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Good practice policies to bridge the emissions gap in key countries

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A R T I C L E   I N F O

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A B S T R A C T

One key aspect of the Paris Agreement is the goal to limit the global average temperature increase to well below 2 °C by the end of the century. To achieve the Paris Agreement goals, countries need to submit, and periodically update, their Nationally Determined Contributions (NDCs). Recent studies show that NDCs and currently implemented national policies are not sufficient to cover the ambition level of the temperature limit agreed upon in the Paris Agreement, meaning that we need to collectively increase climate action to stabilize global warming at levels considered safe. This paper explores the generalization of previously adopted good practice policies (GPPs) to bridge the emissions gap between current policies, NDCs ambitions and a well below 2 °C world, facilitating the creation of a bridge trajectory in key major-emitting countries. These GPPs are 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. Results show that GPPs can play an important role in each region, with energy supply policies appearing as one of the biggest contributors to the reduction of carbon emissions. However, GPPs by themselves are not enough to close the emission gap, and as such more will be needed in these economies to collectively increase climate action to stabilize global warming at levels considered safe.

1. Introduction

A key aspect of the Paris Agreement is the goal to limit the global average temperature increase to well below 2 °C (UNFCCC 2015). To achieve the Paris Agreement goals, each party of 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

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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, all countries need to collectively increase climate action to stabilize 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. 2021). 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., 2021; Schaeffer et al. 2020).

To assess the contribution of greenhouse gas (GHG) emissions reductions from practices and climate 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 levels (Fragkos et al., 2021; Roelfsema et al. 2020; Schaeffer et al. 2020; van Soest et al. 2021).

Most of these studies indicate the need to close the emissions gap between current policies, the NDCs, 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 (van Soest et al. 2021), or from national models that make use of results from global models (Lucena et al. 2016; Fragkos et al., 2021; Roelfsema et al. 2020; Schaeffer et al. 2020). However, few studies 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 is needed as an alternative to least-cost solutions coming out of IAMs, at least in the short and medium-term (Schweizer 2018; van Vuuren et al. 2020).

To this end, climate change mitigation is typically facilitated in IAMs by a global carbon price to identify cost-effective mitigation strategies (Clarke et al., 2014; Solomon, 2007). However, while price-driven or least-cost trajectories are indicative, they may sometimes not be particularly realistic, as probably in most countries a carbon price is going to be the single most important driver of an efficient low-carbon transition, but with other energy, transport and climate policy measures also playing a role. As such, a carbon price is normally an artifact that IAMs use to indicate mitigation actions: it equals the marginal abatement cost across regions and sectors of a theoretical world with a limited representation of heterogeneous behavior and institutions. Nonetheless, it is worthwhile to explore those mitigation actions in more detail.

This article aims to evaluate scenarios with a new set of standardized practices and policies and their application in national IAMs, identifying how these practices and policies can contribute towards a below 2 °C world, and supporting the revised NDCs and global stocktake in 2023. These scenarios are analyzed in ten different countries and one region - Australia, Brazil, Canada, China, European Union (EU), India, Indonesia, Japan, Russia, South Korea, and the United States, thus covering almost three-fourth of global CO_2 emissions in 2018 (Fragkos et al., 2021; Schaeffer et al. 2020).

The innovation of this article is in the implementation of good practice policies (GPP) in eleven national/regional IAMs that capture national specificities and policy priorities. Furthermore, this study compares the results of the new scenarios with those associated with the implementation of the NDCs, as well as the implementation of current policies scenario and a 2 °C scenario. In this context, to assess the effectiveness of the GPP in closing the emission gap, a Bridge scenario is also considered, which account simultaneously the GPP and 2 °C scenario. It is the first time that such GPP/Bridge scenarios are implemented at the national scale, allowing an analysis of the implementation of these climate policies and a counterpoint to the NDCs. Besides, these scenarios were created jointly by national and global model teams, with the latter also running the same scenario protocol (for more detail on global model runs see van Soest et al. (2021)). 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 a sector-level assessment.

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 ratcheting up in 2023. As described in more detail below, the GPP scenario is based on a set of good practice policies that have been effective in some countries. These policies are related to AFOLU, buildings, industry and transport sectors, and to energy supply, waste management and economy-wide measures. The measures associated with these policies vary according to the income level of the assessed countries, so as not to become a burden for low- and middle-income countries. And the Bridge scenario is based on the GPP scenario until 2030, and then it transitions to a 2 °C pathway afterwards.

Then, these scenarios are compared to a Current Policies (CurPol) scenario, a Nationally Determined Contributions (NDCplus) scenario, which maintains its effort after 2030, and a cost-optimal emission scenario consistent with an average global 2 °C temperature change above pre-industrial levels, which starts in 2030 and is based on the NDC scenario (2Deg2030).

These scenarios were developed for 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/, Fragkos et al. (2021), and van Soest et al. (2021)), with this study focusing on national models results.

For a more detailed discussion on global model results from the COMMIT project, see van Soest et al. (2021). For consistency between national and global analyses, the scenarios analyzed in this study were developed simultaneously at both global and national levels. To that end, the same conditions are incorporated at the global and national levels, providing a consistency between national pathways and global 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.

2.1. Models

Fig. 1 shows the national models participating in this analysis, representing 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 Mexico and Turkey.

The national/regional 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). As said before, 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. (2021). A brief description of each national model can be found in the supplementary material.

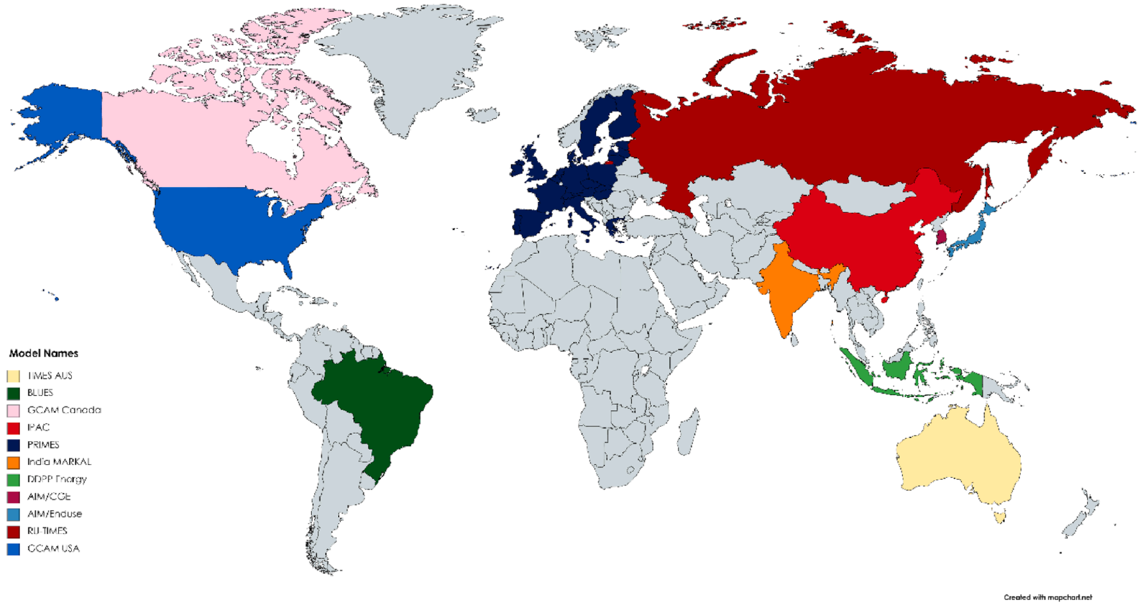

Fig. 1. Economies covered by the national/regional models included in this work.

2.2. *Scenarios*

Five scenarios are explored in this paper in order of stringency, namely a current policies scenario (CurPol), a scenario that represents the nationally determined contributions and the continuation of its efforts (NDCplus), a scenario of applying good practice policies (GPP), and two "mitigation" scenarios corresponding to an increase of global warming up to 2 °C from pre-industrial levels to 2100, one building on NDCs (2Deg2030) and the other referring to a scenario which is based on the GPP scenario until 2030, and then it transitions to a 2 °C pathway afterwards (Bridge).

The CurPol scenario is a middle of the road socio-economic conditions scenario throughout the century, based on the socio-economic development assumptions of 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 and legislated, with a cut-off date of 1st of July 2019. It follows almost the same protocol as shown in Roelfsema et al. (2020) and Schaeffer et al. (2020) and presented in the Climate policy database (http://www.climatepolicydatabase.org/), but with a small update to incorporate recently adopted policies. The continuation of these policies is also considered, as shown in the NDCplus scenario that follows.

The NDCplus scenario relies upon the CurPol scenario and assumes that both unconditional and conditional NDC pledges and targets are implemented by 2030[1] in major emitting economies and considering the continuation of the effort beyond 2030, by the extrapolation of an equivalent carbon price in 2030 using the GDP growth rate as a proxy up to 2050. The equivalent carbon price represents the value of carbon that would produce the same emission reduction as the NDC policies in a region. If a region has a carbon price of zero during the implementation of the NDC in 2030, a minimum carbon price of 1 $/tCO_2$ in 2030 has been assumed. If a region has a negative carbon price in 2030, the resulting trajectory of 1 $/tCO_2$ has been used to offset the model's starting point in 2030. For land use, a $200/tCO2 price cap has been applied, as a higher carbon price might affect food security as the demand for bioenergy would increase (McCollum et al. 2018; Hasegawa et al. 2020).

Our representation of the US NDCplus pathway is consistent with the official U.S. Midcentury report submitted by the U.S. government to the UNFCCC (The White House, 2016). In this representation, the NDCplus scenario for the U.S. coincides with the 2Deg2030 scenario. This is because the US NDC lies on a straight-line path toward 80% reduction in 2050 (Iyer et al., 2017; The White House, 2016), which is in turn consistent with a 2-degree pathway and budget (Feijoo et al. 2020). This is not the case with other countries explored in this study. Thus, it is important to note that that our modeling of the NDCplus scenario for the U.S. assumes that the U.S. will achieve their NDC as stated and will continue to follow through with stringent policies to achieve 80% reduction in economy-wide GHG emissions by 2050. This representation is understandably more ambitious compared to the other countries and regions studied in this paper and care must be taken in interpreting cross-country comparisons.

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 national carbon budget derived from the global budget of 1000 Gt of CO_2 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 by 2100. 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 to individual countries as well, as seen in van den Berg et al. (2020).

The good practice policies (GPP) scenario relies upon the CurPol scenario and assumes the implementation of good practice policies that are effective in some countries[2]. 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 climate policy targets. The description of each of the

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[1] The NDCs here used are those that were already made public as of 15 November 2020.

[2] The protocol for the GPP implementation assumed a national level policy implementation. However, each model has its own regional disaggregation (e.g.: the BLUES model represents 5 Brazilian macro regions, the GCAM model represents 50 states of the US), and this may affect the results of other policy scenarios, such as the Current Policies and NDCplus scenarios.

selected good practice policies is presented in Table 1.

There are good practice policies for six different economic sectors, as well as a policy that affects the entire economy. The range of good practice policies includes policies in the energy, transport, agricultural, industrial, building sectors, among others. These policies, based on the literature (Fekete et al. 2015; Kriegler et al. 2018; Roelfsema et al. 2018), present differentiated targets for high-income and low/medium-income countries. Some of these measures include targets for reducing F-gas emissions, increased uptake of renewable energy sources, greater efficiency in the final energy in the buildings and industrial sectors, 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, at the national level, to minimize the emission gap between the NDCs and more carbon-constrained scenarios.

Finally, the bridging (Bridge) scenario builds upon the GPP scenario, transitioning it 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.

3. Results

The GHG emissions trajectories up to 2050 from the countries/regions represented by the national/regional models and for each of the presented scenarios is available in Fig. 2. Results from the global models are also shown for comparison. Some variations regarding historical emissions are mostly due to the use of different databases, especially historical land-use emissions (Grassi et al. 2021), by the global and national model teams. It is also worth noting that different models might not have the same sectoral representation or have different GHGs represented in their codes. As such, their results are shown only to present a convergence between national and global level results. This variation between global and national results can also be found in the literature, such as in Roelfsema et al. (2020) and Schaeffer et al. (2020).

From the national/regional models' perspective, almost all the presented scenarios show a reduction in the emissions level when compared to 2010 levels. This is not seen in the CurPol scenario for Brazil, Canada, and South Korea, in the Brazilian NDCplus scenario, and in all scenarios for India. Most of the national/regional trajectories are consistent with global models results, with India and the United States being the regions with the largest number of non-converging scenarios, the latter being a consequence of the implementation of certain policies at the subnational (states, cities, and firms) level as well.

By 2030, the good practice policies[3] are effective in reducing GHG emissions (even more effective than NDCs) in a manner consistent with the 2 °C scenario for most of the analyzed countries. In the case of 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 emissions gap towards the expected levels of emissions for the ambition of the Paris Agreement.

In the Australian case, the good practice policies appear to be relevant for reducing carbon emissions until 2030, but these policies alone are insufficient to meet the 2 °C carbon budget for the country. For Brazil, the GPP scenario is slightly more efficient in reducing GHG emissions by 2030 when compared to NDCplus, with the latter not being overly ambitious beyond the AFOLU sector (Köberle et al. 2020). For Canada and the EU, the GPP scenario lead to significant emission

Table 1
The good practice policies assumed in the national models.

Sector	Measure	High-income countries	Low-/medium-income countries	Other (differs per measure)
Agriculture, forestry and other land use	Treat manure from livestock with anaerobic digesters – Reduction of CH_4 emissions from manure, relative to 2015	33% by 2030, 40% by 2050	15% by 2030, 33% by 2050	–
	Increase nitrogen use efficiency – Reduction of N_2O emissions from fertilizer, relative to 2015	10% by 2030	5% by 2030, 10% by 2050	–
	Selective breeding to reduce CH_4 emissions from enteric fermentation – Emission factor reduction (CH_4/ton milk and/or beef) or emissions reduction, relative to 2015	10% by 2030	0% by 2030	–
	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	Tier 1 (China, Latin America): 2%/year	Tier 2 (South & Southeast Asia, Sub-Saharan Africa, Australia): 1% per year	Tier 3 (Europe, Turkey, 23% of Russia, USA): 0.5% per year
	Halt natural forest deforestation	0 ha/year by 2030	0 ha/year by 2030	–
Energy supply	No new installations of unabated coal power plants	By 2025	By 2030	–
	Increase of the share of renewables in total electricity generation per year (starting in 2020, until 2050 and up to 50%, maximum)	1.4 %-point increase per year	1.4 %-point increase per year	–
	Coal mine CH_4 emissions recovery	30% by 2030	30% by 2030	–
	Reduce venting and flaring of CH_4 and CO_2 – emission reduction, relative to 2015	36% by 2030, 95% by 2050	36% by 2030, 95% by 2050	–
Buildings	Improve the final energy efficiency of appliances compared to 2015 (autonomous	17% by 2030, 32% by 2050	7% by 2030, 25% by 2050	

(continued on next page)

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[3] In order to avoid confusion with the GPP scenario, the set of good practice policies (also named GPP) embodied in the GPP, and Bridge scenarios will be referenced as "good practice policies" from this point forward.

Table 1 (*continued*)

Sector	Measure	High-income countries	Low-/medium-income countries	Other (differs per measure)
	improvement as well as due to policy)			
	Improve final energy intensity of new residential and commercial buildings	22 and 30 kWh/(m^2.yr) by 2025	22 and 30 kWh/(m^2.yr) by 2035	EU: 35 and 40 kWh/(m^2.yr) by 2025
	No new installations of oil boiler capacity in new and existing residential and commercial buildings	By 2030	By 2040	EU: by 2020
	Improve the efficiency of existing buildings – Share of existing buildings being renovated	11% by 2030, 24% by 2050	6% by 2030, 14% by 2050	–
Industry	Apply CCS - Carbon captured and stored as a share of the industry's total CO_2 emissions (model-dependent)	1.5% by 2030	1.5% by 2040	–
	Improve final energy efficiency, relative to 2015	11% by 2030, 28% by 2050	6% by 2030, 15% by 2050	–
	Reduce N_2O emissions from adipic/acid production – reduction, relative to 2015	99% by 2030	99% by 2030	–
Transport	Improve the energy efficiency of aviation, starting in 2018	0.78% per year by 2030, 0.52% per year by 2050	0.78% per year by 2030, 0.52% per year by 2050	–
	Improve the average fuel efficiency of new passenger cars	38 km/l by 2030	27 km/l by 2030	–
	Increase the share of non-fossil in new vehicle sales	50% by 2030	25% by 2030	China: 25% by 2025
Waste	Reduce CH_4 emissions, relative to 2015	55% by 2030	28% by 2030, 55% by 2040	–
Economy-wide	Carbon pricing – pathways for three tiers (different than high- and low-income)	Tier 1 (OECD, EU): 40 USD/tCO_2 by 2030, 80 USD/tCO_2 by 2030	Tier 2 (Russia, Eastern Europe, China, Korea, Latin America): 25 USD/tCO_2 by 2030, 65 USD/tCO_2 by 2030	Tier 3 (all others): 10 USD/tCO_2 by 2030, 50 USD/tCO_2 by 2030
	Reduce F-gas emissions, induced by policies, relative to 2015	60% by 2030	38% by 2030	–

reductions from CurPol and NDC levels and they converge towards the 2 °C scenario with little effort, when compared to the NDC scenario. In the Indian scenarios, the good practice policies lead to a 15% decline in the emissions in 2030 (with respect to CurPol), making it more ambitious than its NDCplus scenario. By 2050, the GPP scenario shows a decline of 51% in emissions with respect to CurPol scenario and 45% with respect to NDCplus scenario. However, the GPP scenario is not in line with the cost-optimal budget allocation for India for a 2 °C world and additional effort is needed to bridge this gap. For Japan and Russia, the GPP scenario can reduce carbon emissions by 2030 but are still not enough for closing the emission gap to the 2 °C trajectory. As explained earlier, the USA has a greater emission reduction in its NDC scenario than in its GPP scenario since the scenario is modeled along the lines of the official U.S. Midcentury report submission to UNFCCC and is consistent with a 2 °C scenario (The White House, 2016). Lastly, for Korea the NDC scenario is more effective than the GPP scenario in reducing carbon emissions by 2040. Nonetheless, neither are enough for achieving the national 2 °C carbon budget.

The waterfall charts in Fig. 3 illustrate which are the largest contributors to emissions reduction between NDCplus and GPP scenarios by 2050. This analysis aims to help indicate which sectors has the largest potential contribution to enhance NDCs' ambitions. Additionally, it presents the differences in regional perspectives related to the sectors with the greatest potential for emissions reduction. Regarding AFOLU emissions, some models lack their representation[4], which explains their null contribution in Fig. 3. As explained earlier, the US NDC scenario is consistent with a 2 °C pathway and budget resulting in lower carbon emissions, which are shown in the waterfall chart as negative values in all sectors.

Overall, the residential and commercial (buildings) sector presents itself as the smallest contributor toward GHG reduction in the compared scenarios, while the largest contributions come from the electricity supply and transport sectors, mostly driven by the expansion of renewable energy and electric vehicles, respectively. These results are in line with the global models results presented by van Soest et al. (2021).

By 2050, emissions from energy supply are significantly reduced in Brazil, India, Japan, and Russia with the implementation of the good practice policies, with only a small reduction in South Korea when comparing the NDC and GPP scenarios. Japan, Russia, and South Korea could also take advantage of the good practice policies in the transport sector, such as aviation efficiency improvement and a higher share of non-fossil vehicle sales, for improving their NDC targets.

Regarding carbon emissions from industrial processes, the good practice policies for the industrial sector can be interpreted as a counterproductive for Japan, causing a small increase in its industrial processes emissions when compared to its NDC scenario. On the other hand, the opposite happened for Brazil and South Korea.

In the case of the impacts of the good practice policies on AFOLU emissions, Brazil stood out amongst the other regions. Whilst the good practice policies are somewhat aligned with the Brazilian NDC concerning natural forest deforestation, GPP scenario also consider the improved rates of natural reforestation, which accounts for almost 17% of GHG emission reduction compared to the NDCplus scenario.

When comparing the 2030 results for the NDC and GPP scenarios, as seen in Fig. S1 in the Supplementary Material, it can be noticed that the good practice policies are more effective than the NDCs for reducing carbon emissions, with the exception of EU, South Korea, and the USA. Once more, the selected good practice policies for energy supply and transportation are more effective in reducing GHG emissions, when compared to NDCs.

The electricity share in final energy consumption from national/regional and global models is available in Fig. 4. Figs. S2-S4 in the Supplementary Material present the share of electricity in industry,

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[4] *GCAM-Canada, Primes, IND-MARKAL, AIM/Enduse/RU-Times.*

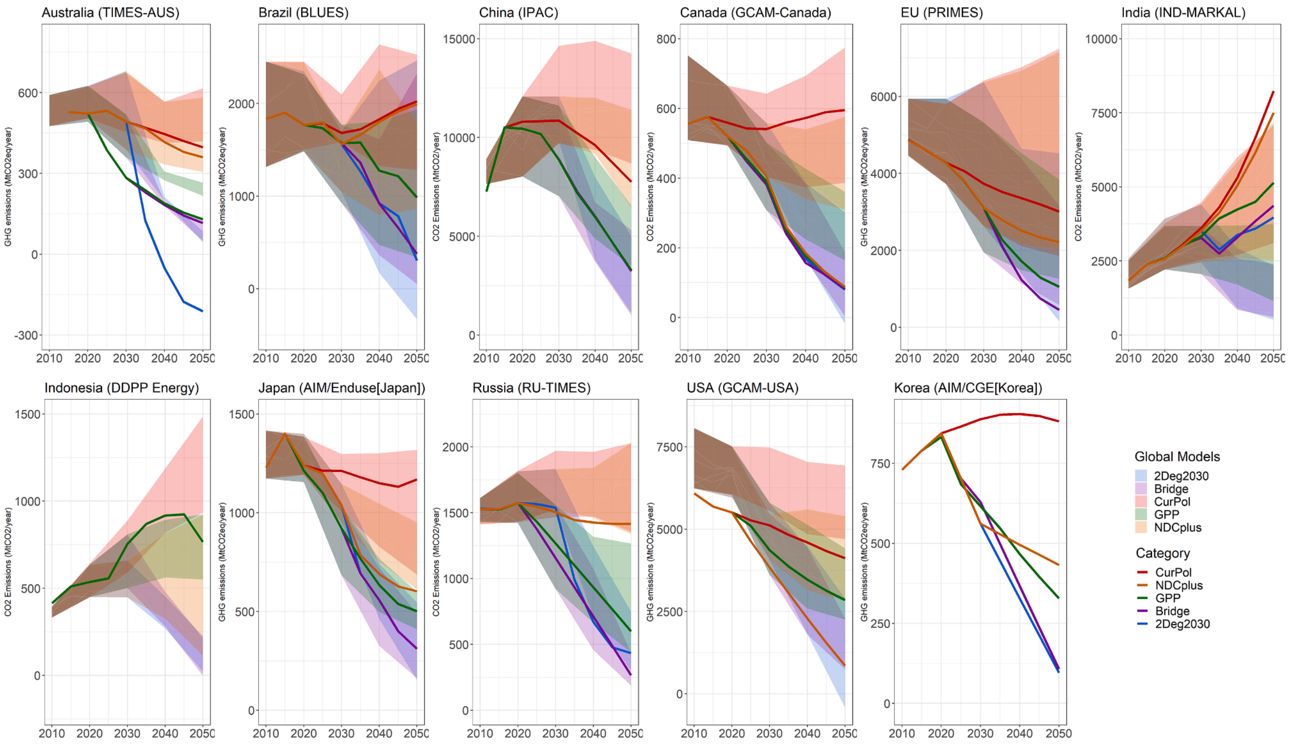

Fig. 2. Greenhouse gas emissions trajectories from national/regional models (lines) and global models (wedges) up to 2050. For Canada, China, India, and Russia only CO_2 emissions are presented. Different scales are applied to facilitate reading the results for each region.

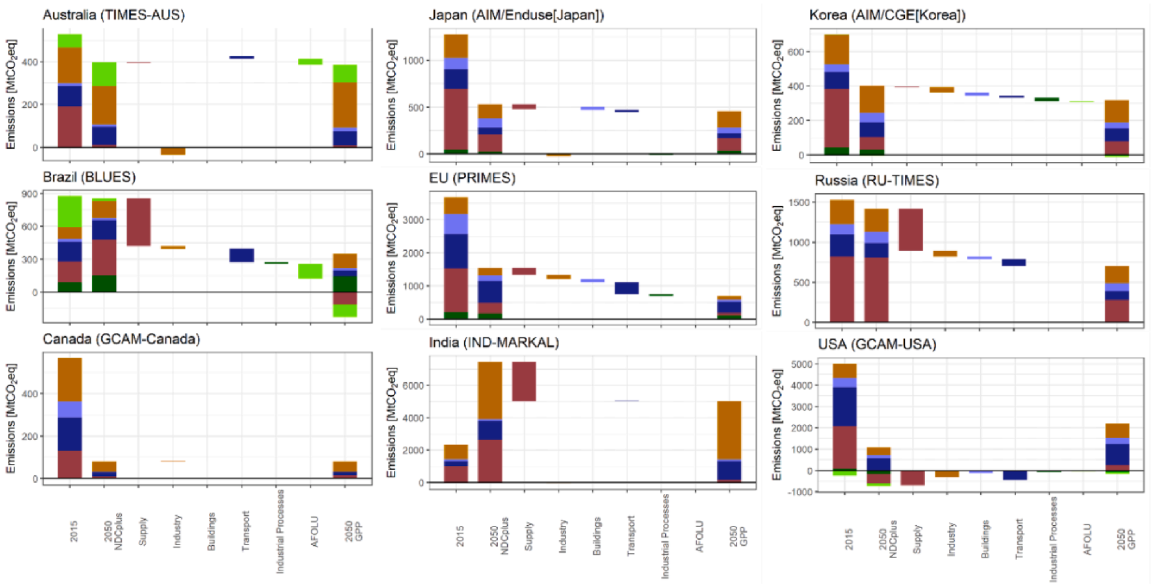

Fig. 3. Contribution of each sector to the reduction of carbon emissions between the NDCplus and GPP scenario in 2050. Emissions in 2015 are shown for comparison (Negative values represent an increase in emissions between the compared scenarios). Different scales are applied to facilitate the reading of the results for each region. The sectoral representation varies according to the model, which may explain some zero values.

transportation, and residential and commercial (buildings) sectors, respectively. In the case of Australia, Brazil, India, and Japan, global models estimate a higher share of electricity consumption in final energy than national/regional 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 scenarios, with higher trends in electrification shown in Canada and the 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, Russia, and South Korea. The same occurs in the residential and commercial (buildings) sectors, with electrification occurring earlier in Canada, Japan, the EU, and South Korea. Excluding India and the USA, the GPP scenario presents higher electrification rates in the transportation sector, following the good practice policies of

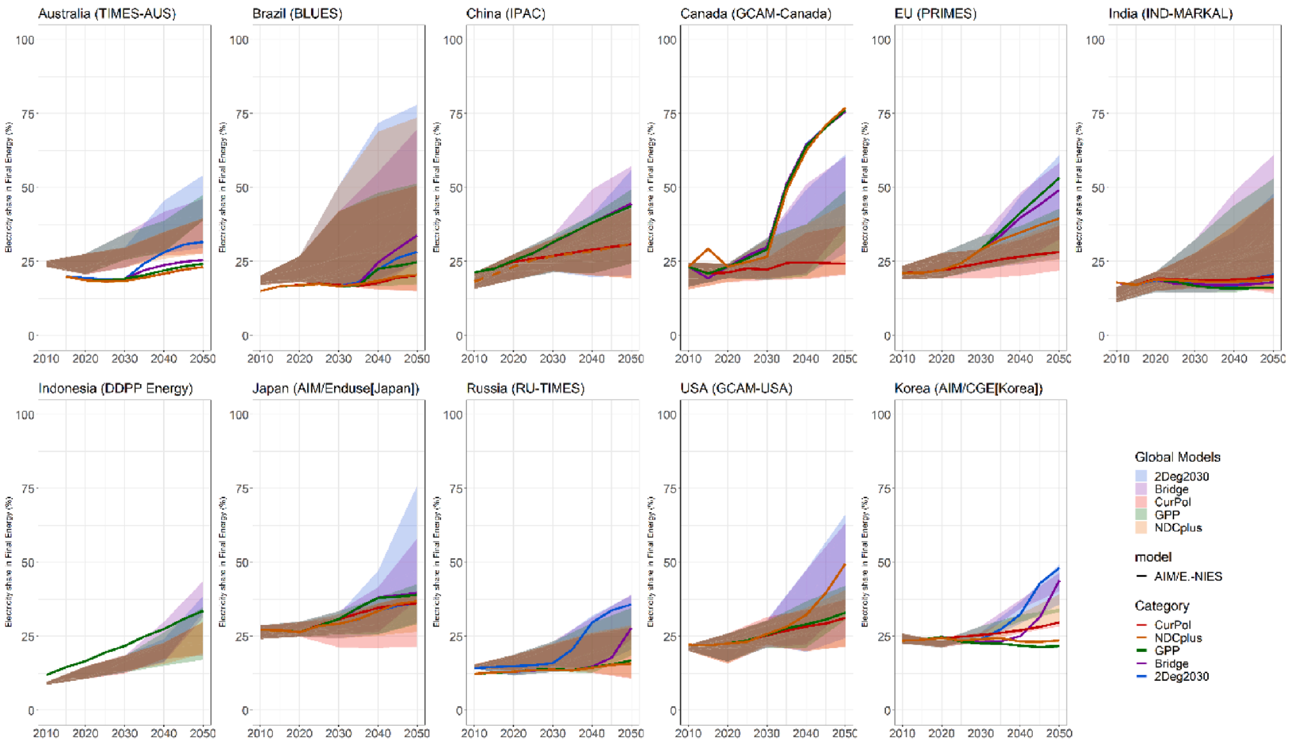

Fig. 4. Share of electricity in final energy consumption from national/regional models (lines) and global models (wedges).

higher fuel efficiency in vehicles and increased share of electric and hydrogen cars in new vehicles sales. Additionally, 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 available in the Supplementary Material.

4. Country-level discussions

Based on the results mentioned above, this section focuses on specific and individual analyses for each country/region.

In the case of Australia, the intensification of electrification occurs in more restrictive GHG emission reduction scenarios, with electricity production achieving almost zero emissions due to the vast Australian renewable energy resources, as seen in Reedman et al. (2018). Compared to the current policies scenario, the share of electricity in the final energy use in the GPP 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 by 2050 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, which is not the case by 2050. In the GPP's transport sector, there is an increase in the share of ethanol use in the short term. However, the Bridge scenario presents shift towards electrification, reducing ethanol consumption, which is in line with what was found by Lucena et al. (2018) and Rochedo et al. (2018). Moreover, the good practice policies help to reduce the need for carbon capture by up to 12% by 2050 to mitigate carbon emissions in carbon restricted scenarios, reducing the need of technologies with a lower level of technological readiness, confirming results of previous studies (Henriques, Dantas and Schaeffer 2010).

Carbon dioxide emissions in China are reduced by almost 20% with the implementation of the good practice policies by 2030, when compared to the CurPol scenario. The largest reductions occurring in the industrial, residential, and commercial sectors. By 2050, these policies lead to a reduction of more than 50% in carbon emissions, greatly driven by the reduction of emissions in electricity generation, with the share of coal-fired power plants being reduced below the levels presented by Jiang et al. (2019). This reduction in the emission factor of the Chinese electricity grid allows for a greater reduction in Chinese carbon emissions further facilitated by the increased share of electricity of final energy, which achieves more than 42% of the final energy consumption by 2050. The good practice policies scenario increases the share of renewable sources in the Chinese electricity matrix by 70% by 2050 when compared to the Current Policies scenario.

In the EU, the good practice policies present an opportunity to reduce carbon emissions from the power and industrial sectors, reducing them by almost 60% below their NDC scenario levels by 2050. The increased uptake of renewable energy significantly reduces 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) and Fragkos et al. (2017), in which measures such as electrification, which is 34% higher in the GPP scenario than in the NDC scenario by 2050, can be considered 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 the NDC scenario. In the short term, the most effective policy instrument for India appears to be a carbon tax which would help to phase out fossil fuels from the system. Moreover, the GPP scenario can also contribute towards reducing the burden of mitigation in the later years by preventing problems such as technological lock-in of carbon-intensive technologies (especially coal-fired power plants). However, as presented by Mathur and Shekhar (2020), such early actions may be more expensive in the short term. It is worth mentioning that this study focuses on climate/energy related policy impacts only, and as such it does not cover implementation costs (for studies analyzing costs in a cost optimal policies scenario, see McCollum et al. (2018) and Sun et al. (2019)). For a detailed analysis on the cost and economic impacts of GPP scenarios at the global level, please see van Soest et al. (2021).

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 et al. (2017), Oshiro et al. (2020). The good practice policies are consistent with the emissions from the high budget scenarios presented in Oshiro et al. (2020), which is compatible with the upper limit of emissions under the Paris Agreement. However, the good practice policies are more efficient in the buildings sector, while the increase in effort in the transport sector is marginal when comparing them with the results of Oshiro et al. (2020).

In the case of Russia, good practice policies are capable of reducing emissions from the energy sector by more than half by 2050, while improving energy efficiency measures that reduce primary energy consumption, when compared to the NDC scenario. Similar to that presented in Golub et al. (2019), the adoption of climate policies may weaken some barriers to new technologies in the energy sector, thus showing the importance of policies of good practices to bridge the gap for the Russian energy sector.

For the United States, good practice policies fail to prove to be more effective than the USA NDC, which is largely due to the Mid-Century Strategy for Deep Decarbonization, as presented in Feijoo et al. (2020). Therefore, the good practice policies are not sufficient to reduce USA carbon emissions, as its NDC is much more stringent in reducing carbon emissions.

5. Final remarks and conclusions

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 over time. Namely, the alignment of the policy of renewable electricity share increases with the intensification of carbon pricing in the analyzed economies have shown to be a great contributor for closing the gap. These policies also reduce the need for carbon capture in some regions, which reduces the dependence on technologies with a low level of technological readiness. Nonetheless, these policies are still not enough to completely close the emission gap. In fact, initial good practice policies have to be complemented, after 2030, by additional policies and measures, so as to emulate, as much as possible, the Bridge scenarios explored in this study.

Finally, there are two additional main issues that still need to be addressed, such as the homogeneity of these policies in such disparate countries/regions, and the political feasibility of the policy packages across regions and sectors. The first presents itself as the problem related to the development of a standardized set of good practice policies, given that each country/region has its own specificities, therefore requiring different approaches for implementation and further analysis to allow individual adaptation without compromising the endgame. Therefore, these policies must be reevaluated by policymakers in order to align them with each country specifically.

The second, is related to the political feasibility of policy packages and other social issues across regions and sectors, which in turn can be greatly facilitated by the way they are designed and implemented. Experience has shown that policy packages need to balance different objectives and administer their interactions to succeed and last long, so as to also reach additional objectives successfully from other policy domains (Pahle et al., 2021). It is also worth mentioning that alternative approaches to the NDCplus scenarios could also be used, such as the approach presented by Fawcett et al. (2015), as the authors have considered a minimum decarbonization rate regarding CO2 emissions per unit of GDP. Complementing this, the NDC scenario is mainly used as a counterfactual to the good practice policies scenario.

This study has shown that the assessment of the implementation of good practice policies at the country/regional level can be used by policymakers to understand how these policies can add to each country's/region's NDC. Furthermore, these good practice policies can contribute to more ambitious NDCs aiming at a higher consistency with the objectives of the Paris Agreement, adding to the first global stocktake, which is due to take place in 2023. As a matter of fact, good practice policies should serve as a guide for the next global stocktake towards more ambitious NDCs, which later on will need to follow a pathway similar to that given by the Bridge scenarios, towards a below 2 °C world. In fact, complementary to this study, van Soest et al. (2021) present the results of global models, in which it is shown that rapidly implemented climate policies are more effective and cheaper than delayed climate action. As long as there is no immediate climate policy, the good practice policies can put the world on a path more compatible with a 2 °C world, later on to be complemented by a Bridge scenario.

Data availability

Model results can be found in the COMMIT scenario explorer: https://data.ece.iiasa.ac.at/commit/#/login?redirect=%2Fworkspaces. Policy relevant data is available in the Global Stocktake tool: https://themasites.pbl.nl/o/global-stocktake-indicators/#home. The scenario data generated in this study have been deposited in the Zenodo database under accession code https://doi.org/10.5281/zenodo.5163588.

Author contribution

LR developed the scenarios for the TIMES-AUS model; LBB, RS, PR and others in the BLUES team developed the scenarios for the BLUES model; CQ and KJ developed the scenarios for the Chinese models; NM developed the scenarios for the GCAM-Canada model; PF and MK developed the scenarios for the PRIMES model; SS developed the scenarios for the India MARKAL model; RD and US developed the scenarios for the DDPP Energy model; KO developed the scenarios for the AIM/Enduse[Japan] model; GS developed the scenarios for the RU-TIMES model; GI and KS developed the scenarios for the GCAM-USA model; CP developed the scenarios for the AIM/CGE[Korea] model. LBB coordinated the analysis and wrote the paper, HvS and LBB created the figures; all authors contributed to the definition of the good practice policy package, the analysis, and article review; RS and PR supervised the preparation of the paper.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2022.102472.

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