the 350 Gigawatts under construction, 158 Gigawatts have been abandoned between January and July 2016 alone[4]. Several countries are engaging in a joint fight against climate change and atmospheric pollution. China, for example, has seen its emissions decrease by around 0.7% in 2015, while in the USA, emissions dropped by about 2.6%[5].

Africa could partially leapfrog a carbon intensive development and commit itself directly to greener methods of development. The financial world is increasingly integrating long-term issues, and is giving positive signals by taking into account climate change within its investment mechanisms. Unfortunately, the pace of the transition remains sluggish.

The Paris Agreement, confirmed at the COP22 in Marrakech, should be the starting point for a deep transformation. We have no choice but to commit as soon as possible to a drastic reduction in GHG emissions. The fine line between « It is still possible » and « There is no longer any chance » is inextricably linked to our engagements and actions in the next three years. Without a remarkable, rapid mobilization, COP 21 would be remembered as a disappointment at best, or, at worst, as a historical moment of collective blindness.

[4] Christine Shearer, Aiqun Yu and Ted Nace for CoalSwarm (2016), "A Shrinking Coal Plant Pipeline: Mid-2016 Results from the Global Coal Plant Tracker"

[5] Le Quéré et al. (2016): Global Carbon Budget 2016, Earth System Science Data

II- Methodology: how to apply a « carbon budget » to GHG emissions reduction trajectories

All the trajectories were built under the core assumption of 1000 Gt of cumulative CO_2 emissions since 2011. This number is extracted from the IPCC reports and the United Nations Framework Convention on Climate Change (UNFCCC):

- "*According to the 5th IPCC Assessment Report, the total global cumulative emissions since 2011 that are consistent with a global average temperature rise of less than 2°C above pre-industrial levels at a likely (>66 per cent) probability is approximately 1 000 Gt CO_2*"[6] ;
- "*According to the AR5, global cumulative CO_2 emissions after 2011, for a likely chance of keeping global average temperature rise below 2°C, should be limited to less than 1 000 Gt CO_2*"[7].

This « carbon budget » is qualified as "*likely*", which corresponds to a 66% confidence level to achieve the +2°C goal. The following results and conclusions should therefore not be taken as certainties, but rather as inputs to define reasonable emissions trajectories. The budget is expressed in carbon dioxide Gigatons (Gt CO_2), which means that only CO_2 emissions are considered, excluding other GHGs that were converted to a CO_2 equivalent.

For example, in 2011, global emissions of CO_2 were about 38 Gt CO_2, while total global emissions of GHG were about 49 Gt CO_2eq.

Net anthropogenic emissions are considered, in accordance with the terms used in the Paris climate agreement, as "*anthropogenic emissions by sources and removal by sinks of greenhouse gases*"[8]. "Removal" means a proper use of revegetation, soil, storage and CO_2 transformation technologies, and so forth. Note that even with a considerable research effort and rapid industrial development, the impact of CCS could only be significant by 2030.

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[6] CCNUCC (2016), "Updated synthesis report on the aggregate effect of INDCs – published 2 May 2016", pp.13-44. <http://unfccc.int/focus/indc_portal/items/9240.php>

[7] CCNUCC (2016), "Updated synthesis report on the aggregate effect of INDCs – published 2 May 2016", pp.48-211. <http://unfccc.int/focus/indc_portal/items/9240.php>

[8] Paris agreement, Article 13 §7 a)

III- INDCs: conversion from Gt CO2eq to Gt CO_2

Intended nationally determined contributions take into account all GHG and are expressed in Gt CO_2eq. In order to be consistent with the 1000 Gt CO_2 « carbon budget », we must consider the part of CO_2 alone, stemming from the INDCs.

The baseline scenario we use is INDC 2030 as stated by the UNFCCC in its May 2nd 2016 report[9]. This scenario provides GHG emissions levels for the years 2015, 2020, and 2035. We assume the constant rate of change between GHG and CO_2 for intermediate years

Example: in 2020 the INDC value is 54 Gt CO_2eq, that's +10.2% compared to 2011; therefore the calculated level of CO_2 for the same year would be + 10.2% applied to the 38 Gt of 2011, which gives 42 Gt CO_2.

The GHG emission levels for the years 2015, 2020, and 2035 have been selected to adequately model arcing emissions trajectories. A linear reduction was applied between these three points.

The data used for the modelling was taken from the UNFCCC report[10], specifically from Figure II:

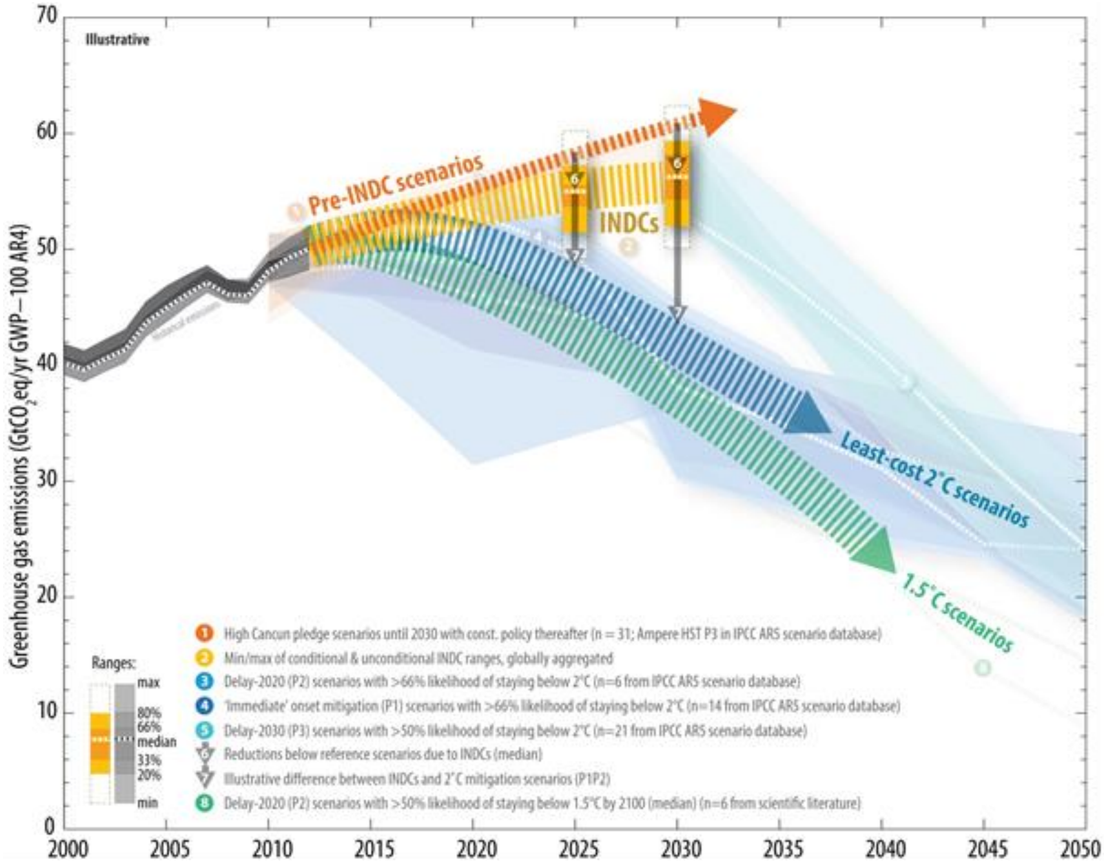

Figure II – CCNUCC (2016), "Updated synthesis report on the aggregate effect of INDCs – published 2 May 2016"

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[9] It should be noted that we used a steady CO_2 ratio in the GHG mix throughout the 2011-2100 period of time. However, this ratio will actually change from a few percentage points. Indeed, the share of CO_2 would probably decrease in particular because of the release of methane that will not keep the same pace than CO_2 emissions. See OECD Environmental Outlook to 2050 (2012), Climate Change Chapter, pp.53 <http://www.oecd.org/env/cc/Outlook%20to%202050_Climate%20Change%20Chapter_HIGLIGHTS-FINA-8pager-UPDATED%20NOV2012.pdf> (Figure 3.20: GHG abatements in the 450 Core Accelerated Action and 450 Core scenarios compared to the Baseline, 2020 and 2030, Abatement by GHGs)

[10] CCNUCC (2016), "Updated synthesis report on the aggregate effect of INDCs – published 2 May 2016". <http://unfccc.int/focus/indc_portal/items/9240.php>

IV- Evaluation of trajectories at a steady pace of effort

The data extracted from Figure II gives annual and cumulated CO_2 emissions since 2011. It is therefore possible to evaluate the remaining carbon budget for each year, as well as the emissions abatement rate which respects this budget[11]. It is also possible to calculate the number of years in which emissions rates can continue at constant levels, before exhausting the emissions budget

Calculations from year 2011 until 2025 are displayed in Table I, below.

Table I – Evaluation of CO_2 emissions reduction rates needed depending on the changeover starting year

	INDC (Gt CO_2eq)	Emissions (Gt CO_2)	Cumulated emissions (Gt CO_2)	Remaining Carbon budget (Gt CO_2)	Number of remaining years at constant rate of emissions	Exponent	Yearly emissions reduction rate (%/an)
2011	49	38	0	1000	26,32	-0,0380	-3,73
2012		38,54	38,54	961,46	24,95	-0,0401	-3,93
2013		39,09	77,63	922,37	23,60	-0,0424	-4,15
2014		39,63	117,26	882,75	22,28	-0,0449	-4,39
2015	51,8	40,17	157,43	842,57	20,97	-0,0477	-4,66
2016		40,51	197,94	802,06	19,80	-0,0505	-4,93
2017		40,85	238,79	761,21	18,63	-0,0537	-5,23
2018		41,20	279,99	720,01	17,48	-0,0572	-5,56
2019		41,54	321,53	678,47	16,33	-0,0612	-5,94
2020	54	41,88	363,40	636,60	15,20	-0,0658	-6,37
2021		42,03	405,44	594,56	14,14	-0,0707	-6,83
2022		42,19	447,63	552,37	13,09	-0,0764	-7,35
2023		42,34	489,97	510,03	12,05	-0,0830	-7,97
2024		42,50	532,46	467,54	11,00	-0,0909	-8,69
2025	55	42,65	575,12	424,88	9,96	-0,1004	-9,55

[11] Every « A » year corresponds to a given level of emissions « EA » that comes with remaining carbon budget « SA » calculated as the difference between the initial 1000 Gt of CO_2 and the cumulated emissions from the year 2011. The mathematical equation that represents a steady level of reduction of carbon emissions (same yearly reduction rate on a year-to-year basis) starting on year A is a function with an exponential declining shape:

EN (N-year emissions) = EA EXP (e (N-A)) with e= -EA/SA as the exponent.

- The mathematical integration of this equation between A and the infinite equals to the carbon budget SA.
- Yearly reduction rate on a year-to-year basis is : EXP(e)-1

V- Evaluation of key values

The goal is to identify how many years are needed to cut carbon emissions by a given factor, x. That number of years equals LN (1/x) / e (with e the exponent of the curve).

Example: to cut emissions by a factor of 2 with a yearly emission reduction rate and an exponent of -0.05, we need EXP (-0.05 N) = 0.5, so N = LN (0.5)/-0,05, or about 14 years.

Depending on the changeover year chosen in Table II, it is possible to obtain the number of years required to cut emissions by a given factor.

Table II – « Speed » of emissions reductions

	Number of years needed to cut emissions by a given factor			
	Factor 2 -50%	**Factor 4 -75%**	**Factor 10 -90%**	**Factor 20 -95%**
2011	18,2	36,5	60,6	78,8
2012	17,3	34,6	57,4	74,7
2013	16,4	32,7	54,3	70,7
2014	15,4	30,9	51,3	66,7
2015	14,5	29,1	48,3	62,8
2016	13,7	27,4	45,6	59,3
2017	12,9	25,8	42,9	55,8
2018	12,1	24,2	40,2	52,4
2019	11,3	22,6	37,6	48,9
2020	10,5	21,1	35,0	45,5
2021	9,8	19,6	32,6	42,4
2022	9,1	18,2	30,1	39,2
2023	8,3	16,7	27,7	36,1
2024	7,6	15,3	25,3	33,0
2025	6,9	13,8	22,9	29,8

VI- Illustrations

Figure I – 2°C-compatible emissions trajectories

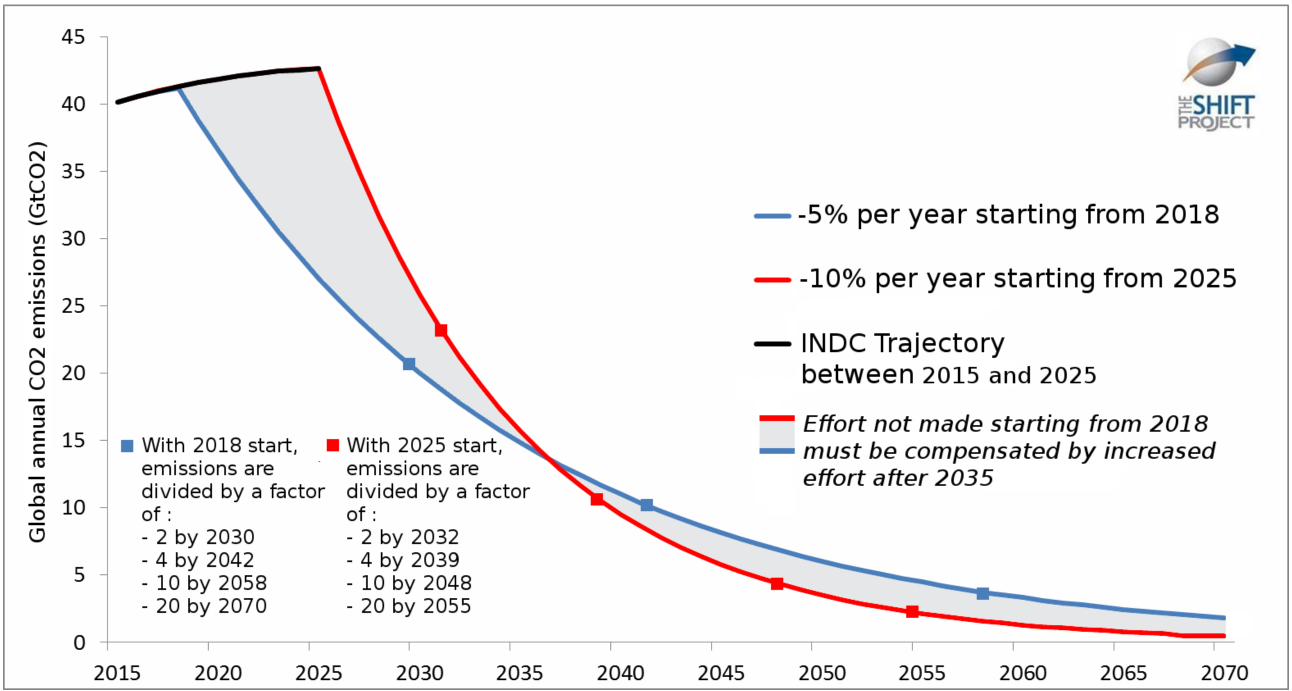
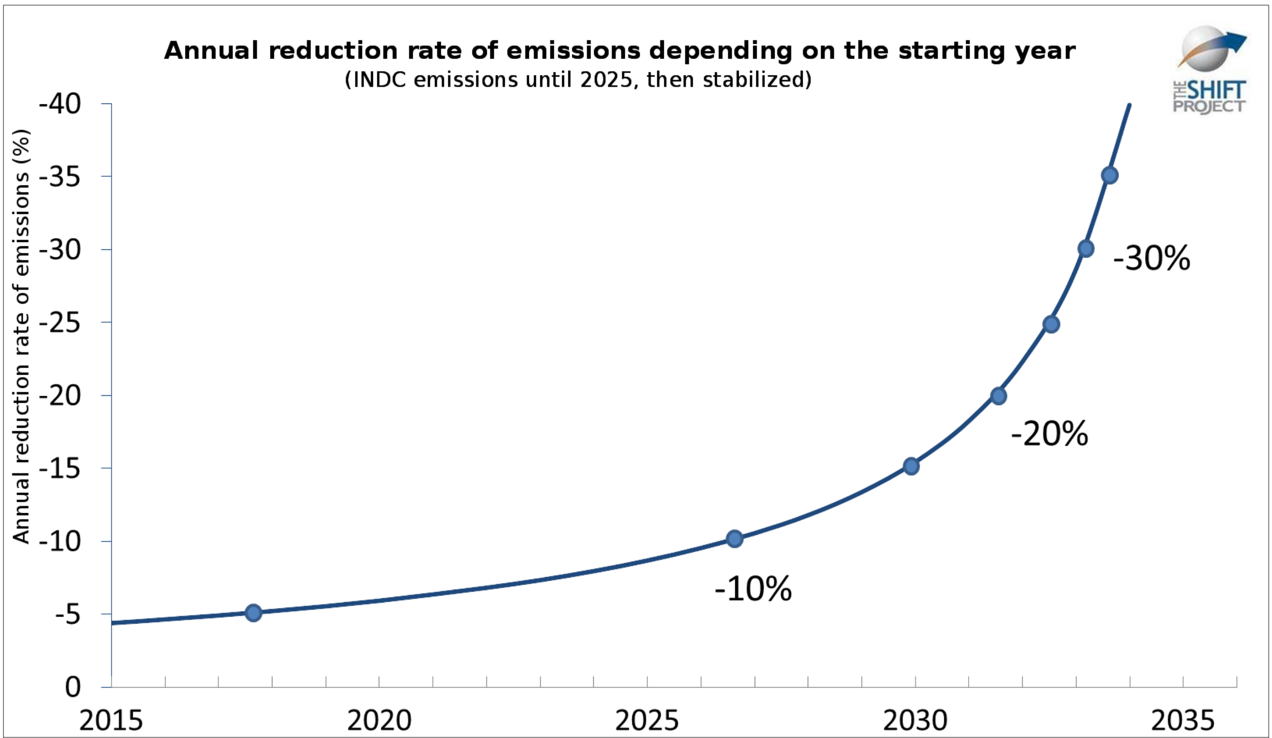


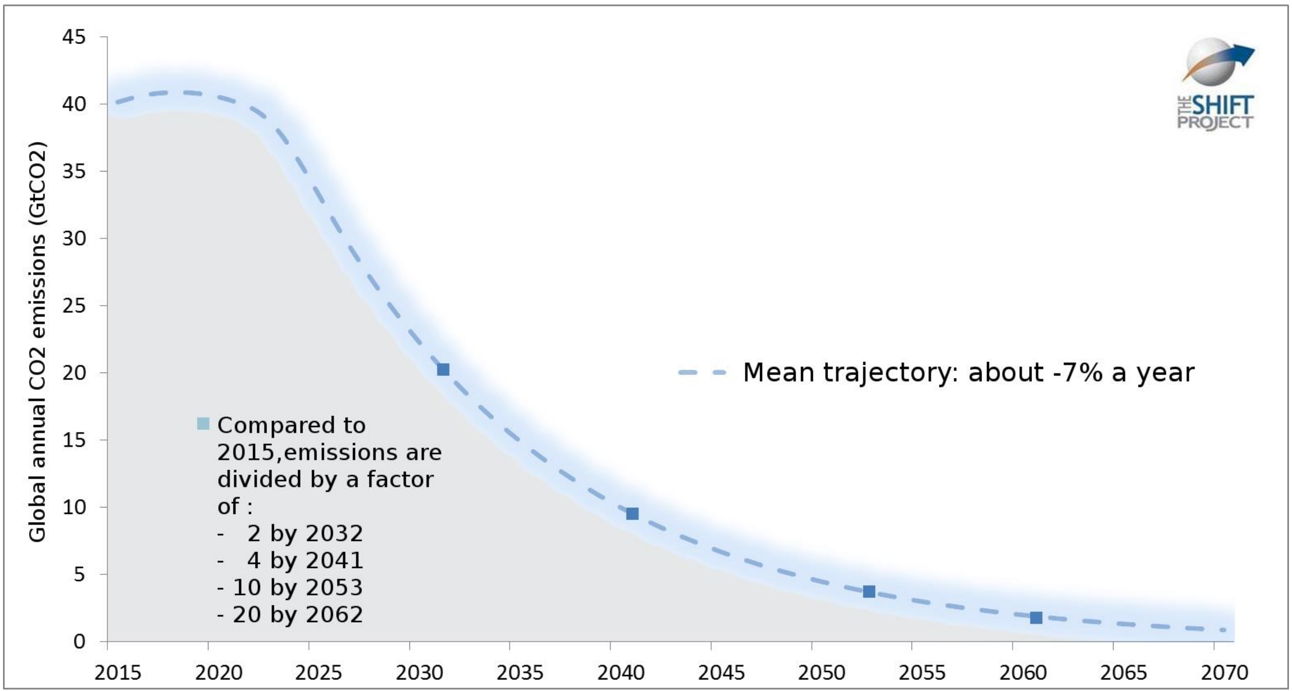
Figure III – Yearly emissions reduction rate as a function of the changeover year



VII- Including a transitional period after the changeover year

It is likely that carbon emissions will not instantly switch from a weak growth situation to one exhibiting a steady -5% to -10% decrease. Activating the reduction process may take about two or three years in the best of cases. The scenario that is illustrated in Figure III assumes that the changeover occurs in 2018, after which the trajectory catches up with an average and steady -7% yearly emissions reduction rate.

Figure IV – Target emissions trajectory



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