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RESEARCH ARTICLE

# Assessing the ambition of post-2020 climate targets: a comprehensive framework

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**ABSTRACT**
One of the most fundamental questions surrounding the new Paris Agreement is whether countries' proposals to reduce GHG emissions after 2020 are equally ambitious, considering differences in circumstances between countries. We review a variety of approaches to assess the ambition of the GHG emission reduction proposals by countries. The approaches are applied illustratively to the mitigation part of the post-2020 climate proposals (nationally determined contributions, or NDCs) by China, the EU, and the US. The analysis reveals several clear trends, even though the results differ per individual assessment approach. We recommend that such a comprehensive ambition assessment framework, employing a large variety of approaches, is used in the future to capture a wide spectrum of perspectives on ambition.

**POLICY RELEVANCE**
Assessing the ambition of the national climate proposals is particularly important as the Paris Agreement asks for regular reviews of national contributions, keeping in mind that countries raise their ambition over time. Such an assessment will be an important part of the regular global stocktake that will take place every five years, starting with a 'light' version in 2018. However, comprehensive methods to assess the proposals are lacking. This article provides such a comprehensive assessment framework.

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## 1. Introduction

At the 21st session of the Conference of the Parties (COP21) to the United Nations Framework Convention on Climate Change (UNFCCC) held in 2015, the Paris Agreement was adopted as the new international climate policy agreement for the post-2020 period (UNFCCC, 2015a). The Agreement subsequently entered into force on 4 November 2016 after it had been ratified by the required number of countries.

In the lead-up to COP21, countries were asked to put forward proposals on how, and by how much, they are willing to reduce their GHG emissions after 2020; these are the so-called 'intended nationally determined contributions' (INDCs).[1] Nearly 190 countries submitted their INDCs before the COP21 (Höhne et al., 2016; UNFCCC, 2015b). With each country's ratification of the Paris Agreement, its '*intended* nationally determined contribution, INDC' turns into a 'nationally determined contribution, NDC'.

In order to effectively implement and achieve the goals of the Paris Agreement, i.e. to hold the increase in the global average temperature to well below 2°C above pre-industrial levels and pursue efforts to limit it to 1.5°C (UNFCCC, 2015a), the total ambition level of the NDCs needs to be increased (Rogelj et al., 2016). To guide this process, the NDCs of countries will have to be assessed on their relative ambition level. Indeed, the Paris

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Agreement (Article 4) specifically mentions that 'each Party's successive nationally determined contribution will (…) reflect its highest possible ambition, reflecting its common but differentiated responsibilities and respective capabilities, in the light of different national circumstances'. Countries have thus confirmed their intention to share reductions according to 'common but differentiated responsibilities and respective capabilities' (CBDR-RC). Interpretations of this principle, however, still diverge (Meinshausen et al., 2015; Winkler & Rajamani, 2014). Assessments of ambition will continuously take place, in particular at the 'facilitative dialogue' that is planned for 2018 and at the global 'stocktake' to be held every five years starting 2023. Assessment methodologies for these events are urgently needed.

The EU, China, and the US were among the first to announce a proposal for their efforts in the 2015 climate agreement. The EU proposed to reduce its domestic GHG emissions by at least 40% by 2030 (European Council, 2014). This was followed by joint announcements by China and the US (White House, 2014), according to which China aimed to peak $CO_2$ emissions by around 2030, make best efforts to peak earlier than this date, and to reach around 20% of non-fossil fuels in their primary energy consumption by 2030. The INDC from the US registered an aim to reach 26–28% reductions in GHG emissions below the 2005 level by 2025. All three officially submitted their INDCs ahead of the Paris conference. From the announcement to the submission of its INDC, China added an additional element, of a reduction in $CO_2$ emissions by unit of gross domestic product (GDP) by 60–65% from 2005 to 2030.

Judging the fairness and relative ambition of countries' contributions to reduce GHG emissions is not easy, as countries have different types of targets and differ in terms of development, industrial structure, capabilities and responsibilities – aspects which also change over time. Many approaches to judge contributions have been introduced and no single approach is 'better' than the other; they all have their pros and cons (den Elzen, Höhne, & van Vliet, 2009; Stavins et al., 2014). The approaches may come to different results on the relative ambition level of countries. Current literature assessments focus on (1) where countries need to be in 2030 to be compatible with the 2°C objective based on effort-sharing approaches (Hof, den Elzen, & Mendoza Beltran, 2016; Höhne, den Elzen, & Escalante, 2014a; Kuramochi, Asuka, Fekete, Tamura, & Höhne, 2015; Meinshausen et al., 2015), (2) global cost-effective distributions (Clarke et al., 2014; Tavoni et al., 2015), or (3) a set of different metrics related to emissions, energy and carbon prices, as well as GHG abatement costs (Aldy, Pizer, & Akimoto, 2016). However, assessments of national emission reduction proposals based on a comprehensive set of comparability metrics (Aldy et al., 2016) or approaches to evaluate the ambition level of reduction proposals, are limited (Kuramochi, 2015). This is especially the case for peer-reviewed literature on comparisons of post-2020 emission reduction proposals of the three highest-emitting economies – China, the EU, and the US (Aldy et al., 2016).

We argue that to evaluate the ambition level of NDCs, a comprehensive assessment of several approaches should be used that reflect the different viewpoints of the Parties under the UNFCCC. In this context, the main objective of this article is to provide an overview of assessment approaches, and to assess their pros, cons, and results, so that a comprehensive framework of approaches to evaluate the ambition level of NDCs can be designed.

We focus on mitigation only, acknowledging that other elements, such as adaptation and financial support, are also very important. Our framework is based on a review of existing evaluation approaches, in which the approaches are described and evaluated using relevant characteristics, and in which their main challenges are assessed (Section 2). In Section 3, we apply these approaches illustratively for the NDCs by China, the EU, and the US, ranking for each approach the respective ambition. Finally, we draw conclusions from the analysis and identify further research needs (Section 4).

## 2. Review of approaches to assess the ambition of NDCs

A large number of studies have assessed countries' mitigation efforts since COP3 held in Kyoto in 1997 (Aldy et al., 2016). In addition, in recent years, several approaches and associated comparability metrics or indicators have been proposed to evaluate the ambition level of NDCs (Aldy et al., 2016; Höhne, Ellerman, & Fekete, 2014b; Kuramochi, 2015; NIES, 2015). From this literature, we have identified eight distinct approaches (Table 1).

**Table 1.** Framework to evaluate the ambition level of NDCs, grouped by the two strands related to CBDR-RC drawing from (Aldy et al., 2016; Höhne et al., 2014b; Kuramochi, 2015; NIES, 2015).

| Assessment approach | Description | Can be determined unambiguously | Captures also past action | Challenges |
|---|---|---|---|---|
| **Approaches related mainly to moral obligation:** | | | | |
| 1. Reduction from 1990 levels | In the framework convention adopted in 1992, the base year of 1990 was introduced, as it states the general goal of returning emissions of developed countries by the end of the century to the level of 1990. Since then the base year for 1990 is a common comparison for developed countries. | + | + | Can only be applied to developed countries. If evaluated on per capita emissions (not absolute emissions), it can also take into account changes in population since 1990. |
| 2. Change in recent trends (Höhne et al., 2014b) | One can assess whether the new offer constitutes a change in recent trends, indicating that *additional* action is required to meet the NDC. This acknowledges that all countries need to change their *trend*; they need to do something *new* or *additional* compared to the past (unless they are on a trajectory to zero or negative emissions). | – | – | 'Recent trends' can have very different definitions; it may exclude existing policies ('no policies' baseline) or assume that all currently existing policies continue ('current policies' scenario). In fact, for countries that made significant efforts in the past, a deviation from recent trends may be more difficult. Recent trends always remain counterfactual, as they always depend on a (hypothetical) emission projection and cannot be verified. |
| 3. Time and level of peaking per capita emissions | All countries have to undergo a transition where at some point GHG emissions per capita or per GDP peak and then decline. The UNFCCC Copenhagen Accord and the Cancun Agreements (UNFCCC, 2010a, 2010b) called for the peaking of national emissions as soon as possible. | + | + | A 'fair' level of peaking is not equal for all countries as it depends on the time when it occurs. Owing to technological progress, a country that peaks later can reach the same development status with less emissions. It is difficult to determine to which exact amount. |
| 4. Effort-sharing (Höhne et al., 2014a) | A wide range of literature allocates global emissions and emission reduction targets to individual countries based on 'effort-sharing' principles to determine 'fair' ambition levels. The principles include responsibility (e.g. those who emitted more in the past now have to reduce more) or capability (e.g. those with higher per capita income levels should do more), equality (i.e. equal emission rights per capita), cost-effectiveness (total abatement cost per GDP), as well as combinations. | – | +/– | The range of possible emissions allowances is wide owing to the different focus of the effort-sharing approaches. There is also large uncertainty and debate as to the level of global carbon budget to achieve the 2 °C target with a relatively high probability, an assumption that significantly drives the results. |
| **Approaches related mainly to technical necessity:** | | | | |
| 5. Decarbonization indicators (Aldy et al., 2016; Höhne et al., 2011; Höhne et al., 2014b; Linthorst, de Beer, Blok, & Meindertsma, 2014; NIES, 2015) | A number of disaggregated indicators can be used to compare countries' circumstances and developments. On the national level: status of emissions per capita, energy use per capita, or emission intensity of the energy mix. On the sectoral level: emissions per kilometre travelled or per ton of cement or steel produced. Indicators can measure activity (e.g. vehicle kilometres travelled) or intensity (emissions per vehicle kilometre) | +/– | + | Some assumptions about the future may be required for some indicators. Emissions per GDP need GDP forecasts, emissions per vehicle kilometre may need modelling. Many factors that are unrelated to mitigation policies can affect these indicators. |

(*Continued*)

**Table 1.** Continued.

| Assessment approach | Description | Can be determined unambiguously | Captures also past action | Challenges |
|---|---|---|---|---|
| 6. Globally cost-effective scenarios (Aldy et al., 2016; Höhne et al., 2014b) | Modelling exercises can identify necessary reductions by countries if the aggregated global costs of emission reductions are minimized. As a result, reductions are achieved in the sectors and countries where they are the cheapest from a global perspective. | – | + | The calculation of mitigation potentials depends on many assumptions, including a no-policy business-as-usual or recent trend plus assumptions of e.g. future energy prices. This results in limited transparency of the calculations and large differences of the results across models or studies. |
| 7. Policy package or a policy menu (Höhne et al., 2014b) | One can compare the extent to which a country implemented supporting policies, addresses barriers, or has counterproductive policies in place. A contribution can be regarded as ambitious if it includes many policies that are considered good practice, while it would be less ambitious if the country would not implement the policies that most of its peers have already successfully implemented. | – | + | The critical element of this approach is the definition of the list of good practice policies that are used as the benchmark. There may be a debate over a list of policies to be evaluated because suitable policies may depend largely on national circumstances. |
| 8. Energy price indicators (including carbon price) (Aldy et al., 2016) | Fossil energy prices (including all taxes and exceptions and implicit and explicit carbon prices) allow for a comprehensive assessment of all price-based policies implemented in the country. The energy prices are a key driver for energy demand and supply as well as investment in energy efficient technologies in the end-use sectors. | – | + | Energy prices fail to capture most effects of non-price based policies that reduce emissions without influencing energy prices.<br>A low energy prices does not necessarily have to be an indication of low ambition. For example, high shares of renewables in the electricity market may significantly decrease the electricity prices.<br>Moreover, there are large regional disparities in natural gas and coal prices owing to the differences in fossil energy resource availability and transportation constraints.<br>There is also question of whether to look into prices of individual energy sources in different sectors or take the average energy prices of the entire economy. |

Note: '+' (dark grey) means high agreement with the criterion, '+/–' (light grey) means partial agreement, '–' (grey) means low agreement.

For each evaluation approach, Table 1 provides a description, an assessment of its different characteristics and challenges, as well as an indication on whether it focusses on one of two main strands that relate to the principle of CBDR-RC[2]:

- *Moral obligation/equity*: From this viewpoint, emission commitments should be based on countries' moral obligations to reduce their emissions, so that the resulting regime is equitable and fair. This strand relates to the 'differentiated' element of the agreed principle of CBDR-RC. Differentiation is often based on indicators such as historical responsibility and capability.
- *Technical necessity/efficiency*: The starting point of this viewpoint is whether a country's proposal is in line with what is technically necessary from now on for a given global goal, irrespective of moral obligation, equity or past action. This could be judged by whether the country's proposal (1) is in line with its contribution in globally cost-effective mitigation scenarios, (2) leverages all mitigation potential, or (3) covers all policies that the country's peers undertake. This strand relates more to the 'common' element of the agreed principle of CBDR-RC and can also be referred to as 'required by science'.

For this article we consider 'ambition' to include both moral obligation and technical necessity. Although some would consider only moral obligation, fairness, or equity as ambition, here we take a wider approach in order to cover as many viewpoints as possible.

The two strands may lead to fundamentally different outcomes. A developing country, for example, may have limited moral obligation because of its low historical emissions, but at the same time, high mitigation potential, as in general developing countries tend to be characterized by higher energy and carbon intensities, rapidly rising baseline emissions, and by a high share of new infrastructure (Clarke et al., 2014). Many developed countries, in contrast, have a high moral obligation, but may also face higher technical difficulties to reduce domestic emissions by the same order of magnitude without retiring old infrastructure before the end of its life ('carbon lock-in' or 'stranded assets') leading to relatively high costs. Countries with high moral obligation but low domestic technical potential could provide technical and financial support to other countries to implement what is technically necessary. We grouped the approaches according to whether they relate more to moral obligation or technical necessity, although some approaches may relate to both elements in different degrees.

We also assessed the different methods against two further important characteristics, and discuss their main challenges in this regard (Table 1):

- *Can be determined unambiguously*: Some of the approaches are straightforward to calculate and the results will not depend on the entity that is applying the approach, and its parameterization. Other approaches allow for different interpretation and parameter settings and therefore different users will yield different results.
- *Captures also past action of countries*: The NDCs are primarily intentions for the future. But future mitigation action may depend on (the lack of) past actions. An approach for rating future action could therefore also take into account past actions of a country, to put the future actions in better perspective.

The overview presented in Table 1 shows that each approach has strengths but also weaknesses, and no single approach stands out. Although the simplest approach of 'reduction of GHG emissions from 1990 levels' can be determined unambiguously and takes into account past action, it is not a good indicator to compare the relative ambition levels of countries which differ in their stages of development, as these usually show very different emission trends. Time and level of peaking is easy to calculate, but difficult to interpret, as it is difficult to determine how much lower a peak should be attributable to technological progress if it occurs later. Change in recent trends is difficult to calculate as 'recent trends' can be defined in different ways. Decarbonization indicators are close to actual action in the sectors, but can only capture the difference in national circumstances between countries to a limited extent. The same holds for comparison to best practice policies, which is difficult to obtain and very difficult to differentiate among countries according to equity principles.

## 3. Illustrative assessment

In this section, we assess the NDCs of China, the EU, and the US by applying seven of the assessment approaches[3] presented in Table 1, and then compare them qualitatively. Data sources used across the approaches are described in the appendix (Supplementary Information). The results of the evaluation are summarized in Table 4 (see later)

### *3.1. Reduction of GHG emissions from 1990 levels*

The approach 'reduction of GHG emissions from 1990 levels' takes into account early mitigation action by countries. The EU aims for a 40% reduction relative to 1990 by 2030. This is more ambitious than the NDC of the US, which consist of a 26–28% reduction target by 2025 relative to 2005, which translates into around 27% below 1990 by 2030 (Figure 1).[4]

As mentioned in the previous section, this metric is not a good indicator for countries which differ in their stage of development, so we do not assess China by this criterion.

### *3.2. Change in recent trends*

The rating for this criterion strongly depends on the reference point, and on the extent to which the effect of past action is included. We illustrate this using the NDCs of China, the EU, and the US.

For countries that have already implemented climate policies and have a downward trend in emissions, a further change in this trend may not be feasible. For those countries, the criterion does not take into account the efforts made earlier. The EU, for instance, has implemented a large number of climate policies in the past and is accelerating its downward trend of 1.0% per year from 1990 to 2012 to 1.6% per year from 2012 until 2030 (based on own calculations, see Appendix for data sources (Supplementary Information). From this perspective, the 2020 pledge of a 20% reduction is quite weak, as it requires only a 0.1% annual decline from 2012 to 2020. From that level to the new 2030 target of 40% would be a considerable step change requiring a 2.8% annual decline until 2030. But the EU is likely to reduce its emissions by more than 20% by 2020 (European Environmental Agency, 2014), with a projected annual reduction of 1.3% from 2012 to 2020. This implies that the annual reduction from 2020 to 2030 would need to be 1.9% to reach the 2030 target of 40%. Therefore, in total, the new target constitutes a slight improvement in the trend.

The proposal of the US implies changing its current trend of 1.0% reduction per year from now until the 2020 target to 2.5% per year from 2020 until 2025 (in total also 1.6% per year from 2012 to the NDC target). This implies a higher change in recent trends than the EU, although it is reducing at the same rate as the EU from 2012 to the target.

The comparison to a 'current policy scenario' (Figure 1) shows that the US targets constitute a significant deviation from the current policy scenarios. This could indicate a high ambition level for their NDC, but could also be an indication that policies lag behind the goals set in the NDC. The EU is close to achieving its NDC with already implemented policies. For a country with increasing emissions and/or limited climate policies, the emission trend can be significantly altered through the introduction of new policies. This applies to China in particular, where the proposal to peak emissions by 2030 is a significant deviation *after 2030* from the usual reference assumption that emissions would continue to rise for decades after that[5] (Tavoni et al., 2015). But as said before, this significantly depends on this reference assumption. For example, analysis suggests that the effect of all current policies is sufficient to meet the 20% non-fossil target by 2030 (den Elzen et al., 2016; Grubb et al., 2015).

### *3.3. Time and level of peaking of per capita emissions*

China's NDC includes the intention to peak in 2030 or earlier. We estimate that the peak in GHG emissions will be at around 9.0–9.6 $tCO_2e$ per capita at a projected per capita GDP of 12,600 $US\$_{2005}$.[6] GHG emissions in the EU already peaked in 1979 at 13 $tCO_2e$ per capita (JRC/PBL, 2012) with a per capita GDP of 17,450 $US\$_{2005}$, while emissions in the US peaked in 2007 at 24.5 $tCO_2e$ per capita with a per capita GDP of 44,300 $US\$_{2005}$. The GDP figures shown are based on GDP figures measured in market exchange rates (MER); if GDP measured in

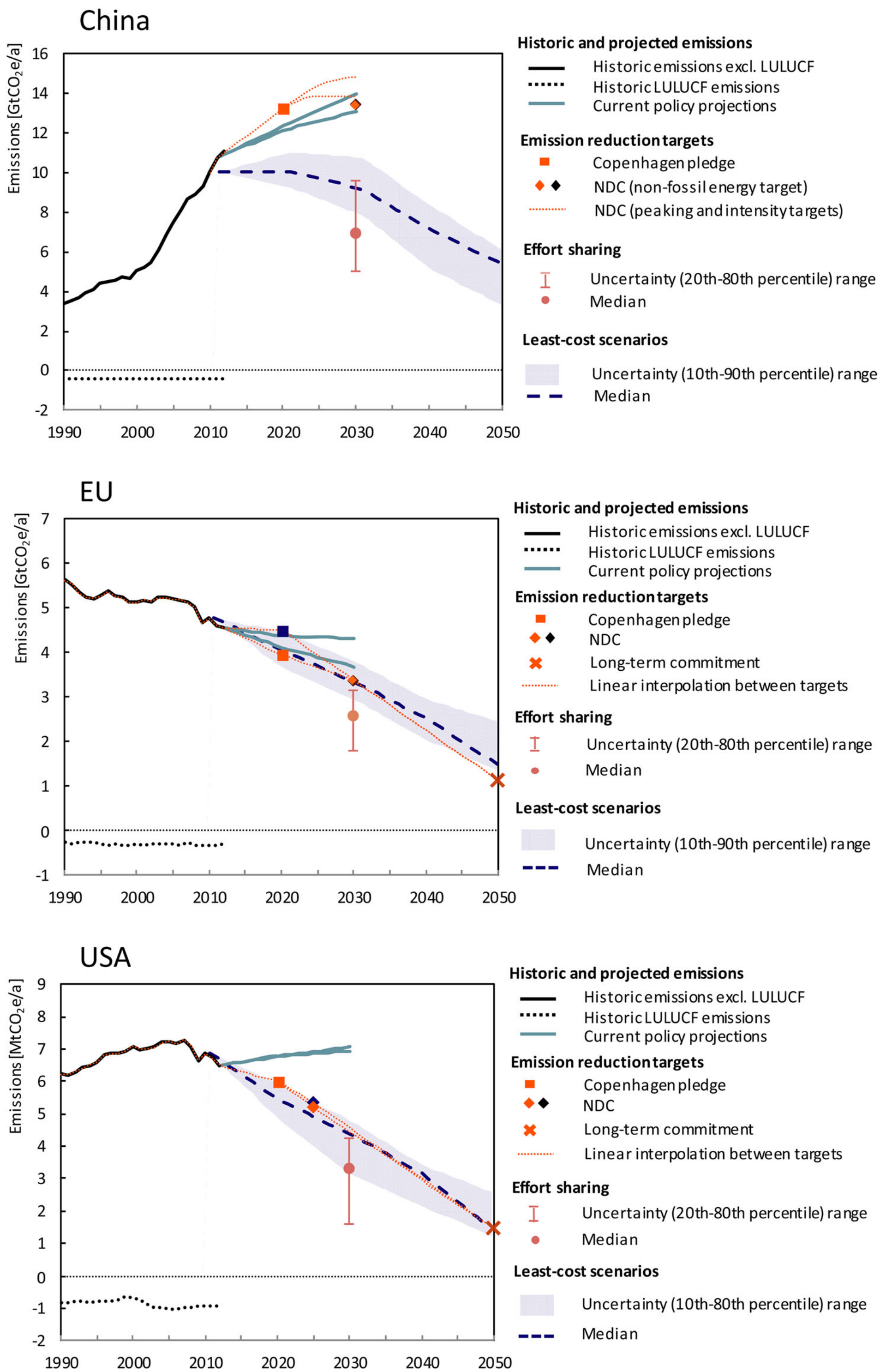


**Figure 1.** Emissions of China, the EU, and the US (see Appendix for sources and assumptions (Supplementary Information)).

purchasing power parity were to be used, the per capita GDP for China would be a factor of more than three higher, and would therefore surpass the per capita GDP level of the EU at the peak year.

Comparing peaking levels at different points in time is not straightforward, because technological change allows countries to reach the same development level today with lower emissions than countries that developed earlier (den Elzen, Olivier, Höhne, & Janssens-Maenhout, 2013). For example, the UK started its industrialization with inefficient steam engines, whereas developing countries that undergo a similar development today use best available current technology right away, which emits much less GHGs.

With this in mind, China is projected to peak its per capita emissions about 50 years after the EU, but at a level which is 27% lower (Green & Stern, 2016). If technological progress implies that the emissions efficiency increases by 0.5% per year, it could be argued that countries that peak 50 years later in time, should peak at a level which is 22% lower,[7] meaning that China will peak at a relatively lower level than the EU did. For an annual 1% increase in emissions efficiency, the peak should be 39% lower, meaning that the EU peaked at a relatively lower level. den Elzen et al. (2013) estimated an improvement rate of 1.3% per year during 1990–2005, owing to the combined effect of technological progress in energy efficiency and a transition to renewable energy sources, based on IEA statistics,[8] which would mean that the EU peaked at a lower level than China is projected to do.

### 3.4. Comparison to effort-sharing calculations

In previous papers, the authors summarized effort-sharing calculations for the IPCC Fourth Assessment Report (Box 13.7 (Gupta et al., 2007) and its related papers (den Elzen & Höhne, 2008)), as well as for the IPCC Fifth Assessment Report (Clarke et al., 2014; Höhne et al., 2014a) of the Intergovernmental Panel on Climate Change (IPCC) and provided country-level results for the Climate Action Tracker.[9] Although most studies included in these assessment reports calculated country- or region-specific emissions allowance trajectories up to a certain future year (2030 or 2050), as reviewed in Höhne et al. (2014a), some studies also calculated remaining cumulative emissions allowances (de Vos, van Breevoort, Höhne, Winkel, & Sachweh, 2014; Kuramochi et al., 2015).

Figure 1 provides ranges of GHG emission reduction targets for 2030 according to a wide variety of effort-sharing approaches based on over 40 studies from various authors, some of which provide country-level data for the selected stabilization level (450 ppm $CO_2$e) (based on Figure 2 of Höhne et al. (2014a)). The results in Höhne et al. (2014a) are at the level of ten regions; for the US we have used the reduction percentages of the region North America (US, Canada), and for China, the region East Asia (incl. China, Korea, Mongolia). For the EU, we applied a reduction percentage consisting of 70% of the results from the region Western Europe and of 30% from the region Economies in Transition, to take into account that the EU is part of both regions. As in Höhne et al. (2014a), the range is shown for all studies in all effort-sharing categories (except cost-effectiveness, as we consider this to be a separate approach, see Section 3.6) using the 20th to 80th percentile range.

Depending on the chosen effort-sharing approach, the reduction targets may differ significantly. Still, the full range of results can be used as an indication of the fairness of the countries' reduction proposals in relation to the 2°C goal.

Principles based on responsibility and capability considerations would usually result in higher reduction targets for developed countries owing to their higher economic capability and historical responsibility. At the extreme end, they would allocate zero or even negative emission allowances by 2030 to, for example, the US and the EU. Acknowledging that they cannot achieve these reduction targets domestically, these countries/regions are expected to finance emission reductions in other countries. Developing countries' reduction targets are usually required to reduce later or less stringently.

Effort-sharing calculations provide a mixed picture across the three countries. The evaluation depends significantly on the choice of the effort-sharing approach or category and selection and weighting of the studies. Taking the effort-sharing data and methodology from the IPCC AR5 (Clarke et al., 2014; Höhne et al., 2014a), the reduction target calculated as the median over all studies for the US and China in 2030 is 51% (20th–80th percentile range: 38–77%) and 30% (4–50%) below their 2010 levels and for the EU 46% (34–62%) below its 1990 levels, which are all beyond their announced reduction targets, in particular for China. China ranks significantly better for approaches based on equal cumulative per capita emissions and those putting

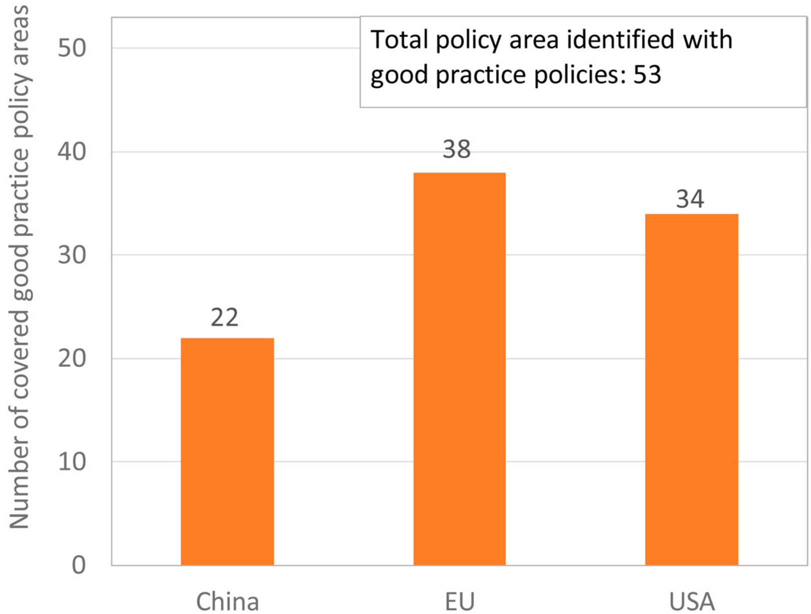


**Figure 2.** Number of good practice policy areas covered by currently implemented polices (based on Höhne et al., 2015).

high weights on responsibility and capability. The level of one study (from the 40 studies) is close to the Chinese proposal, but this study is in the 10th percentile, i.e. outside of the range shown here. The EU and US rate better for approaches that assume equal costs per GDP. The EU also rates better for the per capita emissions convergence approaches, given its lower per capita emissions by 2030 compared to the US and China.

### 3.5. Comparison to benchmarks of sectoral decarbonization indicators

China, the EU, and the US have proposed actions at the national level, not disaggregated to sectors (IEA, 2008; SDSN and IDDRI, 2014). To make an assessment of sectoral decarbonization indicators, a starting point could be model calculations that disaggregate national emissions to sectors, based on, for example, the planned national policies to achieve the overall targets. Such assessments show that the results of the comparison depends on the decarbonization indicator used (Climate Action Tracker, 2014; Cronin et al., 2015; IEA, 2012; UNFCCC, 2008).

By way of illustration, we provide a few decarbonization indicators implied by the NDCs in 2030 (Table 2). We derived these values from background material from the countries or from own calculations. We provide examples of 'activity rate' (e.g. how much floor space is used and how many kilometres are travelled) and a 'GHG emissions/energy intensity' (emissions per $m^2$ floor area or per travelled kilometre). Both, together, determine the level of GHG emissions.

Table 2 shows that the EU has lower values than the US on per capita activity indicators (e.g. consumption levels such as electricity consumption and floor area) and on GHG emission intensities (e.g. $CO_2$ emissions per kWh electricity generated or $CO_2$ emissions per vehicle kilometre), both currently and in 2030. China's values on per capita activity levels are also lower than those of the US, but the picture is mixed for GHG/energy intensities. China's activity levels are lower than those of the EU, but some GHG/energy intensities are higher.

### 3.6. Comparison to globally cost-effective 2°C scenarios

Models have been used extensively, e.g. in the IPCC AR5 scenario database (Clarke et al., 2014), to come up with a range of global cost-effective scenarios, often also disaggregated to the country level, at least for the three considered here. A globally harmonized carbon price is applied in these models to equalize marginal abatement costs around the world.

**Table 2.** Comparison of sector-level decarbonization indicators: current levels (for 2010–2014) and target levels as implied by the NDCs in 2030, where possible.

| Sector | Figures with recent developments | | China | EU | US |
|---|---|---|---|---|---|
| Electricity generation (IEA, 2015) | Activity: electricity generation per capita [kWh/cap][a] | 2013 | 4000 | 6400 | 13,500 |
| | | 2030 (NDC implementation case)[b] | 6500 | 6600 | 13,000 |
| | Intensity: $CO_2$ emission intensity [$gCO_2$/kWh] | 2013 | 780 | 380 | 490 |
| | | 2030 (NDC implementation case)[b] | 540 | 220 | 355 |
| | Renewable energy share (incl. hydro) in total electricity generation | 2013 | 20% | 27% | 13% |
| | | 2030 (NDC implementation case)[b] | 30% | 44% | 24% |
| Industry | Intensity: Energy saving potential for iron & steel production [GJ/t steel] | 2011 (IEA, 2014) | 6.7 | 1.6[c] | 2.1 |
| | | 2030 | N/A | N/A | N/A |
| | Intensity: Energy saving potential for cement production [GJ/t cement] | 2010 (IEA, 2012) | 1.1 | 0.7 | 1.6 |
| | | 2030 | N/A | N/A | N/A |
| Buildings (residential and commercial) | Activity: Building floor space per capita ($m^2$/cap)[d] | 2013 | 40 | 57 | 100 |
| | | 2030 (current trends) | 49 | 63 | 107 |
| | Intensity: final energy consumption per floor area [$MJ/m^2$][e] | 2013 | 390 | 660 | 640 |
| | | 2030 (NDC implementation case)[b] | 350 | 590 | 550 |
| Transport | Activity: Car ownership [passenger LDVs per 1000 persons) (ICCT, 2012; World Bank data, 2015b) | 2010 | 44 | 480 | 740 |
| | | 2030 (baseline case) | 210 | 610 | 820 |
| | Intensity: Average $CO_2$ intensity of passenger LDVs [$gCO_2$/v-km] (Cronin et al., 2015) | 2014 | 210 | 155 | 215 |
| | | 2030 (current trends) | 175 | 105 | 125 |

Source: Various publications from the IEA (including data of the WEO2015 New policies Scenario IEA, 2015). For each indicator, the value leading to the lowest emissions is indicated in dark grey, the middle in grey and leading to the highest emissions in light grey.
[a]Own calculation using the UN population projections (medium fertility variant) (United Nations, 2015).
[b]The WEO 2015 New Policies Scenario takes into account the energy-related components of the NDCs submitted as of 1 October 2015, but does not assume that all NDC targets are achieved.
[c]For OECD Europe.
[d]Own calculations based on IEA (2014) and UN population projections (United Nations, 2015). Linear interpolation (for 2013) and extrapolation (for 2030) of the trends between 2011 and 2025 were performed.
[e]The 2013 and 2030 total floor area were estimated from the above-calculated per capita floor area and the population data from UN (United Nations, 2015). Final energy consumption data were taken from the IEA WEO 2015 New Policies Scenario (IEA, 2015).

For the global cost-effective emission pathways (also referred to as least-cost or cost-optimal pathways), we used the median estimate and the 10th–90th percentile range across the six modelled 2°C scenarios (Tavoni et al., 2015), scaled to the 2010 GHG emission estimate.

The models usually assume high mitigation potential and lower costs in developing countries, which is also visible for our three examples (Figure 1). The scenarios starting with immediate reductions prescribe faster reductions in China, e.g. peaking by 2020 or 2025 instead of 2030 as proposed by China. The EU and the US are broadly in the range of the cost-effective 2°C scenarios.

The assessment would be different if one would assume cost-optimal pathways from 2020 onwards (Tavoni et al., 2015); then also China would be in line with the cost-effective path.

### *3.7. Comparison to a good practice policy package or a policy menu*

For a comparison of national climate policies, the critical element is the definition of the list of good practice policies that are used as benchmark. In this context, the UNFCCC secretariat has started to prepare policy menus (UNFCCC, 2014). The Climate Action Tracker team compared the policies of Australia and Mexico to a

**Table 3.** Comparison of policy packages based on Fekete et al. (2015).

| | China | EU | US |
|---|---|---|---|
| General | • Nationally binding climate targets with the 5-year plan | • EU-wide binding climate law based on several Directives | • Government plan to use regulation, but no nationally binding climate law |
| Energy supply | • Regional targets<br>• Mandatory closing of inefficient power plants<br>• Renewable capacity targets<br>• Pilot emission trading systems and national roll out | • EU-wide emissions trading system<br>• Member state level binding renewable targets<br>• Comprehensive support policies for renewables | • Clean power plan regulating emissions per kWh<br>• State level renewable targets<br>• State level emission trading systems |
| Industry | • Targets for the top 10,000 energy consuming companies<br>• Mandatory closing of inefficient plants<br>• Pilot emissions trading systems and national roll out | • EU-wide emissions trading system<br>• Member state level binding renewable targets<br>• Comprehensive support policies for renewables | • Voluntary programmes<br>• Efficiency standards for industrial motors<br>• State-level Emissions Trading Scheme |
| Buildings | • Building standards in residential and commercial sector<br>• Mandatory labelling | • Building standards in residential and commercial sector going to zero energy by 2021<br>• Efficiency standards for broad range of appliances | • Building standards in residential and commercial sector<br>• Mandatory labelling for a broad range of appliances |
| Transport | • Car standard<br>• Truck standard<br>• Biofuel support<br>• Tax incentives for energy efficient cars | • Car standard (most ambitious level of the three countries)<br>• Truck standard<br>• Tax incentives and quota for biofuels | • Light duty vehicle standard<br>• Truck standard<br>• Tax incentives and quota for biofuels |

good practice policy package (Ecofys & Climate Analytics, 2011, 2012). An initial comprehensive collection of a good practice policy package and an assessment of whether countries have implemented a list of good practice policies has been performed by Fekete et al. (2015) and Höhne, Fekete, Kuramochi, Iacobuta, and Prinz (2015). Based on this previous work we provide a short overview of policies (Table 3).

Given that some countries are clearly more ambitious than others in some areas, an unambiguous overall ranking is not possible. The EU is clearly more ambitious with its nationally binding climate law and more than 10 Directives, as the US does not have a nationally binding climate law. However, determining whether the approach to efficiency in industry is more ambitious in China, the EU or the US cannot unambiguously be done.

Another approach is to look at how many policy areas are covered that could be considered good practice policies. Höhne et al. (2015) developed a matrix of policies by sector and thematic area (e.g. energy efficiency, renewable energy, shift in lifestyle or economic activity, etc.), identified policy measures that are considered as 'good practice' for each policy area (e.g. fuel economy standards in the transport sector) based on a literature review, and assessed to what extent the major countries cover the good practice policy matrix.

Preliminary results of Höhne et al. (2015) for China, the EU, and the US before COP21 are presented in Figure 2. Based on the policy data gathered from various sources, the EU was leading over the US and China in terms of the coverage of policy areas with good practice policies. Nevertheless, even for the EU, about 30% of the policy areas are not yet covered with good practice policies, indicating the need for further efforts.

The results likely depend on the definition of the areas of good practice as well as the availability of up-to-date policy information. Moreover, only looking at whether good practice policies exist disregards the effectiveness of the implemented policies.

The three countries/regions have not explained in detail which policies they are going to use to implement their NDC. It is crucial to investigate what kind of policy measures are envisioned in each country/region to achieve the

**Table 4.** Assessment of the ambition of the NDCs of China, the EU, and the US using various evaluation approaches.

| NDC description | China (Peaking $CO_2$ around 2030; 60–65% $CO_2$ emission intensity reduction; 20% non-fossil fuels in primary energy consumption) | | EU (at least 40% below 1990 by 2030) | | US (−26% to 28% below 2005 by 2025) | |
|---|---|---|---|---|---|---|
| Method | | Rank | | Rank | | Rank |
| **Approaches related mainly to moral obligation** | | | | | | |
| **Reduction from 1990 levels** | Not applied to China | | 40% | 1 | 27% | 2 |
| **Change in recent trend** | Not applied to China 2012–2020 vs 2020–2030 | | −1.3% vs. −1.9% | 2 | −1.0% vs. −2.5% | 1 |
| Change compared to 'current policy scenario' | Small difference | 2 | Small difference | 2 | Significant difference | 1 |
| **Time and level of peaking of per capita emissions** | 2030 or earlier, at 9.0–9.6 $tCO_2e$ per capita with a per capita GDP of 12,600US$ | 2 | 1979, at 13$tCO_2e$ per capita with a per capita GDP of 17,450US$ | 1 | 2007, at 24.5 $tCO_2e$ per capita with a per capita GDP of 44,300US$ | 3 |
| **Comparison to equity-based effort-sharing calculations** Median estimate of GHG emission allowances based on effort-sharing data from the IPCC AR5 (20th–80th percentile range). | 30% below 2010 by 2030 (4%; 50%) (compared to 48% above 2010 levels with NDC) | [a] | 46% below 1990 by 2030 (34%; 62%) (compared to 40% below 1990 with NDC | [a] | 51% below 2010 by 2030 (38%; 77%) (compared to 34% below 2010 by 2030 under the extrapolated NDC[b]) | [a] |
| **Approaches related mainly to technical necessity** | | | | | | |
| **Comparison to benchmarks of decarbonization indicators** | | 2 | | 1 | | 3 |
| Number of indicators in the lead (see Table 2) | 8 | | 8 | | 0 | |
| Number of indicators second | 4 | | 7 | | 5 | |
| **In line with globally cost-effective model pathways** Starting in 2010 (10th–90th percentile range of emissions) | Not in line (5% above 2010 to 20% below 2010 levels) | 2 | In line (20 to 40% below 2010 levels) | 1 | In line (30 to 55% below 2010 levels) | 1 |
| Starting in 2020 (10th–90th percentile range of emissions) | In line (20% to 55% above 2010 levels) | 1 | In line (20 to 30% below 2010 levels) | 1 | In line (30 to 40% below 2010 levels) | 1 |
| **Comparison to best practice policy package or policy menu** Number of good practice policy areas covered by currently implemented polices | 22 | 3 | 38 | 1 | 34 | 2 |

Note: For each approach, the country with the highest ranking (rank value of 1) is indicated in dark grey, with the middle ranking (rank value of 2) in grey and with the lowest ranking (rank value of 3) in light grey.

[a]No rank provided.

[b]Extrapolated to 2030 based on a linear path towards the 2050 target of 83% below 2005 levels and took the average over the high and low 2025 target.

mitigation targets under the NDCs. It may be that one country with a low coverage of policies needs to increase its coverage significantly to meet its NDC, whereas another country would need to add only a little.

### 3.8. Summary evaluation

In a final step, we summarize the results for the three countries/regions (Table 4). The table includes the evaluation results as well as a relative ranking among the three. If a ranking could not be determined unambiguously, we have applied the same rank.

As expected, examples score very differently between the approaches. However, the overview of the ensemble of the results shows certain tendencies. For example, the EU scores first among the three on many approaches (in many cases together with China and or the US). Only on changes in recent trends is the US clearly ahead of the EU. This coincides with the countries' own explanations of the level of ambition of their approaches: The NDC of the US states that 'Achieving the 2025 target will require a further emission reduction of 9–11% beyond our 2020 target compared to the 2005 baseline and a substantial acceleration of the 2005–2020 annual pace of reduction, to 2.3–2.8 percent per year, or an approximate doubling.'

The comparison of China and the US is, in essence, determined by how far the different development levels should be taken into account: China is consistently ahead of the US in decarbonization indicators and in level and timing of peaking emissions. Owing to a lower development level, its emission intensity and activity levels are lower than in the US. The US, on the other hand, has a more comprehensive policy package and proposes more change from the current policy scenarios.

As the NDCs in aggregate are insufficient to meet the long-term goals of the Paris Agreement (Rogelj et al., 2016), the total ambition level has to be increased. The overview evaluation directly shows the shortcomings of the NDCs and therefore provides hints to where improvements could take place. Although the EU scores well on many aspects, our framework shows that the current NDC constitutes only limited progression from current trends. Even with a step change in policy, our comparison of approaches shows that activity and energy intensity levels in the US are still much higher than in other countries. Regarding China, although its activity and energy intensity indicators are still low and it is undertaking significant policy efforts in *some* areas, the analysis reveals that many policy areas remain unaddressed.

How robust is this evaluation? The overview of the results may depend on the selection of the evaluation approaches. To minimize this point, we have deliberately selected many approaches and have not aggregated the results into one rating. This would have put even more emphasis on the selection and weighting of the approaches.

Future analyses of this kind could split the effort-sharing evaluation into more categories, which would give these points more implicit weight. Future research could also include more studies, and therefore be more precise on the percentiles where countries' NDCs lie.

An important caveat with the analysis is that some of the indicators require a reference scenario, which is hard to define. This is especially the case for the approaches 'Change in trend' and 'In line with globally cost-effective 2°C scenarios'. These approaches are only constructive for climate negotiations if countries can agree on the reference scenario or at least its definition. Another caveat is that, although our method works well for comparing the proposals of a few countries, a comparison with many countries may prove difficult owing to the extent of data and analysis effort needed.

While providing a range of approaches for comparing ambition, we still do not take into account general social, political and institutional factors, which may influence a consideration of ambition levels.

The major advantages of our method are its transparency and the fact that many viewpoints with regard to fairness are taken into consideration. It automatically reveals the strengths and weaknesses of the emission reduction proposals. Furthermore, it can reveal quite clearly whether a proposal really scores well or not on many perspectives or only from a limited set of viewpoints.

## 4. Conclusions

One of the key elements of the Paris Agreement are the post-2020 contributions that most countries have submitted before the Paris climate summit. For the functioning of the Paris Agreement with constantly new and strengthened national contributions it is of crucial importance that countries can judge how the proposals of other countries compare to their own proposal.

In this article, we identified eight approaches from the review of a large variety of approaches to assess the ambition of the post 2020 climate proposals (NDCs) by countries. We applied seven evaluation approaches (where sufficient data were available) illustratively to the NDCs of China, the EU, and the US.

We draw the following conclusions:

First, a comprehensive assessment of ambition of climate proposals can only be undertaken using a large variety of evaluation approaches. Each single approach has its pros and cons, starts from a very particular perspective, and no single approach is truly comprehensive. The different nature of the evaluation approaches leads to different outcomes; only if all of them are applied, does it become evident if a country is broadly ambitious, or only under very selective perspectives. Such a comprehensive approach could therefore be usefully applied as preparation for the facilitative dialogue in 2018, and the global stocktake that is to take place every five years starting from 2023.

Second, we put forward just such a comprehensive framework of evaluation approaches that covers, to our knowledge, the broadest possible range of approaches. The framework would evaluate countries using all eight approaches shown here, rank countries relative to each other where possible, and present the results alongside each other (without aggregating into one overall rating). The illustrative cases of China, the EU, and the US show that such a comparison is very insightful, and can result in concrete suggestions for improving the NDCs.

Finally, we find that the ambition level of China, the EU, and the US varies, depending on the perspective. The EU ranks consistently first or second across many of the approaches. Only on changes in recent trends is the US clearly ahead of the EU. The comparison of China and the US is, in essence, determined by how far the different development levels should be taken into account.

Several research questions are still open: complete sets of decarbonization indicators, also covering future developments under the NDCs, are still lacking. Furthermore, comprehensive comparisons of policies implemented by countries have to be undertaken. Globally cost-effective pathways would best be disaggregated by as many countries as possible (currently, most studies distinguish only up to around 25 regions). Finally, new calculations would need to be undertaken that are compatible with 1.5°C, as such scenarios are currently covered only to a limited extent.

This future research should be undertaken urgently, so that a comprehensive framework as proposed here can be applied at the 2018 facilitative dialogue in 2018 and the 2023 global stocktake.

## Notes

1. UNFCCC decision 1/CP.19, http://unfccc.int/resource/docs/2013/cop19/eng/10a01.pdf#page=3.
2. We have not included the criterion 'universal applicability' of Aldy et al. (2016), because all approaches included in our assessment are universally applicable.
3. The criterion excluded from the analysis are energy price indicators including carbon prices as there are few data available on future energy and carbon prices under NDCs in respective countries.
4. The target translates to 14–16% below 1990 in 2025. We extrapolated to 2030 based on a linear path towards the 2050 target of 83% below 2005 levels and took the average over the high and low 2025 target.
5. For example, the emission level in 2030 is 8–15% below the Chinese business-as-usual emission projections (no policy scenarios) of the modelling comparison study (Tavoni et al., 2015), whereas the median of the Chinese business-as-usual projections peaks at 2080.
6. The GDP figures are measured in market exchange rates (MER) and the historical estimates are based on World Bank data (2015a). The GDP projections are based on the GDP growth estimates of the World Energy Outlook 2014 for the 2030 projection of China
7. (100%–0.5%)^50–100% = −22%.
8. More specifically, this is based on the combined effect of innovation on emissions efficiency improvement of about 0.8% per year for 1990–2005, and the autonomous emissions improvement over total primary energy supply owing to transition to renewable energy sources of 0.5% (IEA, 2008).
9. www.climateactiontracker.org.
10. www.climateactiontracker.org.

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