Good practice policies to bridge the emissions gap

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1. Introduction

In the Paris Agreement, countries agreed to limit global warming to well below 2 °C, and if possible to 1.5 °C. For implementation, the Paris Agreement relies on mitigation action at the national level. These actions are communicated via nationally determined contributions (NDCs) and long-term strategies, containing each country’s pledged contribution to global mitigation. A key question is whether the collective action of all countries leads to the implementation of the Paris Agreement’s climate goals. For this, countries agreed on a global stocktake process to periodically review collective progress and to adapt efforts in order to meet the Paris Agreement’s global climate mitigation goals.

Several publications have already shown that the aggregated impact of NDCs is insufficient (the so-called ambition gap). In addition, nationally implemented policies are, collectively, not even reaching the global emissions of the NDCs (the so-called implementation gap). This means that NDCs and policies need to be strengthened to overcome the resulting emission gap. In this report, we explore whether so-called good practice policies – i.e. policies that have proven to be successful in one country – can be upscaled as a possible way to significantly reduce the emission gap in order to meet the overall Paris goals.

This document merges three related deliverables that were planned in the original COMMIT project proposal (in agreement with the European Commission): i.e. an update of D4.1, offering a comparison of the global and national pathways developed in COMMIT; D2.3, being the paper focusing on the national model results; and D3.2, the paper focusing on the global model results. In the first two chapters, the two notes looking at the global and national results are attached. These will be submitted as journal papers. There may still see some small updates before journal submission, upon co-author feedback or scenario updates. The comparison can be found in the fourth chapter, including references to figures in D2.3 and D3.2 that show both national and global model results.
2. A global roll-out of nationally relevant policies bridges the emissions gap

2.1 Introduction

The cost-optimal scenarios from global integrated assessment models (IAMs) can provide guidance on how to do this. In reality, however, it is not always possible to implement these pathways. For instance, influential societal actors might be able to prevent certain measures if they go against their interests. Market distortions can also make certain measures unattractive. Other solutions might lack societal support and also the rate at which a transition can be implemented may be slowed down, such as in the case of closing coal mines and power plants (given the impact on coal miners and coal-dependent regions and communities). At the same time, however, there is also evidence of effective implementation of policies. Here, good practice policies are defined as successfully implemented policies in one or more countries with a noticeable impact on greenhouse gas (GHG) emissions. In some cases, these policies are not even part of the cost-optimal mix suggested by models but could be easier to implement. It has been suggested that scaling up these good practice policies to other parts of the world might in the short-term be a more feasible and convincing strategy. Fekete et al., Roelfsema et al. and Kriegler et al. investigated the impact of replicating such good practice policies in other parts of the world by focusing on global GHG emissions and sector-level indicators related to feasibility. Although helpful as first step, the work of Roelfsema and Kriegler is limited by 1) the formulation of good practice policies at the global scale, and 2) being based on a single model.

Better information on such good practice policies is needed to support the UNFCCC global stocktake in 2023. Here, we build on the work of Roelfsema et al., Kriegler et al. and Fekete et al., also going beyond relatively abstract cost-optimal pathways as guidance for policy-making by focusing on concrete policy measures that can be implemented to close the emission gap. We do this for the first time using multiple models (both global and national) to assess a common set of reduction measures. These measures have been defined in consultation with national experts, making the scenarios more relevant. The key scenario is referred to as the bridge scenario, as it aims to bridge the gap between the ambition levels set out by countries by 2030 and those consistent with the Paris Agreement. This scenario includes a set of well-defined measures that can be implemented in the 2020-2030 period and go beyond the ambition of the NDCs, and that would still allow reaching the Paris climate goals in the long-term. The bridge scenario was developed in multiple rounds. First, national modelling teams responded to the proposed good practice

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policies (based on literature), considering whether these policies could be realistically implemented in their countries and, if not, what other target levels or years would be feasible. Second, the policy list was adjusted to further differentiate country groups, in terms of timing and stringency of the targets. Third, some national models ran the refined scenarios and provided feedback, upon which the list was further refined. As such, we eventually defined three country groups, which was found to offer enough differentiation to be nationally relevant, while still adhering to a common set of measures. Finally, all national and global model teams ran the agreed set of scenarios. In the context of the global stocktake, here we focus on the results at the global level and a number of large countries, while more detailed national-level results by national models can be found elsewhere.

2.2 Methods

Models
Both national and global model teams followed the same scenario protocol for comparability. The global models included here are: AIM/CGE, COPPE-COFFEE, IMAGE, MESSAGEix-GLOBIOM, POLES, PROMETHEUS, REMIND-MAgPIE, TIAM-Grantham, WITCH-GLOBIOM 5.0. National-level results are presented in Schaeffer et al.

Scenarios
In line with the global stocktake, the ratcheting up mechanism has been applied in constructing the scenario protocol (see Supplementary Information part C for the full protocol text and Supplementary Information part A for the detailed lists of good practice policies). This means that the scenarios build upon one another in terms of ambition and modelling assumptions. The Current policies scenario is the least ambitious and the 2°C scenario is the most ambitious.

The Current policies (CurPol) scenario incorporates middle of the road socio-economic conditions throughout the century, based on the second marker baseline scenario from the Shared Socioeconomic Pathways (SSP2). It also assumes that climate, energy and land use policies that are currently ratified are implemented (cut-off date 1 July 2019).

The NDC-plus scenario builds further upon the CurPol scenario and assumes that the conditional NDCs (both unconditional and conditional NDC actions) as submitted by April 2020 are implemented by 2030. After 2030, the scenario reflects continuation of effort (see below).

The Bridging (Bridge) scenario builds upon the CurPol scenario and assumes that certain good practice policies, which have shown to be effective in some countries, will be implemented globally from 2020 until 2030 (see Supplementary Information part A: Table A 1 lists the good practice policies while Table A 2 gives an overview of their implementation in models). After 2030, the bridge scenario transitions to a 2°C scenario following a cost-effective pathway. A distinction is made between low/medium income and high income countries in terms of timing and stringency of good practice policy targets. The set of policies was defined in dialogue with national model teams, granting a more realistic scenario narrative (for more details, see the Supplementary Information). As opposed to Fekete et al., carbon pricing is included as good practice policy, although it may be considered as a top-down policy of different nature than the other policies. Carbon pricing and emission trading schemes have been successfully implemented in various countries. Furthermore, previous work (Kriegler et al., 2018) highlights that good practice regulatory policies should be considered as complements to pricing-based approaches. In the simulations, the carbon price applies to all gases and sectors, hence represents an idealized view of carbon pricing schemes. It does not take the highest carbon price currently observed as starting point, but rather an approach in which countries were divided in three tiers with different carbon price levels and timelines to be most relevant to the countries
represented here. This was the result of the exchanges between global and national model teams, in which the REMIND model was applied to arrive at a first proposal for the timelines per tier. As a variant and to analyse the effect of this measure, some models ran an additional scenario excluding the carbon price measure (see SI Figure B 5).

The 2 °C (2Deg2020) scenario assumes that an average temperature increase of 2 °C without overshooting is reached by 2100 in a cost-effective way, i.e. minimising global aggregate economic costs. National modelling teams used a carbon budget derived from the global carbon budget of 1,000 Gt CO₂ in the period 2011-2100 (including 2011 emissions), as done in CD-LINKS (https://www.cd-links.org/). This global carbon budget represents a high probability (66%) of keeping global warming below 2 °C. Carbon budgets have been revised since the CD-LINKS project in such a way that 1,000 Gt is even more stringent than previously. Cumulative CO₂ emissions in the 2 °C scenarios (2Deg2020 and Bridge) are not all exactly 1000 Gt, but range from 910 Gt CO₂ to 1630 Gt CO₂ (2011-2100), which is still within the range considered to be in line with 2 °C. Here, we focus on the 2Deg2020 scenario for comparison with the Bridge scenario because it is the cost-optimal pathway to well below 2 °C that is often used (e.g. in the UNEP emissions gap reports), although it is increasingly unlikely.

For the CurPol and NDC-plus scenarios, a continuation of efforts after the target year was assumed. This was implemented by extrapolating the “equivalent” carbon price in 2030, using the GDP growth rate of the different regions up to 2050. The equivalent carbon price represents the value of carbon that would yield the same emissions reduction as the NDC policies in a region. If a region has a carbon price of zero while implementing the NDC in 2030, a minimum carbon price of 1 $/tCO₂ in 2030 was assumed. If a region has a negative carbon price in 2030, the trajectory resulting from 1 $/tCO₂ was offset to the model’s 2030 starting point. For land use, a carbon price ceiling of $200/tCO₂ was applied.

2.3 Analysis of the bridge scenario
In order to discuss the possible impacts of the Bridge scenario, we compare it to three other scenarios i.e. the impacts of current policies (CurPol), the conditional NDCs (NDCplus), and the models’ cost-optimal pathway towards 2 °C (2Deg2020) (see Methods and Supplementary Information for more details). For the first two scenarios, the current policies and NDCs were extended beyond 2030 by assuming equivalent effort, i.e. by extrapolating the ‘equivalent’ carbon price in 2030, using the GDP growth rate of the different regions up to 2050 for the extrapolation (see Supplementary Information part C). For the Bridge scenario, the defined set of measures was implemented up to 2030 (Table 1) and a cost-optimal path towards 2 °C was implemented after 2030 (see Supplementary Information part C). A full description of the scenarios and additional results can be found in the Supplementary Information.
Table 1: The good practice policies that were assumed to be replicated globally in the Bridge scenario, with differentiated targets for high-income and low-/medium-income countries.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Measure</th>
<th>High-income countries</th>
<th>Low-/medium-income countries</th>
<th>Other (differs per measure)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>AFOLU (Agriculture and LULUCF)</strong></td>
<td>Treat manure from livestock with anaerobic digesters – Reduction of CH$_4$ emissions from manure, relative to 2015</td>
<td>33% by 2030</td>
<td>15% by 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase nitrogen use efficiency – Reduction of N$_2$O emissions from fertilizer, relative to 2015</td>
<td>10% by 2030</td>
<td>5% by 2030</td>
<td></td>
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<tr>
<td></td>
<td>Selective breeding to reduce CH$_4$ emissions from enteric fermentation – Emission factor reduction (CH$_4$/tonne milk and/or beef) or emissions reduction, relative to 2015</td>
<td>10% by 2030</td>
<td>0% by 2030</td>
<td></td>
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<tr>
<td></td>
<td>Increase natural forest afforestation and reforestation – rates for three tiers (different than high- and low-income): % increase in forest area per year, for 2015-2030</td>
<td>Tier 1 (China, Latin America): 2%/year</td>
<td>Tier 2 (South &amp; South East Asia, Sub-Saharan Africa, Australia): 1% per year</td>
<td>Tier 3 (Europe, Turkey, 23% of Russia, USA): 0.5% per year</td>
</tr>
<tr>
<td></td>
<td>Halt natural forest deforestation</td>
<td>0 ha/year by 2030</td>
<td>0 ha/year by 2030</td>
<td></td>
</tr>
<tr>
<td><strong>Energy supply</strong></td>
<td>No new installations of unabated coal power plants</td>
<td>By 2025</td>
<td>By 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase of the share of renewables in total electricity generation per year (starting in 2020, until 2050 and up to 50%, maximum)</td>
<td>1.4 %-point increase per year</td>
<td>1.4 %-point increase per year</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Coal mine CH$_4$ emissions recovery</td>
<td>30% by 2030</td>
<td>30% by 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduce venting and flaring of CH$_4$ and CO$_2$ – emission reduction, relative to 2015</td>
<td>36% by 2030</td>
<td>36% by 2030</td>
<td></td>
</tr>
<tr>
<td><strong>Buildings</strong></td>
<td>Improve final energy efficiency of appliances compared to 2015 (autonomous improvement as well as due to policy)</td>
<td>17% by 2030</td>
<td>7% by 2025/2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improve final energy intensity of new residential and commercial buildings</td>
<td>22 &amp; 30 kWh/(m$^2$.yr) by 2025</td>
<td>22 &amp; 30 kWh/(m$^2$.yr) by 2035</td>
<td>EU: 35 &amp; 40 kWh/(m$^2$.yr) by 2025</td>
</tr>
<tr>
<td></td>
<td>No new installations of oil boiler capacity in new and existing residential and commercial buildings</td>
<td>By 2030</td>
<td>By 2040</td>
<td>EU: by 2020</td>
</tr>
<tr>
<td></td>
<td>Improve efficiency of existing buildings – Share of existing buildings being renovated</td>
<td>11% by 2030</td>
<td>6% by 2030</td>
<td></td>
</tr>
<tr>
<td>Sector</td>
<td>Measure</td>
<td>High-income countries</td>
<td>Low-/medium-income countries</td>
<td>Other (differs per measure)</td>
</tr>
<tr>
<td>--------------</td>
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<td>----------------------------</td>
</tr>
<tr>
<td>Industry</td>
<td>Apply CCS - Carbon captured and stored as share of industry’s total CO₂ emissions (model-dependent)</td>
<td>1.5% by 2030</td>
<td>1.5% by 2040</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improve final energy efficiency, relative to 2015</td>
<td>11% by 2030</td>
<td>6% by 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reduce N₂O emissions from adipic/acid production – reduction, relative to 2015</td>
<td>99% by 2030</td>
<td>99% by 2030</td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>Improve energy efficiency of aviation, starting in 2018</td>
<td>0.78% per year by 2030</td>
<td>0.78% per year by 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Improve average fuel efficiency of new passenger cars</td>
<td>38 km/l by 2030</td>
<td>27 km/l by 2030</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Increase the share of non-fossil in new vehicle sales</td>
<td>50% by 2030</td>
<td>25% by 2030</td>
<td>China: 25% by 2025</td>
</tr>
<tr>
<td>Waste</td>
<td>Reduce CH₄ emissions, relative to 2015</td>
<td>55% by 2030</td>
<td>28% by 2030</td>
<td></td>
</tr>
<tr>
<td>Economy-wide</td>
<td>Carbon pricing – pathways for three tiers (different than high- and low-income)</td>
<td>Tier 1 (OECD, EU): 40 USD/tCO₂ by 2030</td>
<td>Tier 2 (Russia, Eastern Europe, China, Korea, Latin America): 25 USD/tCO₂ by 2030</td>
<td>Tier 3 (all others): 10 USD/tCO₂ by 2030</td>
</tr>
<tr>
<td></td>
<td>Reduce F-gas emissions, induced by policies, relative to 2015</td>
<td>60% by 2030</td>
<td>38% by 2030</td>
<td></td>
</tr>
</tbody>
</table>
A bridge over the emissions gap

The model outcomes (Figure 1 and Supplementary Figure B 6) show that the CurPol and NDCplus scenarios both fall considerably short of the reductions needed to implement the Paris Agreement (consistent with earlier work). In contrast, the good practice policies included in the Bridge scenario are able to reduce GHG emissions close to the needed levels in 2030, followed by a longer-term trajectory similar to the ambitious benchmark of 2Deg2020. The Bridge scenario has a less steep reduction in the short term, offering a pathway that largely closes the 2030 emissions gap without adding substantial challenges in the short and medium terms. Here, the emissions gap is defined as the difference between the NDCplus scenario and the 2Deg2020 scenario. The Bridge scenario closes that global emissions gap by 71% (median, range 26%–275%) by 2030, and compensates the slower start by a slightly deeper reduction in 2050, 106% (101%–112%). The 2030 emissions gap is closed by 16% in the USA, 54% in India, 56% in the EU and 68% in China.

Figure 2 shows the rates of GHG emissions reductions in the Bridge scenario, compared to the CurPol, NDCplus, and cost-optimal case (2Deg2020). In contrast to the increase in GHG emissions under current policies in some countries, emissions decline everywhere in the Bridge scenario, especially in the 2030–2050 period. In the short term (2030), the Bridge scenario shows smaller reductions than the immediate action 2Deg2020 scenario in most countries. As such, good practice policies can constitute an alternate pathway in line with the Paris Agreement’s climate goals, without relying on carbon pricing only as in cost-optimal scenarios, while not significantly increasing the burden in the longer term.

Figure 1: global GHG emissions (Gt CO2eq/year) between 2010 and 2050, as projected by the global models. Vertical bars: model range in 2050. Circles: model median in 2050. Thick solid lines: median. Projections for the Bridge scenario without the carbon tax measure are shown in Supplementary Figure B 5, for NDCplus variant NDC_2050convergence in Figure B 6, and for 2050 – 2100 in Figure B 7.
Which measures have the largest effect on emissions?
The energy sector (through higher renewable energy share, electrification, energy efficiency improvement) is the largest contributor to emissions reductions between the NDCplus and Bridge scenarios, both in 2030 and in 2050 (Figure 3). This indicates potential to enhance NDC ambition in specific areas. In most models, also mitigation of non-CO2 emissions, the transport sector (zero-carbon vehicles and efficiency improvements), and AFOLU (notably in 2030) play an important role.
Figure 3: Contribution of each sector to emission reductions between the NDCplus and Bridge scenario (negative values denote an increase in emissions between NDCplus and Bridge, and are indicated with hashes). First bar: Emissions by sector in 2015. Second bar: emissions by sector in 2030 (upper graph) and 2050 (lower graph), under NDCplus. Third - ninth bar: emission reduction in energy supply, industry, buildings, transport, industrial processes, AFOLU (agriculture and LULUCF), non-CO2 emissions. Last bar: emissions by sector in 2030 (upper graph) and 2050 (lower graph), under Bridge. The IMAGE model is shown here as an illustrative example; full model ranges are shown in the table, while individual model results are shown in the SI (Figure B.3). In addition, Figure B.4 shows the sectoral contributions to emission reductions between the Bridge and 2Deg2020 scenarios in 2030.

Changes in energy and land-use systems
Figure 4 shows projected changes in energy and land-use systems under four scenarios: CurPol, NDCplus, Bridge, 2Deg2020. The Bridge scenario significantly increases mitigation action compared to the CurPol and NDCplus scenarios. In fact, on several indicators, the prescribed policies (Table 1 and Supplementary...
Information part A) close the gap with the cost-optimal 2Deg2020 scenario almost completely. By 2050, the Bridge scenario goes beyond the 2Deg2020 scenario for many indicators, compensating for the delay with respect to the cost-optimal pathway. Figure 4 Panel a, for example, shows that the target to increase the renewable electricity share by 1.4% per year in the Bridge scenario (measure 9) leads to deployment far beyond the CurPol and NDCplus scenarios in 2050 (i.e. towards 75%, versus around 50%), but similar to the 2Deg2020 (in line with previous research13). In 2030, however, the Bridge scenario is similar to 2Deg2020, so it does not increase the global trend in terms of installing renewables in the short term (it may do so regionally, however, see Baptista et al.11). As a result of the assumed penetration of non-fossil fueled vehicles (measure 20), the Bridge scenario shows a significant increase in the share of electricity in transport, even more so in Bridge than in 2Deg2020 (Panel b). This starts in 2030, but manifests especially in 2050. However, in some models, the target to increase non-fossil fueled vehicles actually leads to an increase of biofuel powered engines rather than electrification (explaining the relatively large range). Following CCS (measure 13), efficiency improvement (measure 14), and F-gas emission reduction (measure 10) targets in industry, industrial emissions (expressed as CO2 emissions from industrial processes as well as F-gases, panel c), are projected to decrease, in Bridge slightly more so than in 2Deg2020 (by 2050). Because the measures in the buildings sector focus on efficiency improvements (measures 3-6), the share of electricity in buildings (panel D) is not projected to change significantly in the short term, but Bridge makes up for that by 2050. Panel E shows that the afforestation policy (measure 16) leads to slightly more afforestation in 2030, followed by a large scale-up in 2050. As such, CO2 emissions from agriculture, forestry and other land-use (AFOLU) are projected to be reduced by 38% (model median) by 2030 and by 120% by 2050 in the Bridge scenario, relative to 2015 levels. Supplementary Figure B 1 shows the same indicators but for the NDCplus-convergence scenario instead of NDCplus: by 2050, the convergence scenario is closer to the bridge scenario than NDCplus for most indicators. Figure B 2, finally, shows the projected changes in the primary energy mix. Bridge sees lower total primary energy supply mainly due to the efficiency improvement and transport electrification measures, but not as low as 2Deg2020, and a shift from fossil fuels to renewable energy sources, especially by 2050. As a result of the scale-up of renewable energy, electrification of energy demand, and efficiency improvements, CO2 emissions from the energy sector are projected to decrease.

Figure 4: Projected changes in various indicators, for 2030 and 2050, for the CurPol, NDCplus, Bridge and 2Deg2020 scenarios. Bars show model median, error bars show the full range, and symbols show individual model results. Panel a) share
Costs of building the bridge

While the good practice policies may have benefits in terms of social and political acceptability, earlier work (Kriegler et al., 2018) has highlighted that a set of regulatory measures may be more costly than a comprehensive carbon pricing scheme, leading to a non-cost-optimal transition across regions and sectors. A uniform price signal ensures that mitigation happens first where costs are lowest, leading to the overall efficient outcome, in absence of other market failures. Furthermore, climate action as represented in the Bridge scenario implies a more gradual path for emission reductions in the period 2020-2030 compared to the immediate implementation of the cost-optimal policy (2Deg2020). This delay can further raise costs of the Bridge scenario, depending on the evolution of technology costs. The salience of a carbon price, however, may also raise opposition especially from low-income households facing energy poverty and food-insecurity14, carbon-intensive regions and vulnerable trade-exposed industries that may complicate or delay its implementation. Arguably, the good practice policies included in the Bridge scenario face lower implementation barriers and could speed up climate action compared to a scenario in which cost-optimal policy measures are pursued. A fair evaluation of the costs of the Bridge scenario therefore involves two comparisons: one with the immediate and cost-optimal climate policy (2Deg2020), and one with a delayed implementation of uniform carbon pricing, starting in 2030 (2Deg2030) and therefore requiring more disruptive action to meet the 2 °C target.

Our results (Figure 5) indicate that although the Bridge scenario raises policy costs (as expressed by GDP cost per tonne CO2e abated relative to the Current Policy scenario) in 2050 by more than 20% (1%–38%) compared to an immediate implementation of a cost-optimal 2 °C scenario with globally uniform carbon prices (2Deg2020), it has lower policy costs (Figure 5a) and carbon prices (Figure 5b) in the near term (2030). The Bridge scenario also outperforms a delayed 2 °C scenario (2Deg2030, see Supplementary Information part C) with costs being more than 10% (-6%–33%) lower in 2050. As such, our analysis suggests that early but non cost optimal action is preferred over climate policy delay.

Interestingly, not all models in the ensemble agree on the size and sign of the trade-off between early and cost-optimal policy implementation. Multiple and counteracting effects are at play. Generally, good practice regulatory policies would raise costs particularly when the resulting energy system deviates strongly from the cost-optimal one. If the necessary changes are obvious, or when there are low-hanging fruits for climate policy, then a similar outcome may be achieved through regulation and carbon prices. The phase-out of coal and the scale-up of renewable power generation technologies15-17 may be an example that comes close (Supplementary Figure B 8 shows that investments in the electricity sector are projected to shift from fossil fuels to renewables). However, for other trade-offs, such as efficiency improvements versus fuel shift, or the allocation of emission reductions across sectors, a mix of regulatory measures that leads to an outcome resembling the cost-optimal one may be more difficult to achieve. Therefore, while regulatory policies can be a pragmatic entry-point for climate policy, efficiency in the medium and long-term is more easily achieved via comprehensive carbon pricing schemes across all sectors and regions to avoid inter-sectoral and inter-regional leakage12. The costs of delaying climate action, on the other hand, depend on technological progress and the availability and scalability of negative emission technologies (NETs) in the future, among others18. For three out of four models that capture economic growth endogenously, the costs of delay outweigh the additional cost of regulatory good practice policies in 2050.

An advantage of the regulatory measures as implemented in the Bridge scenario is that carbon prices remain at lower levels in the near term, which may facilitate acceptability and implementation of carbon pricing schemes with a broad sector coverage. If political consensus in favour of a comprehensive pricing scheme is not found over time, then a further intensification of the good practice policies may serve as a practical way forward to close the emissions gap. At the same time, the advantages of good practice policies in terms of acceptability may be challenged if ambitious climate targets bring cost elements to the forefront of the political debate.
Hence, our results suggest that a global roll-out of good practice policies can be a useful approach to close the emission gap in the near term, while their role in climate policy in the longer term should be reconsidered in the context of a broader policy mix\textsuperscript{19}, including carbon pricing\textsuperscript{20}.

*Figure 5: Panel a) GDP (in market exchange rates, MER) loss (relative to the CurPol scenario) in Bridge, relative to 2Deg2020 (light blue) and 2Deg2030 (dark blue), for 2030 (left) and 2050 (right). Panel b) Carbon price (US$2010/tCO\textsubscript{2}), in 2030, 2040 and 2050. Bars: median, error bars: full range, symbols: individual models.*
2.4 Discussion and conclusions

Parties to the Paris Agreement were supposed to submit updated NDCs and communicate their long-term strategies to the UNFCCC in 2020. Due to the COVID-19 pandemic, these timelines have been delayed, but scaling up climate ambition and action remains necessary to keep the Paris goals within reach. As the emissions gap seems hard to close, we built a set of relevant scenarios that may provide a pathway based on successful examples of policies. The mitigation measures were defined in a two-way interaction with country experts and assumptions were adjusted for different regions if necessary. These scenarios, especially the good practice policies (Bridge scenario), can support the ratcheting up of mitigation ambition of NDCs.

Although the granularity of the bridge scenario has improved in terms of country differentiation compared to earlier studies, some limitations remain. Firstly, in most cases we only distinguished developed and developing countries, and while the measures were assessed to be implementable, this might not always be the case. Secondly, the type of models applied here are not particularly fit for studying possible indirect impacts and costs of regulatory measures such as end-use efficiency standards, and a global roll-out of such measures may be equally unrealistic as a global carbon price. Therefore, Baptista et al.11 discusses the same set of scenarios in the context of national feasibility considerations. Thirdly, not all models were able to implement the full set of measures. Thus, limited implementation of the measures may explain a model’s higher emissions projections. The ranges, however, do tell a robust story about the bridge scenario in relation to the reference scenarios. Although set at a relatively low level, the carbon price measure was the single most effective policy in the short term. Removing it from the set of measures resulted in significantly higher emissions. However, as many countries or regions already have a form of carbon pricing, it deserves a spot in the selection of good practice policies, especially given the differentiated timelines and pricing levels assumed in the bridge scenario. Fifthly, we have not considered the impact of the COVID-19 pandemic quantitatively, effectively assuming a full recovery without significant effect on long-term, global emissions. A longer lasting or recurring crisis may affect economic activity and energy-related investments such that it shows in global emissions levels, but only time will tell. The policy measures explored here, however, can inform governments that aim for ‘green’ recovery packages.

We have shown that good practice policies can help to reach the 2 °C target in the long-term. They ensure closing the global emissions gap between NDCs and a cost-optimal 2 °C scenario by 71% (model median) by 2030. After 2030, more ambitious measures are needed. Such a Bridge scenario leads to lower energy sector emissions due to scale-up of renewable energy, electrification of energy demand, and efficiency improvements, and to lower land-use emissions due to afforestation—at levels and rates of change that are somewhat less than the 2Deg2020 case. The scenario is still in a position that allows meeting the Paris goals. Although the Bridge scenario raises policy costs (as expressed by GDP relative to the CurPol scenario) in 2050 by more than 20% compared to a cost-optimal 2 °C scenario, the Bridge scenario outperforms the delayed 2 °C scenario with global economic impacts being more than 10% lower in 2050. As such, early but non-cost-optimal action is preferred over climate policy delay. In the absence of immediate, all-encompassing and ambitious climate policy measures, therefore, a global roll-out and successful implementation of good practice policies can put the world on track to a 2 °C-compatible pathway without posing large additional challenges.

These results illustrate that short-term implementation of practical regulation-based policies is preferable over delayed climate action. At the same time, the institutional set-up should aim to avoid inefficient policy lock-in, as more efficient instruments may gain political and societal support over time.

Data availability
Model results can be found in the COMMIT database: to add link – open access. Policy relevant data is available in the Global Stocktake tool: https://themasites.pbl.nl/globalstocktake-indicators/.
Code availability

The models are documented on the common integrated assessment model documentation (https://www.iamcdocumentation.eu/index.php/IAMC_wiki), and several have published open source code, visualisation tools or detailed documentation (see references). The R-script that was used to generate the figures can be found on GitHub: https://github.com/Hel1vs/Bridge
3. Good practice policies to bridge the emissions gap in key countries

3.1 Introduction

A key aspect of the Paris Agreement is the goal to limit global average temperature increase to well below 2 °C (UNFCCC 2015). To achieve the Paris Agreement goals, each party to the United Nations Framework Convention on Climate Change (UNFCCC) needs to play its part, by presenting, and periodically updating, its Nationally Determined Contribution (NDC) towards more ambitious emission reduction targets. NDCs are a set of policies and targets aiming to reduce country level emissions and are determined by each country, with no legal obligation towards its implementation, and should be updated every five years (Schaeffer et al. 2020). Recent studies show that NDCs and national policies are not sufficient to cover the ambition level of the temperature limit agreed by the Paris Agreement, meaning that, perhaps, we need to collectively increase climate action to stabilise global warming at levels considered safe (Rogelj et al. 2016, Vrontisi et al. 2018, Roelfsema et al. 2020). To that end, we may need unprecedented and far reaching national and global responses in terms of practices and policies (van Soest et al. 2020). In fact, several options are on the table, including: energy efficiency improvements, electrification of final energy uses, uptake of renewable energy in power generation, advanced biofuels, carbon capture and storage (CCS), bioenergy with carbon capture and storage (BECCS), afforestation, reforestation, reducing deforestation etc, depending on national priorities and local conditions (Fragkos et al. 2020, Schaeffer et al. 2020).

To assess the contribution of greenhouse gas (GHG) emissions reductions from practices and policies, Integrated Assessment Models (IAMs) provide a thorough analysis of potential trade-offs, opportunities and challenges for their implementation. IAMs are widely used by the climate research community with studies ranging from policy implementation to climate scenarios and inter-model comparison analyses, both at the global and national level (Fragkos et al. 2020, Roelfsema et al. 2020, Schaeffer et al. 2020).

Most of these studies indicate the need to close the emissions gap between NDCs, current policies, and the more ambitious climate targets set by the Paris Agreement. Many studies focus on how to achieve climate goals, either through the use of global models, or from national models that make use of results from global models (Fragkos et al. 2020, Roelfsema et al. 2020). However, few focus on regionalized policy packages and their effects. This may be an indication that a broader selection of new, eventually already proved, policies and practices at the national level are needed as alternatives to least-cost solutions coming out of IAMs, at least in the short term (van Vuuren et al., 2020).

This article aims to evaluate a new set of practices and policy scenarios and their application in national IAMs, identifying how these practices and policies can contribute towards a 2°C world, and supporting the global stocktake in 2023. These scenarios are analyzed in ten different countries and one region - Australia, Brazil, 

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Canada, China, European Union (EU), India, Indonesia, Japan, Russia, South Korea and the United States, thus covering almost 75% of global CO2 emissions in 2018 (Fragkos et al. 2020).

The innovation on the part of this article is in the implementation of good practice policies in eleven national/regional IAMs that capture national specificities and policy priorities and comparison of results with those associated with the implementation of the NDCs, as well as the implementation of current policies and a 2°C scenario. Common indicators are calculated and shown to present whether the implementation of these practices and policies is sufficient to bridge the emission gap and contribute to the strengthening of the NDCs over time, along with sector-level assessment.

3.2 Methods
To evaluate a new set of practices and policy scenarios, named here as Good Practice Policies (GPP) and Bridging scenarios (Bridge) and their application in national IAMs, we identify how these practices and policies can contribute towards a 2°C world, and how they can support the global stocktake in 2023. Then, these scenarios are compared to a Current Policies (CurPol) scenario, a Nationally Determined Contributions (NDCplus) scenario, which maintains its effort after 2030, and an emission scenario consistent with an average global 2°C temperature change above pre-industrial levels (2Deg2030).

These scenarios are analyzed in eleven major-emitting economies- Australia, Brazil, Canada, China, European Union, India, Indonesia, Japan, Russia, South Korea and the United States. Eleven national/regional and nine global models were part of the COMMIT project (for more detail about the COMMIT project, see https://themasites.pbl.nl/commit/, Van Soest et al, 2020 and also Fragkos et al. 2020), and this paper focuses mostly on national models results.

For a more detailed discussion on global model results from the COMMIT project, see van Soest et al. (2020). For consistency between national and global levels, the scenarios analyzed in this study were developed simultaneously in both global and national levels. To that end, the same conditions are incorporated at the global and local levels, as well as carbon emission budgets, as done in Schaeffer et al. (2020). Thus, both national and global model teams involved in this effort followed the same scenario protocol for comparability.

Models
The countries and regions covered by these models are Australia, Brazil, Canada, China, Europe, India, Indonesia, Korea, Japan, Russia and the United States. As seen in Figure 1, the national models participating in this analysis represent more than 75% of global GDP and carbon dioxide emissions, as well as 57% of the global population. They represent 13 of the largest economies in the world, except Turkey and Mexico.
The national models included here are: AIM/Enduse (Japan), AIM/CGE (Korea), BLUES (Brazil), DDPP Energy (Indonesia), GCAM_Canada, GCAM-USA, India MARKAL, IPAC-AIM/technology (China), PRIMES (EU), RU-TIMES (Russia) and TIMES-AUS (Australia). This paper focuses on national models and results, comprising some comparisons to some global models results, while global results are deeply explored in van Soest et al. (2020). A brief description of each national model can be found in the supplementary material.

Scenarios

Five scenarios are explored in this paper, a current policy scenario, a scenario that represents the nationally determined contribution and the continuation of its efforts, a scenario of applying good practice policies, and two scenarios of climate emission corresponding to an increase of up to 2°C from pre-industrial emission levels to 2100, one referring to NDCs and the other referring to good practice policies.

The CurPol scenario is a middle of the road socio-economic conditions scenario throughout the century, based on the second marker baseline scenario from the Shared Socioeconomic Pathways (SSP2). It also assumes the implementation of energy, climate, and land-use policies that are currently endorsed, with a cut-off date of 1st of July 2019. It follows the same protocol as shown in Schaeffer et al. (2020) and Roelfsema et al. (2020), and presented in the Climate policy database (http://www.climatepolicydatabase.org/). The continuation of these policies is also considered.

The NDC-plus scenario relies upon the CurPol scenario and assumes that both unconditional and conditional NDC actions are implemented by 2030 and considering the continuation of the effort.

The 2°C (2Deg2030) scenario assumes a carbon budget until the year 2100, consistent with a warming of 2°C above pre-industrial levels by 2100. Each national modeling team used a carbon budget derived from the global carbon budget of 1,000 Gt of CO2 in the period from 2011 to 2100, as done in CD-LINKS (https://www.cd-links.org) and presented in Schaeffer et al. (2020). This carbon budget represents a high probability (66%) to keep global warming levels below 2°C. This carbon budget derives from global models and may be subject to the least-cost optimization to reflect the smallest impact on the global economy. Other methods can be applied to allocate such emissions, as seen in van den Berg et al. (2020), and others.

The Good practice policies (GPP) scenario also relies upon the CurPol scenario and has the implementation of good practice policies that have been shown to be effective in some countries. These policies are considered to
be implemented by 2050, taking into account distinctions between low/medium income and high-income countries in terms of timing and stringency of policy targets. The description of each of the selected good practice policies is presented in van Soest et al. (2020).

The Bridging (Bridge) scenario builds upon the GPP scenario and it transitions towards a 2 °C scenario after 2030. The GPP and Bridge scenarios were developed in a multi-round approach, consisting of an initial round with responses to literature-based good practice policies by national modeling teams, regarding the feasibility of implementing these policies in their countries or which target level or years would be possible.

The range of good practice policies varies from policies in the agricultural, industrial, building sectors, among others. These policies, based on the literature (cite), present differentiated targets for high-income and low/medium-income countries. Some of these measures include targets for reducing F-gas emission, greater efficiency in the final energy of the industrial sector, greater fuel efficiency in new passenger cars, the impediment to deforestation of natural forests, carbon pricing with tiers differentiating countries, and others.

Thus, these scenarios serve as a background to analyze how these good practice policies can contribute, in a cost-optimal way and at the national level, with the NDCs and carbon-constrained scenarios.

3.3 Results

Figure 2 presents GHG emissions trajectories up to 2050 from the countries represented by the national models and for each of the presented scenarios, results from the global models are shown for comparison. From the national models perspective, almost all of the presented scenarios show a reduction in the emission level when compared to 2010, which is not seen in the CurPol scenario for Brazil, Canada, and Korea, in the Brazilian NDCplus scenario, and all scenarios for India. Most of the national models trajectories are in accordance with global models results, with India and the United States being the regions with the largest number of non-converging scenarios. By 2030, GPP policies are effective in reducing GHG emissions in a manner consistent with the 2°C scenario for most of the analyzed countries, and in Australia, these policies are shown to be effective as an early action measure. However, until the year 2050, it is clear that there is still an unabated amount of carbon emissions to close the emission gap, thus reaching the level of ambition of the Paris Agreement.

In the Australian case, the good practice policies appear to be relevant to reduce carbon emissions until 2030, but these policies alone are insufficient to meet the 2 °C carbon budget for the country. For Brazil, the Bridge scenario is aligned with the 2Deg2030, but by 2030 there is not much change when compared to the Brazilian NDCs, which are not too ambitious beyond the AFOLU sector (Roelfsema et al., 2020, Kriegler et al., 2018). For Canada, the good practice policies converge towards the 2 °C scenario with little effort when compared to the NDC scenario. In the Indian scenarios, the GPP policies do not make significant changes in carbon emissions until 2030, but are more effective than Indian NDCs until 2050, with the Bridge scenario needing to achieve an emission reduction to converge with the carbon budget. For Japan and Russia, the good practice policies further reduce carbon emissions by 2030, but are not enough for the two-degree celsius trajectory. The USA has a greater emission reduction in its NDC scenario than in its GPP, which is consistent with an 80% GHG emission reduction in 2050 when compared to 2005 levels (cite). For Korea, NDCs are more effective than the GPP scenario in reducing carbon emissions by 2040, however, both are not enough for a 2 °C carbon budget.
Figure 2 - Greenhouse gas emissions trajectories from national models (lines) and global models (wedges) up to 2050. For China, Canada, India and Russia, only CO2 emissions are presented.

The waterfall charts in Figure 3 illustrate which are the largest contributors to emissions reduction between NDCplus and GPP scenarios. This helps indicates which sector is most interesting to analyze policies with a potential contribution to enhance NDC ambition. USA NDCs are more restrictive than the GPP scenario, resulting in lower carbon emissions, which are shown in the waterfall chart as negative values in all sectors. Overall, the residential and commercial sector presents itself as the smallest contributor toward GHG reduction in the compared scenarios.

By 2050, emissions from the energy supply are significantly reduced in Brazil, India, Japan, and Russia with the implementation of good practice policies, with only a small reduction in Korea when comparing the NDC and GPP scenarios. Japan, Korea, and Russia can also take advantage of the good practice policies for the transport sector, such as aviation efficiency improvement and a higher share of non-fossil vehicle sales, for improving its NDC targets. For the carbon emissions of industrial processes, the good practice policies are seen as a bottleneck for Japan, causing an increase in its carbon emissions when compared to its NDCs, but resulting in lower emissions for Brazil and Korea. In the case of emissions from the AFOLU sector in Brazil, the good practice policies are aligned with the Brazilian NDC concerning the zero rate of natural forest deforestation, while the GPP improves the rates of natural reforestation in Brazil.

When comparing the 2030 results for the NDC and GPP scenarios, as seen in Figure A.Y, it is noted that the good practice policies are more effective than the NDCs, with the exception of Korea and the USA. The selected good practice policies for energy supply and transport are more effective in reducing greenhouse gas emissions when compared to NDCs.
Figure 3 - Contribution of each sector to the reduction of carbon emissions between the NDCplus and GPP scenario (Negative values represent an increase in emissions between the compared scenarios).

Figure 4 shows the electricity share in final energy consumption from national and global models and figures A.X presents the share of electricity in industry, transportation, and residential and commercial sectors. In the case of Australia, Brazil, India, and Japan, the global models estimate a higher share of electricity consumption in final energy than the national models, which can be represented by a greater degree of optimism regarding electrification in these models. Overall, the good practice policies contribute to a greater share of electrification in final energy consumption when compared to CurPol and NDCplus, with higher trends in electrification shown in Canada and EU.

In the Industrial sector, a higher share of electrification is seen in GPP and Bridge scenarios in most of the analyzed countries, with significant changes in China, EU, Korea, and Russia. The same occurs in the residential and commercial sectors, with electrification occurring earlier in Canada, Japan, EU, and Korea. Excluding the US and India, the GPP scenario presents higher electrification rates in the transportation sector, following the GPP policies of higher fuel efficiency in vehicles and increased share of electric and hydrogen cars in new vehicle sales. Some models may consider hybrid electric or biofuel powered fuel cell vehicles as an alternative towards vehicle electrification (in particular to achieve the fuel efficiency targets), which is only indirectly shown in the share of electricity in the transport sector figure.
3.4 Discussion

Based on the results mentioned above, more specific results can be analyzed in terms of countries/regions. In the case of Australia, the intensification of electrification occurs in more restrictive GHG emission reduction scenarios, where electricity production occurs with almost zero emissions with the vast Australian renewable energy resources, as seen in Reedman et al. (2018). Compared to the current policy scenario, the share of electricity in the final energy use in the good practice policy scenario and the Bridge scenario is slightly higher, with the latter scenarios having a reduction in total final energy consumption. Land use changes play an important role in reducing Australian carbon emissions, which are 26% lower when comparing the NDCplus with the Bridge scenario.

For Brazil, the good practice policies for the land use change sector are not as effective in the short term for reducing emissions, when compared to the Brazilian NDC. In the transport sector, there is an increase in the share of ethanol use in the sector in the short term. However, given the good practice policies and the need to comply with a carbon emission limit in the Bridge scenario, there is an inversion in the share of ethanol consumption through the use of electricity in this sector which is in line with what was found by Koberle et al. (2020) and Rochedo et al. (2018). Moreover, the good practice policies help to reduce the need for carbon capture by up to 12% to mitigate carbon emissions in carbon restricted scenarios, reducing the need of using technologies with a low level of technological readiness.

Carbon dioxide emissions in China are reduced by almost 20% with the implementation of the good practice policies in 2030, when compared to the CurPol scenario, with the biggest reductions occurring in the industrial, residential and commercial sectors. By 2050, these policies are projected to lead to a reduction of more than 50% in carbon emissions, greatly driven by the reduction of emissions in the electricity generation sector, with the share of coal-fired power plants being reduced below the levels presented by Jiang et al. (2018). This reduction in the emission factor of the Chinese electricity grid allows for a greater reduction in Chinese carbon emissions facilitated by the increased share of electricity to more than 42% of the final energy by 2050.
Compared to the baseline scenario, the good practice policies increase the share of renewable sources in the Chinese electricity matrix by 70% by the year 2050.

In Europe, the good practice policies present an opportunity to reduce carbon emissions from the electricity and industrial sector, reducing them by almost 60% below their NDC scenario levels. The increased uptake of renewable energy reduces significantly the carbon content of electricity, and leads to a large emission reduction across the EU economy, especially when combined with the increased electrification of energy services, through the uptake of electric vehicles and heat pumps. This shows an alignment with the 'no regret' policy decisions presented by Capros et al. (2019), in which measures such as electrification, which is 34% higher in the GPP scenario than in the NDC, can be considered the ideal choice for a sustainable and cost-effective EU transition to climate neutrality.

The application of good practice policies in India allows a 20% reduction in carbon emissions from energy supply by 2030, and a reduction of more than 90% in emissions in 2050, when compared to NDC. As presented by Mathur and Shekhar (2020), this early action may be more expensive in the short term, but it prevents problems such as technological lock-in of carbon-intensive technologies (especially coal-fired power plants), thus presenting some advantages of these policies.

As in the European case, electrification in Japan occurs more significantly in the GPP and Bridge scenarios, and the good practice policies are presented as an opportunity to reduce Japanese emissions in the short term, as seen in Oshiro and Masui (2015) and in Oshiro et al. (2017).

3.5 Discussion and conclusions

The assessment of the implementation of the good practice policies at the country level can be used by climate negotiators to understand how these policies can add to each country’s NDC. This contributes to more ambitious NDCs in order to ensure consistency with the objectives of the Paris Agreement and add to the first global stocktake, which is due to take place in 2023. Complementary to this study, van Soest et al. (2020) present the results of global models, in which it is shown that rapidly implemented climate policies are more effective than delayed climate action. As long as there is no immediate climate policy, the good practice policies can put the world on a path compatible with a 2ºC world.

Most of the good practice policies play an important role in each region, with energy supply policies appearing as one of the biggest contributors to the reduction of carbon emissions. Namely, the alignment of the policy of renewable electricity share increase with the intensification of carbon pricing in the analyzed economies presented as a great contributor for closing the gap.
4. Comparison of global and national pathways

In the final chapter, we briefly compare the global and national pathways. Figure 2 of Chapter 2 shows emission reduction rates in the 11 COMMIT countries, plotting both the global models and the national models. Based on this the following observations can be made:

- The national scenarios are more ambitious in terms of GHG emissions reductions than the global ones in the case of Australia (in 2030) and Korea.
- The national scenarios are less ambitious than the global ones in the case of Brazil.
- For Japan, global and national scenarios show similar emission reduction rates.
- For other countries, GHG emissions were not reported by the national models (as they often only cover CO₂).

Figures 2 and 4 of Chapter 3 show both global and national model results.

- Most of the national models trajectories are in accordance with global models results, with India and the United States being the regions with the largest number of diverging scenarios.
- In the waterfall plots, the global paper shows a clear ‘winner’ in terms of the contribution to emission reductions, being the energy sector, while the national paper shows a much more mixed picture per region.
- In the case of Australia, Brazil, India, and Japan, the global models estimate a higher share of electricity consumption in final energy than the national models, which can be represented by a greater degree of optimism regarding electrification in these models.

Overall, the national models show relatively low carbon prices, and more importantly, a slower increase than the global models.

![Figure 1: Trajectory of the carbon price](image)
For CO₂ emissions, a similar observation as for GHG emissions (shown in the national paper) can be made: national and global scenarios are fairly well aligned. India is still an exception, but less so than for total GHG emissions.

Figure 2: CO₂ emissions (MtCO₂/year)

Not all models report AFOLU emissions, but those that do show pathways that are somewhat in the range of the global models (Brazil and USA), but others show clear differences (Australia and Korea).

Figure 3: AFOLU CO₂ emissions (MtCO₂ year)
Overall, it can be concluded that closing the remaining emissions gap between Nationally Determined Contributions (NDCs) and the global emissions levels needed to achieve the Paris Agreement’s climate goals will likely require a comprehensive package of policy measures. National and sectoral policies can help fill the gap. The bridge scenario shown here is based on nationally relevant measures informed by interaction with country experts. We implemented the scenario with an ensemble of global and national integrated assessment models (IAMs).

- Using the global models, we show that a global roll-out of these good practice policies closes the emissions gap between current NDCs and a cost-optimal well below 2 °C scenario by two thirds by 2030 and more than fully by 2050. The Bridge scenario leads to a scale-up of renewable energy (reaching 50%-85% of global electricity supply by 2050), electrification of end-uses, efficiency improvements in energy demand sectors, and enhanced afforestation and reforestation. Our analysis suggests that early action via good-practice policies is less costly than a delay in global climate cooperation.

- The national models further extended this. These GPPs were implemented in eleven well-established national Integrated Assessment Models (IAMs) for Australia, Brazil, Canada, China, European Union (EU), India, Indonesia, Japan, Russia, South Korea and the United States, that provide least-cost, low-carbon scenarios up to 2050. Also at the national level, our results show the relevance of good practice policies as a first step to bridge the emissions gap, thus serving as a package of policies to support the ratcheting up of the NDCs.
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