

A Bottom-Up, Non-Cooperative Approach to Climate Change Control: Assessment and Comparison of Nationally Determined Contributions (NDCs)

Carlo Carraro^{1,2}

¹ Ca' Foscari University of Venice and FEEM, Venice, Italy

² Vice-Chair, IPCC WG III

Correspondence: Carlo Carraro, Ca' Foscari University of Venice and FEEM, Venice, Italy. E-mail: ccarraro@unive.it

Received: July 3, 2016 Accepted: August 10, 2016 Online Published: September 27, 2016

doi:10.5539/jsd.v9n5p175

URL: <http://dx.doi.org/10.5539/jsd.v9n5p175>

Abstract

International negotiations on climate change control are moving away from a global cooperative agreement (at least from the ambition to achieve it) to adopt a bottom-up framework composed of unilateral pledges of domestic measures and policies. This shift from cooperative to voluntary actions to control GHG emissions already started in Copenhagen at COP 15 in 2007 and became a platform formally adopted by a large number of countries in Paris at COP 21. The new architecture calls for a mechanism to review the nationally determined contributions (NDCs) of the various signatories and assess their adequacy. Most importantly, countries' voluntary pledges need to be compared to assess the fairness, and not only the effectiveness, of the resulting outcome. This assessment is crucial to support future, more ambitious, commitments to reduce GHG emissions. It is therefore important to identify criteria and quantitative indicators to assess and compare the NDCs.

Keywords: climate change negotiations, Paris agreement, GHG emissions, mitigation

1. Introduction

Last December, the long-awaited Paris Conference on Climate Change (COP 21) approved a new, comprehensive deal that will guide international action to control climate change from 2020. The Paris agreement is just a first step: countries need to find common ambitions not only on mitigation objectives, but also on adaptation measures, financing to support developing countries plans, as well as technology transfers. Nevertheless, the Paris agreement is an important step: for the first time, all the most important GHG emitters are committed to keep their own GHG emissions under control.

A key pillar of the Paris agreement are the so called NDCs (Nationally Determined Contributions), that are a new type of instrument under the UNFCCC, through which both developed and developing countries declare the actions they intend to undertake to tackle climate changes at the national level.

Going beyond the historical dichotomy between Annex I and Non-Annex I countries, the Paris agreement asks indeed for the participation of all countries, which agreed to communicate their targets and plans to reduce GHG emissions well in advance the two-week negotiations in Paris. Table 1 summarizes the main Nationally Determined Contributions adopted at COP 21.

Table 1. *Nationally Determined Contributions* by the top 10 GHG emitting countries (2011 GHG emissions, source CAIT Data Explorer)

Country	Emission reduction target	Reference year	Period of implementation
China	Peak in 2030; 60-65% CO ₂ per unit of GDP	2005	by 2030
United States	26-28%	2005	2020-2025
European Union	≥40%	1990	2021-2030
India	33-35% CO ₂ per unit of GDP	2005	by 2030
Russia	25-30%	1990	2020-2030
Japan	26%	2013	1 April 2021 –31 March 2031
Brasil	37%	2005	by 2025
	43%		by 2030
Indonesia	29-41%	BAU	2030
Mexico	22-36%	BAU(from 2013)	2020-2030
Canada	30%	2005	by 2030

Despite serving the same purposes, the submitted NDCs show many substantial differences. From one side, most advanced economies, including the US and the EU, proposed economy-wide emissions reduction targets from a base year. On the other side, it is not uncommon to find intensity targets among developing nations, as in the case of China, Singapore, and Tunisia, which chose a reduction of GHG emissions per unit GDP, or more frequently, a percentage deviation from a Business as Usual (BaU) scenario.

As for developing countries, usually a lower “unconditional” bound and an upper “conditional” bound were proposed, the latter to be implemented only with financial and technological support from the international community. Moreover, developing countries’ contributions usually put more emphasis on adaptation measures than developed counterparts, which conversely continue to focus mainly on mitigation actions.

Against this background, attempts to evaluate and compare such a fragmented picture recently start to emerge. Looking, for example, at the emission targets pledged by four among the major emitters, namely EU, US, China and Russia, it can be seen that, if absolute levels of emissions are compared, the EU will support a higher effort compared to the other countries. On the contrary, when changes in the GHG/GDP ratio are taken into account, China and Russia will bear a larger burden of the climate action (see Table 2).

Table 2. Comparison of US, EU, China and Russia’s Targets

Comparison among NDCs targets	Country			
	US	EU	Russia	China (Emissions to peak by 2030)
GHG emissions change (%)				
wrt 1990	-16 a -14	-40	-30 a -25	+265 a +291
wrt 2005	-28 a -26	-35	+10 a +18	+76 a +89
Changes in GHG/GDP ratio (kgCO₂eq/US\$)				
wrt 1990 (%/year)	-3.0 a -2.9	-2.8	-3.7 a -3.5	-4.7 a -4.5
wrt 2005 (%/year)	-3.6 a -3.5	-2.9	-4.5 a -4.2	-5.0 a -4.7

This kind of analysis, even though often proposed by governments and NGOs, is however quite superficial. A proper analysis and comparison of NDCs should rather focus on a more precise effectiveness metric, for example the distance of each NDC from the domestic optimal emission pathway to achieve the 2°C target. And it should consider that effectiveness is not the only, and possibly not the most important, metrics when comparing different countries' efforts to reduce GHG emissions. Fairness, and therefore relative costs, is also very important. Cost of reducing GHG emissions can for example be computed with respect to the business as usual emission pathway in each country. The cost in one country can then be compared with costs in the other ones to provide information of the fairness of the proposed NDCs. Efficiency, namely the distribution of marginal costs, is also crucial. Marginal costs should indeed be equalized for the NDCs to be fully efficient. Is this the case for the NDCs approved in Paris?

The objective of this paper is to carry out an analysis of the NDCs for the three major world economies - US, EU and China – covering almost 60% of total GHG emissions. Before proceeding with the analysis, let us note two important features of the NDCs and the Paris agreement.

First, for the first time, more than 180 countries agreed to control their own GHG emissions, including many emerging and developing economies. This is an important step to move beyond the traditional dichotomy between developed and developing countries, the latter claiming that GHG emission control should pertain to developed nations to avoid restrictions to their own economic development.

Second, the Paris agreement reflects the move from a “top down and cooperative” to a “bottom –up and non-cooperative” approach to climate change control. This move can be explained by the failures of many previous negotiations over a global cooperative agreement (the Kyoto protocol, for example, covered only about 14% of total GHG emissions) and by the consequent attempt to achieve a broad agreement with a large number of signatories (the Paris Agreement covers about 95% of total GHG emissions). A crucial question is therefore whether this non-cooperative approach, accompanied by measures to support developing nations' efforts to reduce GHG emissions, and by a strong reputation effect inducing large nations to compete for ambitious emission reduction effort, is sufficient to keep global GHG emissions on track to achieve the 2°C target.

2. Effectiveness and Efficiency of NDCs: How Far from Achieving the 2°C target?

Let us look at the basic facts. China has committed to peaking their emissions by 2030, if not before, with an intensity target of - 60-65% with respect to 2005 (see Table 1). The US says it is shooting for emissions reductions of - 26-28% by 2025 (from 2005 levels). The EU target is -40% of total EU27 GHG emissions in 2030 with respect to 1990.

The US and China also signed a bilateral deal in which they commit themselves not only to reduce emissions but also to develop a joint Research and Development program focused on renewables to increase the share of renewables in their own domestic energy mix. China is committed to achieve a share of renewables equal to 20% by 2030.

A first initial comparison of NDCs requires harmonizing the reference year. By achieving its target of reducing emissions by 26-28% by 2025 (from 2005 levels), the US will have achieved a 16.3% reduction in GHG emissions compared with 1990 levels. Though notable, this target is decidedly less than the about 30% reduction decided by the EU for 2025 (recall that the EU committed to reduce its GHG emissions by 40% from 1990 levels by 2030).

Even so, broadly speaking, both the US and the EU are on track to achieve the 2°C target. To prove this statement let us compare the EU and US targets with the emission levels that would be consistent with the 2°C pathway.

Let us consider three sets of scenarios for US future emissions, all consistent with the achievement of the 2°C target by the end of the century. The first set of scenarios (EMF) is produced by the Energy Modeling Forum (Cf. EMF, 2014). The second set of scenarios (LIMITS) comes from LIMITS, an important project funded by the European Commission (Cf. LIMITS, 2013). The third set of scenarios (SSP) is produced by the IPCC (Cf. IPCC, 2010). The three sets of scenarios identify cost efficient US GHG emissions within the socio-economic pathway leading to a 2°C temperature increase by the end of the century.

As shown in Figure 1, in all scenarios the emission reduction target adopted by the US administration is consistent with the 2°C objective. An important additional effort will be necessary beyond 2025, but the target for 2025 seems to be ambitious enough.

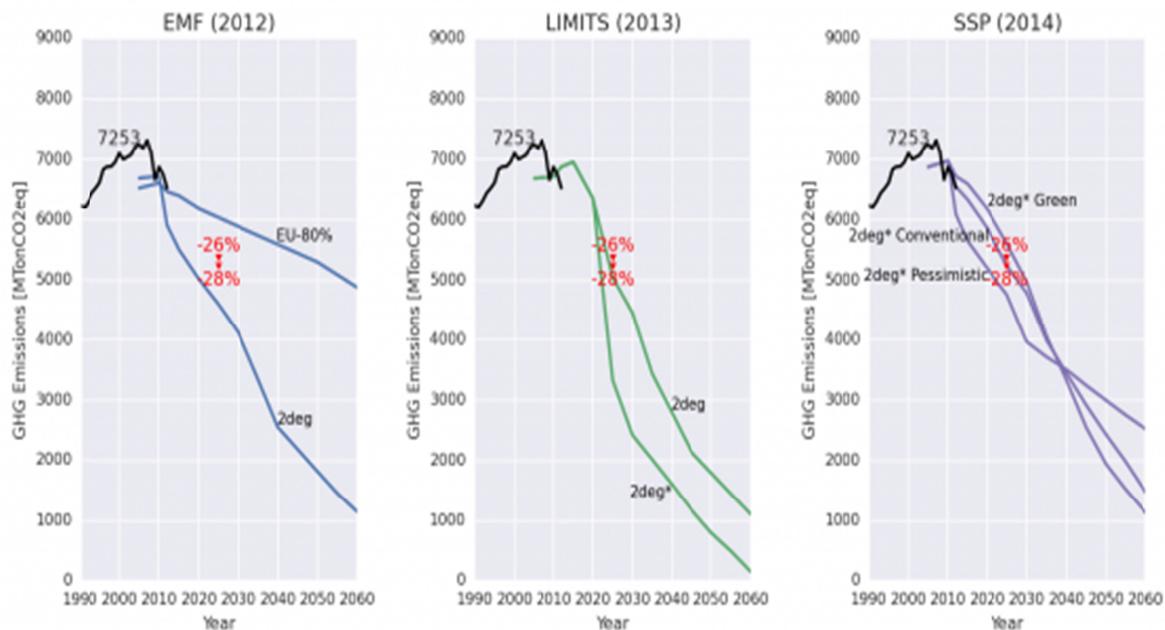


Figure 1. Scenarios of US GHG emissions from 1990 to 2100 consistent with achieving the global 2C target. In red, the target adopted at COP 21 in Paris

A different question is whether the US emission reduction objective is feasible. This target will mean doubling the pace of emissions reduction set for 2005–2020 thereafter. Doubling the US effort to mitigate GHG emissions is likely to be technically and economically feasible. Both US per capita emissions and US emissions per unit of GDP are larger than the EU ones. Hence, the marginal mitigation effort is smaller in the US than in the EU. However, in the US, the most significant barrier to climate change action will be a political one. The US lawmakers in Congress, currently a Republican-dominated body, may oppose any action to effectively reduce GHG emissions. In response to these political obstacles, President Obama may develop a climate action framework through his regulatory power that does not need to be passed through Congress. The most notable of these regulatory mechanisms are the Clean Power Plan, energy efficiency standards, heavy-duty engines and vehicles standards.

Even with this practical approach to avoiding Congress, it is however unlikely that these policies will be able to achieve all of the 26–28% emissions cut needed unless new clean energy technologies are developed. With the Congress obstacle still standing, this could mean looking to private investment to facilitate the development of such clean energy technologies. With lowering costs and an opening market for some renewables in the US, attracting this finance may be viable. This may be the case particularly for solar power, the production of which has grown by 139,000 percent in the US in the past decade.

Let us consider the European Union. The EU target is -20% in 2020 (already adopted a few years ago) and -40% in 2030 (pledged at COP 21 in Paris). The 2014 EU climate and energy framework also contains the indication to reduce GHG emissions by 80% to 95%, compared to 1990 levels, in 2050.¹

¹ In 2014, the European Council agreed on the 2030 climate and energy policy framework for the EU and endorsed new targets on greenhouse gas emissions, renewable energy and energy efficiency for 2030 (EC, 2014). In 2015, the EU adopted an Energy Union Strategy to ensure that Europe has secure, affordable and climate-friendly energy and achieve its climate and energy goals for 2030 (EC, 2015).

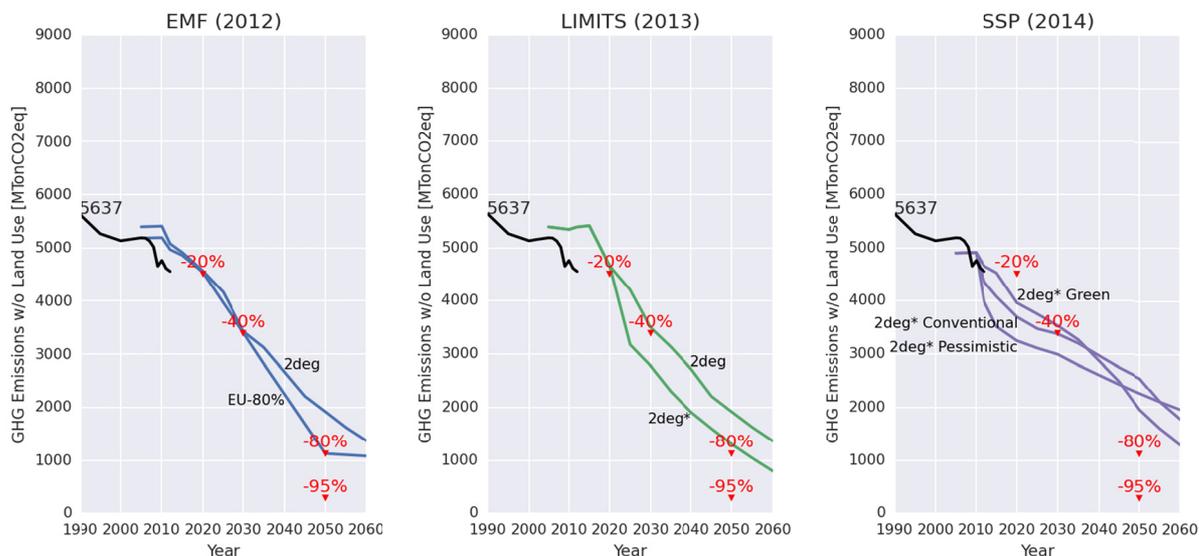


Figure 2. Scenarios of EU GHG emissions from 1990 to 2100 consistent with achieving the global 2°C target. In red, the target adopted at COP 21 in Paris

Again, the EU COP 21 pledge is consistent with the three scenarios that different research institutes suggest as consistent with achieving the global 2°C target. The effort required to EU member countries is considerable. The EU 2030 target will mean increasing the pace of emissions reduction set for 2005-2020 from 1% per year to 1.4% per year in the period 2020-2030. The reduction in GHG emissions needed between the 2030 target level (-40% below 1990) and the 2050 EU objective (at least 80% below 1990) will have to be two to three times steeper than the necessary reduction between current levels and the 2030 target. Nevertheless, the EU is likely to achieve the 2020 target and shows enough political commitment to achieve the 2030 target. Additional efficiency gains in the EU energy system remain feasible and the diffusion of renewable is proceeding rapidly.² EU Member States are now developing low carbon development strategies outlining concrete steps to turn EU-wide, long-term ambitions into national and local actions.

The situation is less positive in China. Prior to the recent commitment to peaking emissions by 2030, China had only a carbon intensity target of reducing emissions per dollar of economic output by 40-45% in 2020 (from 2005 levels). The intensity target has been raised to 60-65% in 2030. Modeling projections from the IEA and EIA suggest that a 45% carbon intensity target would result in overall emissions that are a slightly more ambitious than (IEA) or the same as (EIA) China's business-as-usual trajectory (IEA, 2015). The new intensity target is therefore a commitment to concretely reduce GHG emissions wrt BAU. Most importantly, peaking emission in 2030 is an absolute commitment that constitutes an important step into the right direction. However, can we also conclude that China is on track for the 2°C by 2100 warming limit?

Let us consider again the three scenarios previously outlined and their implications for China. As shown in Figure 3, a peak of emissions in 2030 does not seem to be consistent with the 2°C target in any of the three scenarios. Chinese emissions should peak in 2020-2025 for the 2°C target to be achieved by the end of the century. Nevertheless, the enhanced effort by China is worth being positively considered. Under the old commitment (2005-2020), China was supposed to reduce energy intensity by about 3% per year (a target that China is likely to achieve). Under the new commitment (peaking emissions by 2030) the implicit pace of emission reduction is about 4% per year. It is not a doubling of the emission reduction effort, but it's a significant and costly one.

As for implementation, China seems to rely on two major mechanisms: a nation-wide emission trading scheme from 2017, as announced by President Xi in New York last September, and an effort to increase the share of

² In October 2014, EU heads of state or government agreed to a target of raising the EU-wide RES share to at least 27% by 2030. Assuming that the current pace of renewable energy deployment in the EU (+ 0.8 percentage points per year on average) is sustained until 2030, the 2030 RES share in the EU would be above the 2030 target (EEA, 2015).

non-fossil fuels (renewables and nuclear) in the domestic energy mix up to 20% in 2030.

It is important to stress how important the non-fossil fuel energy target is for China. Solar energy in China is developing at unprecedented rates. Nuclear energy is also growing fast. Unfortunately, China's coal use and overall growth are also developing at unprecedented rates. With the number of coal plants being built, China is already locked into a high level of carbon emissions no matter what actions they take now.

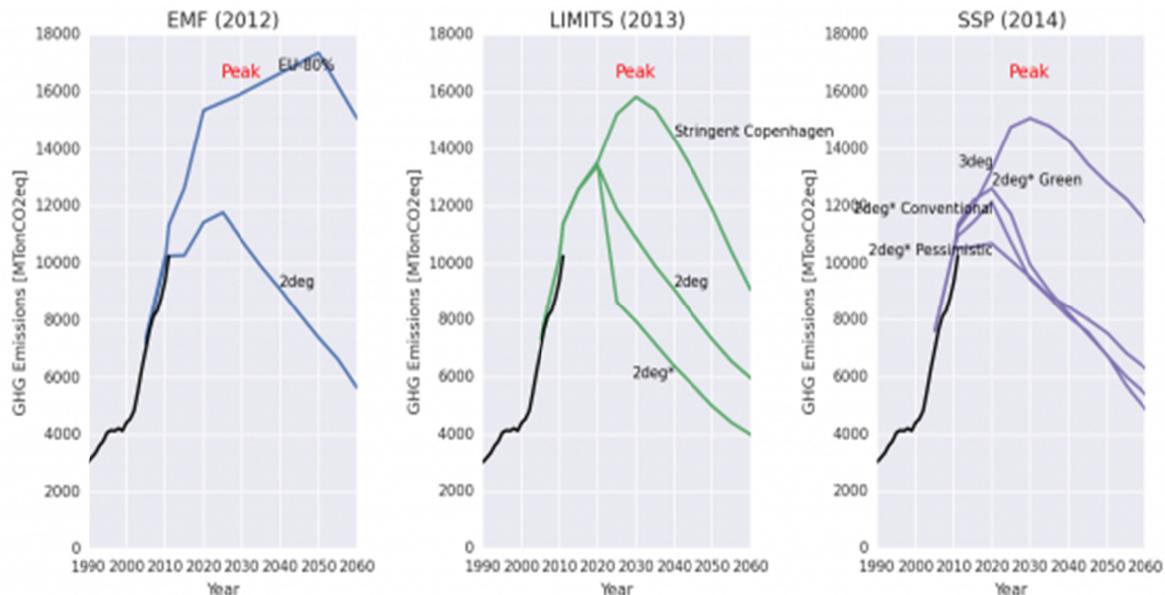


Figure 3. Scenarios of China GHG emissions from 1990 to 2100 consistent with achieving the global 2C target. In red, the target adopted at COP 21 in Paris

With this in mind, hope comes anyway from China's concrete aim of increasing the total share of non-fossil fuel energy to 20% by 2030 at the latest. This commitment is certainly demanding. At the moment, only 10% of China's energy mix comes from non-fossil fuel energy sources. The 20% "clean" energy target would require China to deploy an additional 800-1,000 gigawatts of wind, solar, nuclear and other carbon neutral technologies by 2030. This is greater than the capacity of all coal-fired power plants currently operating in China.

Given this analysis of the pledges coming from the three major players in the global GHG emission game, let us focus on the global effectiveness of the Paris agreement. At the end of October 2015, the UNFCCC published a report synthesizing the aggregate effect of all the NDCs submitted, in order to assess the effectiveness of the proposed actions towards the objective of limiting the global temperature increase to 2°C (UNFCCC, 2015). Results can be summarized as follows. The implementation of the communicated NDCs is estimated to result in aggregate global emission levels of 55.2 Gt CO₂ eq in 2025 and 56.7 Gt CO₂ eq in 2030. Compared with global emissions in 1990, 2000 and 2010, global aggregate emission levels resulting from the NDCs are expected to be higher 8–18 per cent in 2025 and 11–22 per cent in 2030 in relation to the global emission level in 2010. While these figures show that global emissions considering the NDCs are expected to continue to grow until 2025 and 2030, the growth is expected to slow down substantially. The relative rate of growth in emissions in the 2010–2030 period is expected to be 10–57 per cent lower than that over the period 1990–2010, reflecting the impact of the NDCs (UNFCCC, 2015).

In addition, global average per capita emissions considering the NDCs will decline by 8 and 4 per cent by 2025 and by 9 and 5 per cent by 2030 compared with the levels in 1990 and 2010, respectively. And the implementation of the NDCs would lead to lower aggregate global emission levels than in pre-NDC trajectories (UNFCCC, 2015).

Our calculations using the WITCH Model (Aleluja, Carraro and Tavoni, 2015) are shown in Figure 4 and 5. We consider the second Shared Socioeconomic Pathway (SSP2) as business as usual scenario (BAU). SSP2 is a Socioeconomic Pathway with almost no greening of world economic development (IPCC, 2010), unless some effective policy decisions are implemented. In addition to the BAU (the red line), we consider the sum of the

NDCs in two cases: when all unconditional pledges are aggregated (the blue line), and when the conditional pledges are also taken into account (the green line). Figure 4 shows that COP 21 pledges reduce emissions by 19-23% with respect to the SSP2 emission pathway.

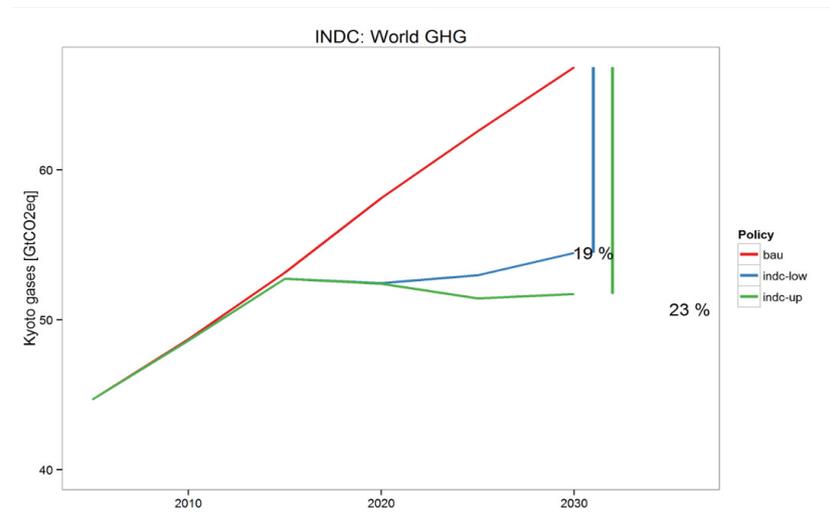


Figure 4. The effectiveness of aggregate NDCs

If the comparison is carried out with respect to the global emission pathway consistent with the 2°C target, results are less encouraging. As shown in Figure 5, COP 21 pledges are slightly above the trajectory that would be required to keep global temperature below 2°C by the end of the century. Additional contributions along with improved negotiating efforts are therefore needed in future climate negotiations. This is not surprising, because the non-cooperative approach adopted in Paris is likely to lead countries to pledge emission reductions close to the ones they would have implemented on the basis of their own domestic interests, without any cooperative effort to control climate global externality.

Is this enough to conclude that Paris COP21 failed to achieve its objectives? Certainly not and for multiple reasons. First, even though not “deep” enough, the Paris agreement is very “broad”. For the first time, a large group of countries, notably US and China, committed to reduce their own GHG emissions with the obvious consequence that, for the first time, a cap on total emissions is likely to be achieved. Second, emission targets are just one of the components of the Paris agreement. Many countries are implementing multilateral and bilateral investments into R&D, which aim to drive the technology innovations and price reductions required to catalyze a clean energy future. Third, the big issue behind climate negotiations of the last years, and Paris COP 21 was no exception, is finance. Many developing and emerging economies are not going to make any effort to achieve their own NDC unless adequate financing support is received by developed countries. The Green Climate Fund, albeit insufficient, is certainly a step forward into the right direction. Fourth, the Paris agreement must be considered the first mile of a long journey. More ambitious emission reduction commitments will be adopted in the coming years. What we do need now is a sound monitoring and verification system to guarantee that all countries actually implement, through domestic policies, what they promised to do in Paris.

There is another element of Paris COP 21 to be underlined. As argued above, the likelihood of keeping the increase of global temperature below the 2°C “security threshold” is far from being at hand. All IPCC scenarios show that the 2°C target can only be achieved not only by progressively reducing the current flow of emissions, but also by removing, at least partially, the stock of emissions already in the atmosphere. As a consequence, the opportunities and constraints in deploying large-scale carbon capture and storage (CCS) systems are thus of the utmost actuality, as the technology promises to get rid of the most common greenhouse gases produced in industrial and energy plants before they reach the atmosphere (or even to achieve “negative” emissions, if combined with biomass).

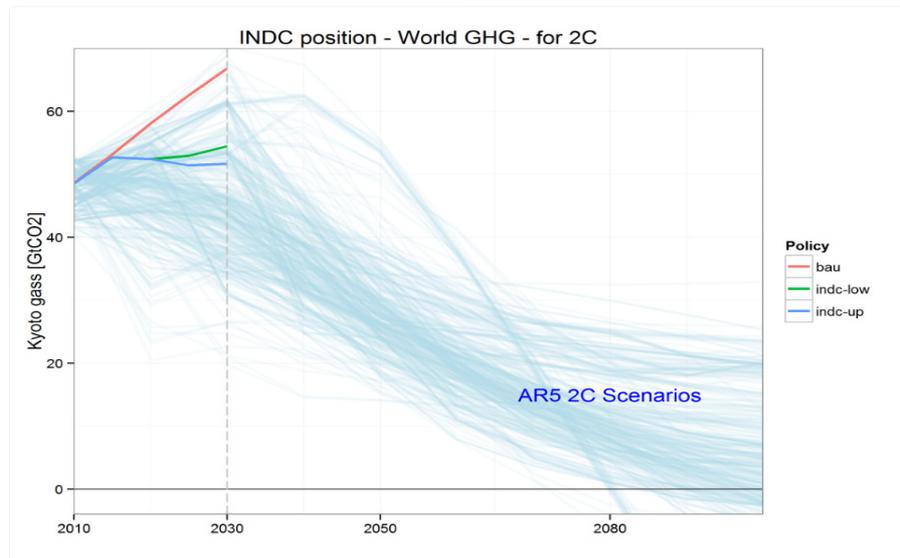


Figure 5. Consistency of COP 21 pledges with the 2°C emission pathways

The potential of CCS is widely recognized: many global climate models cannot reach concentrations of about 450 ppm CO₂eq by 2100 (corresponding to the 2°C target) without CCS. Moreover, in the Fifth IPCC Assessment, scientists observed that mitigation costs become consistently higher if CCS is excluded from the mitigation scenarios. Nevertheless, the challenges that CCS deployment is facing can raise doubts about the role it can play in future climate strategies and plans.

The IEA Greenhouse Gas R&D Program (IEAGHG) recently published a special issue on CCS, with the aim of marking the 10th year anniversary of IPCC's Special Report on CO₂ Capture and Storage (SRCCS), issued in 2005, and outlining the progress made in the field in the last 10 years. According to the report (IEAGHG, 2015), substantial progress has been made in the last decade concerning CO₂ capture, storage efficiency, and methods to assess leakage impacts and risks of induced seismicity. However, the high costs and high-energy penalties of CCS remain a concern and are among the highest barriers to the wide deployment of CCS in the energy sector, where the majority of GHGs are produced.

Over the past 14 years, governments have committed around USD 24 billion to fund CCS projects, and companies have spent at least USD 9.5 billion since 2005 (14). While only one CCS system on a commercial power plant is currently in operation several other projects have been dismissed or are facing investment shortage, such as the FutureGen project of a CCS-equipped coal plant in Illinois, from which the US government pulled out earlier this year. The financial viability of CCS in the power sector is likely to remain a constraint without clear actions leading to credible carbon prices, technology requirements or emissions standards, ideally at the global level.

A recent report by Citigroup noted that CCS represents “a potentially enormous game-changer for energy markets” but its application has been slow and its future deployment may prove to be “too little, too late” with respect to other more cost-competitive, low-carbon technologies (Citigroup, 2015). “Despite progress on the technical front, the industry believes there is a need for government policy to support the business case for broad scale implementation. While the fossil fuel industry, particularly coal, has tended to resist carbon pricing developments, ironically the lack of carbon pricing means there has been no business case for large scale CCS deployment” (Citigroup, 2015). The public acceptability of CCS is a consequent issue of the need for government support, related to the potential competition for public funding between CCS and other low carbon options, and to the real and perceived risks of deploying CCS at the local level.

Summing up, the attempt to move quickly towards a development path consistent with the 2°C target depends more on technology development (for CCS in particular) and financial transfers (the full funding of the Green Climate Fund at least) than on the quantitative emission reduction commitment that will be adopted at Paris COP 21. The NDCs are an important decision, but without financial support to developing countries and without rapid technological improvements in CCS technologies, humanity will have to adapt to a temperature increase larger than 2°C.

Let us conclude this first part of our analysis with a brief comment on the efficiency of the NDCs approved at COP 21. According to our assessment (see Aleluja, Carraro and Tavoni, 2015), high marginal abatement costs are likely to characterize the abatement efforts of the EU, Korea, Australia and the US. The abatement cost will be much smaller in developing and emerging economies, namely Latin America, East Asia, South Asia, China and Transition Economies. Marginal costs are likely to be smaller in these regions both because targets are less ambitious and because abatement opportunities are often much cheaper.

This opens the way to the introduction of measures to increase efficiency. For example, by pricing carbon worldwide, or by adding to the Paris agreement a set of measures to enable the exchange of credits from emissions reductions implemented by a given country in another country, or by linking emission trading schemes implemented in various countries. This kind of mechanisms would progressively move towards the equalization of marginal abatement costs in different world regions.

3. Fairness of the NDCs: Do They Provide an Equitable Distribution of Mitigation Costs?

As stated in the Introduction, fairness is another important ingredient of the Paris agreement. We have already seen how the EU, the US and China have different objectives. China, in particular, is committed to emission reduction less ambitious than the EU and the US, and less consistent with the optimal 2°C trajectory. The reason is likely not to be a lower consciousness of climate change threats in China. It is probably the other way around: China's commitments is enhanced by the high levels of pollution in China's cities and by the high local benefits, in addition to the global ones, generated by China's GHG emission reductions.

The main reason for China slower progress towards the 2°C trajectory is likely to be fairness, namely the total cost of reducing GHG emissions in China with respect to the EU and the US. Consider indeed the cost of implementing emissions reductions consistent with the achievement of the 2°C target in the EU under the three sets of scenarios previously utilized to assess the effectiveness of NDCs. Let us recall that the first set of scenarios (EMF) is produced by the Energy Modeling Forum. The second set of scenarios (LIMITS) comes from LIMITS, an important project funded by the European Commission. The third set of scenarios (SSP) is produced by the IPCC. For the three studies, three different 2°C consistent trajectories are considered. For example, in the case of SSP, figures below show the costs (wrt BAU) of achieving the 2°C objective of three different pathways: SSP1 (green) SSP2 (conventional) and SSP3 (pessimistic).

The results are shown in Figures 6, 7 and 8. Costs (wrt BAU) to achieve the 2°C target seem to be low in the EU in all scenarios. The cost in 2050 is estimated to be between 3% and 6% of EU GDP.

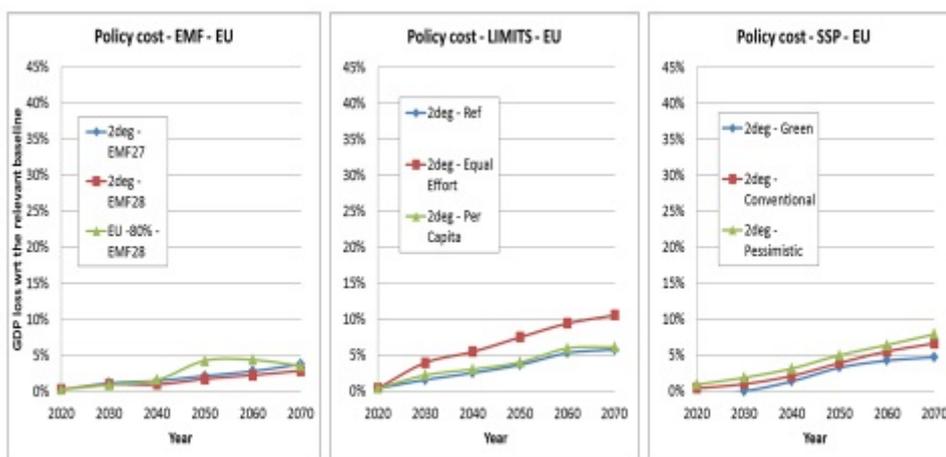


Figure 6. The cost of achieving the 2°C emission reduction trajectory in the EU

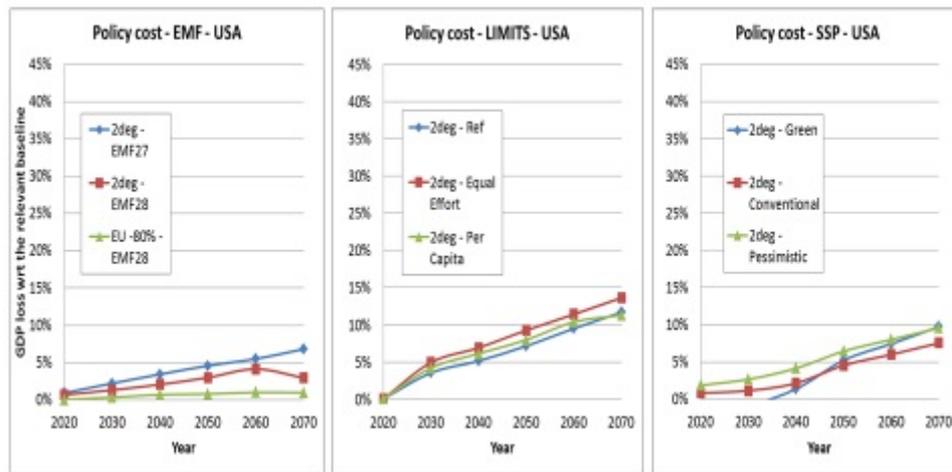


Figure 7. The cost of achieving the 2°C emission reduction trajectory in the US

As shown in Figure 7, costs are slightly higher in the US. In 2050, the range is 3-10%. However, costs are higher in China. Figure 8 shows that costs of reducing GHG emissions consistently with cost-effective 2°C scenarios range between 5 and 20% of China GDP in 2050.

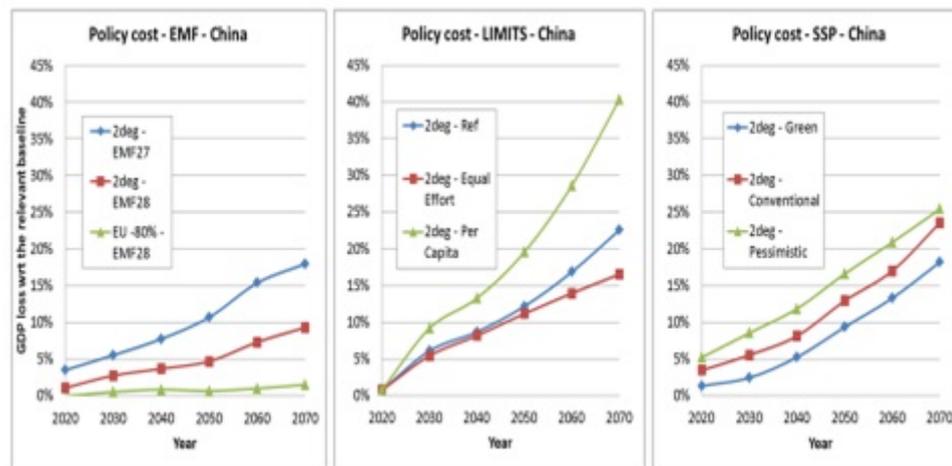


Figure 8. The cost of achieving the 2°C emission reduction trajectory in China

As a consequence, one of the reasons behind China’s less ambitious pledge at COP 21 is likely to be the higher relative cost for China to reduce emissions consistently with the 2°C target. For the EU and the US it seems to be easier, at least in terms of GDP losses, to attain the 2°C target. Therefore, their pledges are more consistent with this objective than China’s one.

4. Conclusions

The non-cooperative bottom-up approach adopted to prepare the Paris Agreement has been unable to deliver a highly effective deal at COP 21. Nevertheless, COP 21 represents a crucial and innovative step towards GHG emission control. After four decades of increasing emissions (and the last decade is the one with the highest emission growth rate), for the first time GHG emissions will be stabilized: emissions in 2030 will almost equal to emissions in 2015. For the first time, almost all countries have submitted concrete and operational pledges to reduce or control their GHG emissions: the divide between developed and developing countries has been largely removed.

These important results have been achieved because a bottom-up non-cooperative approach has been adopted. A broad, even though not deep, agreement has been signed in Paris. This is likely to create consensus for further

future actions, when more ambitious efforts need to be implemented in the coming decades.

The bottom-up non-cooperative Paris agreement obviously lacks effectiveness. Given the absence of coordinated economic instruments (a global carbon price or linked emission trading schemes) it also lacks efficiency. However, it contains a degree of fairness, which explains the large consensus on the Paris agreement emerged at COP 21.

Most importantly, the commitments and pledges adopted in Paris are just the first step in a long journey. Additional emission reduction efforts will need to be implemented in the coming years, and more effective policy measures will need to be adopted, both domestically and internationally. The adoption of robust systems for measurement, reporting, and verification facilitates compliance, but without supporting enforcement measures, countries are unlikely to achieve large emissions reductions. What is missing is both enforcement and vision. It is not enough to agree on a temperature target. It is now urgent to agree on a societal transformation path, which, in market economies at least, can be driven only by a change in relative prices.

For this process to move quickly towards the objective, a set of metrics to measure and assess the effectiveness, efficiency and fairness of the abatement efforts implemented in various countries is necessary. This paper is a first attempt to provide this crucial assessment. Extensions to a larger number of countries and the use of a larger number of models would certainly improve the robustness and usefulness of the results.

Acknowledgments

The author is grateful to Lara Aleluja and Massimo Tavoni for the WITCH modeling runs that provided the results described in this paper. He is also grateful to participants at the Second Protection and Sustainability Forum held in Bath, UK, 9-11 April 2015, for helpful comments and suggestions.

References

- Aleluja, L., Carraro, C., & Tavoni, M. (2015). *The Paris Agreement: Assessment and Comparison of National Emission Reduction Efforts*. FEEM Nota di Lavoro, Milan.
- Barrett, S., Carraro, C., & de Melo, J. (Eds.). (2015). *Towards a Workable and Effective Climate Regime*. VoxEU.org eBook, CEPR, London.
- Citigroup. (2015). *ENERGY DARWINISM II: Why a Low Carbon Future Doesn't Have to Cost the Earth*. Citi GPS: Global Perspectives & Solutions, August 2015, London.
- EC. (2014). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A policy framework for climate and energy in the period from 2020 up to 2030*. COM(2014) 15 final Brussels. Retrieved from <http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52014DC0015&from=EN>
- EC. (2015). *Energy Union Package. A framework strategy for a resilient Energy Union with a forward-looking climate change policy*. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee, the Committee of the Regions and the European Investment Bank COM(2015) 80 final Brussels. Retrieved from http://eur-lex.europa.eu/resource.html?uri=cellar:1bd46c90-bdd4-11e4-bbe1-01aa75ed71a1.0001.03/DOC_1&format=PDF
- EEA. (2015). *Trends and projections in Europe 2015. Tracking progress towards Europe's climate and energy targets*. Report No 4/2015, Copenhagen.
- EMF. (2014, April). The EMF27 Study on Global Technology and Climate Policy Strategies. *Climatic Change*, 123(3-4).
- IEA. (2015, June). *World Energy Outlook 2015 Special Report*. International Energy Agency, Paris.
- IEAGHG. (2015). *Assessment of emerging CO₂ capture technologies and their potential to reduce costs*. International Energy Agency, Paris, December 2014.
- IPCC. (2010). Workshop Report. In Edenhofer, O., Pichs-Madruga, R., Sokona, Y., Barros, V., Field, C. B., Zwickel, T., ... C. von Stechow (Eds.), *IPCC Workshop on Socio-Economic Scenarios*. 1-3 November 2010, Berlin, Germany.
- LIMITS. (2013, November). LIMITS Special Issue on Durban Platform scenarios. *Climate Change Economics*, 4(4).

UNFCCC. (2015). *Synthesis report on the aggregate effect of the intended nationally determined contributions*, UNFCCC, Paris, Oct 2015.

Copyrights

Copyright for this article is retained by the author(s), with first publication rights granted to the journal.

This is an open-access article distributed under the terms and conditions of the Creative Commons Attribution license (<http://creativecommons.org/licenses/by/4.0/>).