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RESEARCH ARTICLE

Reducing global GHG emissions by replicating successful sector examples: the 'good practice policies' scenario

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ABSTRACT

This article shows the potential impact on global GHG emissions in 2030, if all countries were to implement sectoral climate policies similar to successful examples already implemented elsewhere. This assessment was represented in the IMAGE and GLOBIOM/G4M models by replicating the impact of successful national policies at the sector level in all world regions. The first step was to select successful policies in nine policy areas. In the second step, the impact on the energy and land-use systems or GHG emissions was identified and translated into model parameters, assuming that it would be possible to translate the impacts of the policies to other countries. As a result, projected annual GHG emission levels would be about 50 $GtCO_2e$ by 2030 (2% above 2010 levels), compared to the 60 $GtCO_2e$ in the 'current policies' scenario. Most reductions are achieved in the electricity sector through expanding renewable energy, followed by the reduction of fluorinated gases, reducing venting and flaring in oil and gas production, and improving industry efficiency. Materializing the calculated mitigation potential might not be as straightforward given different country priorities, policy preferences and circumstances.

Key policy insights

- Considerable emissions reductions globally would be possible, if a selection of successful policies were replicated and implemented in all countries worldwide.
- This would significantly reduce, but not close, the emissions gap with a 2°C pathway.
- From the selection of successful policies evaluated in this study, those implemented in the sector 'electricity supply' have the highest impact on global emissions compared to the 'current policies' scenario.
- Replicating the impact of these policies worldwide could lead to emission and energy trends in the renewable electricity, passenger transport, industry (including fluorinated gases) and buildings sector, that are close to those in a 2°C scenario.
- Using successful policies and translating these to policy impact per sector is a more reality-based alternative to most mitigation pathways, which need to make theoretical assumptions on policy cost-effectiveness.

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1. Introduction

Most countries have ratified the Paris Agreement, which aims at reducing GHG emissions in order to keep the increase in global mean temperature to 'well below' 2°C above pre-industrial levels, and preferably below 1.5°C (UNFCCC, 2015). The collective impact of all Nationally Determined Contributions (NDCs) submitted by countries

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to indicate their pledges for emission reductions for the period to 2025/2030 are not expected to achieve those temperature goals. Based on different cost-optimal 2°C scenarios from integrated assessment models, Rogelj et al. (2016) find a projected emissions gap for 2030 of 10 to 16 billion metric tonnes of CO_2-equivalent emissions ($GtCO_2e$), between the global emission level consistent with warming below 2°C and the range associated with a full implementation of unconditional NDCs for 2030. Annual emission levels for 2030 consistent with 2°C are between 31 to 44 $GtCO_2e$ (10–90th percentile). The Paris Agreement encourages Parties to increase their pledged GHG emission reductions. The momentum created in Paris could be captured by continuing with the same NDC process and scaling up ambition (Höhne et al., 2017).

In this context, it is important to note that there are already examples of successful sector policies in specific countries that significantly reduce GHG emissions. An important question is whether other countries can learn from such sector policies and achieve similar results. In the literature, it has been suggested that a possible route forward could be to promote a process of international policy learning and 'the emergence of a global marketplace of ideas' (Hadjiisky, Pal, & Walker, 2017). Although it is clear that 'policy transfer' is limited by the country's specific context, countries are learning from both successful and failed actions implemented elsewhere. Examples are the Chinese emission trading system that uses experience gained with the EU ETS (European Union Emissions Trading Scheme) (Gippner, 2016), Chinese renewable energy production and policy implementation induced by policy interventions in Germany and Denmark (Höhne et al., 2017), and energy appliance labelling based on US EPA's (Environmental Protection Agency) Energy Star Program in Canada and Japan (Energy Star, n.d.).

The aim of this article's assessment is to evaluate the potential impact on global GHG emissions if all countries worldwide were to implement climate policies similar to successful examples already implemented by other countries. For this, we first made a shortlist of successful policies per sector. Second, we selected a policy that is most ambitious and potentially replicable to other countries. Third, we translated the result of these successful sector policies by assessing their historical impact on the energy- and land-use systems, and on GHG emissions. Fourth, this impact was translated into model parameters for each model region to analyse the impact in the IMAGE and GLOBIOM/G4M models. The final outcome was an estimate of global GHG emission levels, taking into account overlaps in effects between sectors. These were then compared to GHG levels implied by current policy implementation, NDC targets and the Paris Agreement's objective to keep global temperature increase well below 2°C.

We focus on the potential GHG impact of 'policy transfer'. The 'what-if' analysis does not account for local contextual conditions, as for example was done by Bataille, Waisman, Colombier, Segafredo, and Williams (2016); they explicitly took into account national technical, social and economic priorities and circumstances. In this analysis, we assume that countries can learn from each other, and that countries implement policy instruments (e.g. feed-in-tariff) adjusted to their national circumstances to achieve the implied policy targets. The main contribution of this article is an integrated assessment model analysis of GHG reductions from replicating policy impact of ambitious sector policies that have demonstrated successful implementation. Historically, countries have often implemented policies that are (somewhat) different from the cost-optimal mix (Trutnevyte, 2016).

A few studies have earlier looked into the question of what the impact on GHG emissions could be if countries were to learn from others while implementing reductions beyond current policies or NDCs. Den Elzen et al. (2015) argue that enhanced policies implemented in 13 major emitting countries/regions could reduce emissions by 6.1 $GtCO_2e$ in 2030 relative to a 'current policies' scenario. Sitra (2015), based on Ecofys (2015), assessed 17 'success stories', and showed that upscaling could result in 12 $GtCO_2e$ reductions annually by 2030 relative to a baseline based on current policies and trends. Kuramochi et al. (2018) turn it around and determine policy benchmarks for the short term if the Paris Agreement temperature limit is to be met.

Our study is more comprehensive in the coverage of policy areas and enhanced mitigation measures compared to Den Elzen et al. (2015). We go beyond the work of Sitra (2015) by using an integrated assessment model that enables dynamic, internally consistent and simultaneous assessment of both energy supply and demand sectors. Such a model allows us to correct for possible overlaps between the different policies, for instance policies that at the same time promote renewable energy technology in power supply and reduce electricity demand in end-use sectors.

This article is structured as follows. In Section 2, we discuss the overall methodology and present the successful policies per sector that have been selected. In this section we also discuss how the policies have been represented in the IMAGE and GLOBIOM/G4M models. In Section 3, we present the results relative to GHG emission pathways of current implemented policies and NDCs, and in accordance with the 2°C limit. Finally, in Section 4, we provide a discussion and the conclusions.

2. Methodology

2.1. Model and scenario design

The emission pathways for the energy and industry sectors in our study were estimated using the energy model TIMER. This model forms part of the integrated assessment model IMAGE 3.0 (Stehfest, Van Vuuren, Bouwman, Kram, & Prins, 2014). It describes future energy demand and supply for 26 global regions and is able to assess the implications of energy system trends for all major GHGs and air pollutants. The TIMER model is well suited for a policy impact assessment at sector level, given its relatively high degree of detail for an integrated assessment model. It represents the activity levels in the different sectors in terms of physical indicators (e.g. transport demand or steel production), allowing for a rather straightforward interpretation of the policies implemented. This model simulates long-term energy baseline and mitigation scenarios (Van Vuuren et al., 2014) on the global and regional levels. The investments into different energy technologies are calculated by a multinomial logit function that accounts for relative differences in costs and preferences (technologies with lower costs gain larger market shares). The model is build up from different modules, including energy demand modules for transport, industry, buildings and modules for energy supply, industrial processes and emissions. The policy instrument often used in TIMER is a carbon tax, which often represents a generic policy effort. It is, however, possible to implement other policy instruments, such as fuel efficiency standards, by setting, and thus regulating, the efficiency of new cars sold.

For estimating the impact of policies on land use and land-use change and forestry (LULUCF) emissions and removals, the Global Forest Model (G4M) was used in conjunction with the Global Biosphere Management Model (GLOBIOM) framework. The G4M (Gusti, 2010; Kindermann et al., 2008) model was used to estimate the impact of forestry activities (afforestation, deforestation and forest management) on biomass and carbon stocks. The model itself estimates forest area change, carbon sequestration and emissions from forests, impacts of carbon incentives (e.g. avoided deforestation) and supply of biomass for energy and non-energy uses. For this work, the G4M was linked to GLOBIOM outputs to provide projections for the forest sector consistent with the development of other land use categories. GLOBIOM (Havlík et al., 2011, 2014) itself is a partial equilibrium model with detailed sector coverage, detailed representation of production technologies, and geographically explicit representation of land use and associated GHG emissions.

As a starting point for the calculations, the SSP2 scenario (Riahi et al., 2017) was used as baseline in the models (IMAGE/GLOBIOM/G4M). SSP2 describes a middle-of-the-road scenario in terms of economic and population growth and other long-term trends such as technology development. The main drivers of this scenario for the energy and industry sectors are: population, gross domestic product (GDP), lifestyle and technology change (Van Vuuren et al., 2017), and for the LULUCF sector: agricultural productivity, bioenergy and wood demand (Fricko et al., 2017). The current policies scenario used in this assessment takes into account climate policies that are implemented in 25 major emitting countries based on the IMAGE/GLOBIOM/G4M calculations (Kuramochi et al., 2016). The result of our assessment is modelled in a scenario called the ‘good practice policies scenario’. This scenario was implemented by changing model input parameters to achieve the policy impacts (see Table 2). The ‘good practice’ feature is applied to policies that have proven themselves in one or several countries, and have significantly decreased GHG emissions there, or led to a significant change in other GHG-relevant metrics.

2.2. Overall methodology

The assessment consisted of four steps, which are further elaborated below and with more detail in the Supplementary Information:

(1) A shortlist of successful policies was identified for nine major emitting sectors.
(2) For each sector, we selected the most successful policy based on historical trends of a sector-specific indicator. Policies that could clearly not be translated to other regions (e.g. because they depend on a large hydropower potential) were excluded.
(3) For each policy we determined the impact, based on the historical performance of the sector indicator, and translated them to suitable parameters for input to the models.
(4) Subsequently, the policy impacts were replicated for the period 2015 to 2030 for all regions using the IMAGE energy model and for the period 2010 to 2030 for the GLOBIOM/G4M land use models.

In our selection of policies, we focussed on the following sectors: electricity generation, oil and gas production, industry energy use, fluorinated gases (F-gases), residential buildings, passenger car use and LULUCF. These sectors covered around 65% of global GHG emissions in 2010. The selection was done by first compiling a shortlist of successful policies from the Climate Policy Database (NewClimate Institute, 2015), literature sources (Den Elzen et al., 2015; Forsell et al., 2016; Healy et al., 2016; Höhne, Fekete, Kuramochi, Iacobuta, & Prinz, 2015) and technical papers from the UNFCCC on mitigation benefits of actions, and initiatives and options to enhance mitigation ambition (UNFCCC, 2013, 2014). To our knowledge, these sources together include the vast majority of currently implemented policies that can be modelled by IMAGE. This resulted in a shortlist of sector policies that have proved successful in some countries. Then, for each sector, the most successful policy was selected on the basis of the historical performance of a sector specific indicator (see Table 1 and Supplementary Information).

The historical performance of the policy was used to determine impact at the sector level (see Table 1 and Supplementary Information), which was then replicated through setting specific model parameters at the regional level in the IMAGE and GLOBIOM/G4M model for the period 2015 to 2030. This resulted in a level of GHG emissions, assuming that these impacts based on successful policies were implemented everywhere. This approach, based on proven success, is more realistic than many deep mitigation scenarios normally explored in models that tend toward the goal of minimizing the aggregate economic costs of achieving mitigation outcomes (Clarke et al., 2014).

As an example, the electricity sector shortlist consisted of policies from Costa Rica, Denmark, Dominican Republic, Germany, Morocco, Tuvalu, the UK and Uruguay. For each country, we calculated performance using increase in the share of renewables as the sector indicator (based on International Energy Agency (IEA) data, see Supplementary Information). Some countries were found to have performed well, but under particularly favourable conditions, which would be difficult to replicate in other countries. Such conditions, are for example, mountain regions for installing hydropower technologies (e.g. Uruguay) or large availability of grid connections with neighbouring countries (Denmark). The UK implemented a renewable obligation support scheme, obliging electricity suppliers to generate a portion of the electricity from renewables, and Germany implemented a feed-in-tariff. They showed on average a 1.35%-points annual increase in the renewable electricity share over the period 2004–2012. As these two countries' renewable energy policies were demonstrably successful and were the only ones remaining on the shortlist, their policies were selected. The annual increase of 1.35% points was used to represent the policy impact, which was replicated for all regions in the TIMER model by setting a floor on the minimum renewable share in electricity between 2015 and 2030 (see Table 1). Using this floor as a constraint, the mix of energy carriers for electricity production in the model was calculated using a multinomial logit function, that gives the highest weight to the cheapest option (see Table 2). In our model calculations, we assume that successfully integrating renewable energy or adding storage capacity is possible, based on the evidence that it has already been achieved by some countries (IRENA, 2017).

A short description of model implementation for each policy area can be found in Table 2. A more detailed description of all successful policies per sector, together with how policy impact was determined, can be found in the Supplementary Material.

It should be noted that this method does not allow for tailoring these replicated policies to country or region-specific circumstances. It merely shows by how much global GHG emissions could be reduced by scaling up trends from selected policies that have worked in specific countries. In addition, we do not account for rebound effect that might results from implementing efficiency policies. This approach does constrain

Table 1. Overview of the nine selected good practice policy actions with corresponding country policy instrument and translation to policy impact.

Main sector	Policy action	Successful policy instrument	Policy impact
Energy supply	Increase renewables in electricity production	Renewable portfolio standard, feed-in-tariff in the UK and Germany	+1.35% points growth in share of renewable electricity generation per year
	Reduce flaring and venting in oil and gas production	Regulation and carbon tax in Norway	4.4% annual reduction of oil/gas intensity ($ktCO_2e$/Mtoe) until 2030
Industry	Enhance energy efficiency of industrial production	Energy agreements in Ireland	1% annual energy savings improvement above current efforts until 2030
	Reduce fluorinated emissions	North American Proposal to the Montreal protocol	70% reductions of F-gas emissions below 2010 levels by 2030
Buildings	Enhance efficiency of residential building envelope	EU regulation	Energy intensity of 0 kWh/m^2 by 2030 (space heating)
	Set efficiency standards for appliances and lighting	Appliance standards in EU countries	Average efficiency improvement of 1.8% per year until 2030
Transport	Improve fuel efficiency of cars	Fuel economy standard in the EU	Fuel economy standard of 26 km/l in 2030
	Increase number of electric cars (charged with renewable electricity)	Tax levies and investments in infrastructure in Norway	25% share of new electric vehicles in 2020, 50% in 2030
LULUCF	Reduce deforestation	Regulations and enforcements in Brazil	Decreasing deforestation rate relative to 2010 by 22% in 2020, 44% in 2030.

Table 2. Description of policy impact implementation in TIMER and GLOBIOM/G4M models for the period 2015 to 2030.

Policy impact	Model implementation
1.35% growth in share of renewable generation per year	First the share of technologies used for electricity production is determined in the usual way (multinomial logit function). Then, if the annual increase would reach a renewable share higher than the current policies scenario, the ratio of renewable to fossil technologies is increased until the total renewable share is reached, keeping the ratio between the renewable technologies, and also between the non-renewable technologies, the same.
4.4% annual reduction of oil/gas production intensity ($ktCO_2e$/Mtoe) until 2030	It is assumed that the level of oil and gas production for each region remains the same as in the current policies scenario. As this is an end of pipe measure, additional flaring/venting measures are implemented that decrease GHG emissions to the level that would achieve the annual reduction target of the oil/gas emission intensity. The current oil/gas intensity target of Norway (10 Mtoe/$ktCO_2e$, based on IEA and UNFCCC data) is used as an absolute floor.
1% annual industrial energy savings improvement above current efforts until 2030	The energy efficiency improvement for the cement, steel and other industry sector is fixed at a level of 1% annual improvement above the current policies scenario. This improvement is accomplished through individual technologies, that differ between the different industry sectors (cement, steel, other).
70% reductions of F-gas emissions below 2010 levels by 2030	A carbon tax on F-gas emissions per region is set at a level, that would achieve the reductions as prescribed by the Kigali Amendment.
Average efficiency improvement of 1.8% per year until 2030 in appliances	The price-induced efficiency per unit energy of consumption for appliances (refrigerator, microwave, washing machine, clothes dryer, dish washer, TV, DVD/VCR, PC) is fixed at 1.8% per year additional to the current policies scenario.
Energy intensity of 0 kWh/m^2 by 2030 in residential buildings	Useful heating efficiency (input parameter in terms of MJ/m2/HDD) is set to zero for new residential buildings by 2030, and interpolated between 2015 and 2030. This induces use of different heating technologies and increased insulation and assumes used electricity is 100% renewable.
Fuel economy standard of 26 km/l in 2030 for new passenger cars	The fuel efficiency of new cars is an input parameter and is fixed for the year 2030 and interpolated between the target year of the already implemented corporate average economy standard and 2030, and capped by the current policies scenario efficiency. Non-fuel costs of cars are changed accordingly.
25% share of new electric vehicles in 2030 (from renewable electricity)	First the share of each car type (diesel, biofuel, electric etc.) is determined in the usual way (multinomial logit function). Then the share of electric cars is increased to meet the target level. The remaining share of each remaining car type is decreased, keeping the ratio between these car types the same. Renewable electricity is increased with the same level as electricity use in the transport sector.
Decreasing deforestation rate relative to 2010 by 22% in 2020, 44% in 2030	A carbon tax for deforestation and afforestation activities is set in G4M to the level that equals the annual reduction of the deforestation rate for each country.

implementation to the technological potential of countries, as this is endogenous to the model. However, it does not account for obstacles to effective implementation, such as the need for significant subsidies, the challenges of renewable electricity integration and immature technologies (e.g. carbon capture and storage) (Mathy, Criqui, Knoop, Fischedick, & Samadi, 2016). In order to account for national technical, social and economic priorities and circumstances, more bottom-up pathways are necessary (Bataille et al., 2016). Although some policies, such as fuel efficiency standards, have already been implemented in many countries others need more careful consideration before implementing them worldwide. Therefore, our approach must be seen as a simplified one, which could be used as a starting point for countries to increase ambition. It stimulates countries to learn from successful policy implementation by others, and possibly improve or adjust policies to local circumstances (see Discussion for more details).

3. Impact on GHG emissions

3.1. Global impact on GHG emissions and sectors

The good practice policies scenario was projected to result in global GHG emissions, including LULUCF, just above 2010 levels by 2030. In this scenario, emissions at first increased to 52.3 $GtCO_2e$ in 2020 (about 8% above 2010 levels), and then decreased to 49.6 $GtCO_2e$ by 2030 (2% above 2010 levels). Figure 1 shows each policy's impact on GHG emissions, compared to the current policies scenario (GHG emissions in 2030 are 59.7 $GtCO_2e$), and their collective impact on narrowing the global emission gap for meeting 2°C. Around 35% of emissions in 2010 were emitted in sectors that were not covered by the selected policies (see Methodology). Total primary energy supply (TPES) by 2030 in the good practice policies scenario decreases by 10% relative to the current policies scenario and electricity production decreases by 3%; the renewable share in TPES increases from 11% to 16%. If the impact of individually implemented policy targets are added together, and overlap in implementing different policy targets is therefore omitted, the GHG impact would be 0.6 $GtCO_2e$ larger. This shows that using an integrated assessment model to evaluate GHG impacts avoids overestimating the effect of the individual policy targets in the good practice policies scenario.

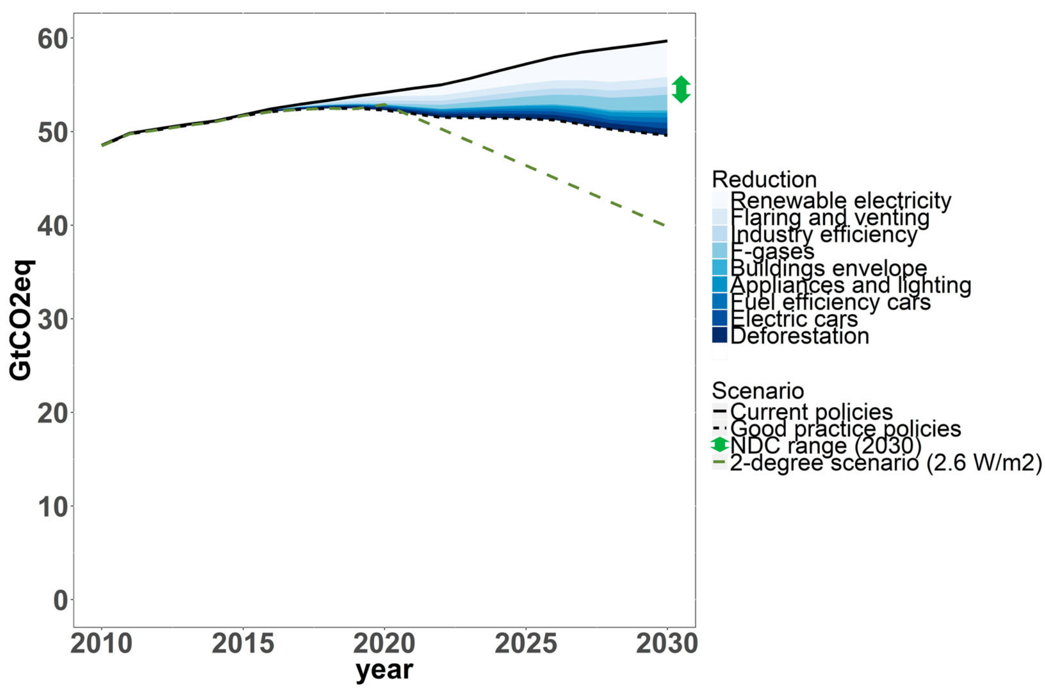

Figure 1. GHG emission levels (including LULUCF) as a result of implementing the selected nine good practice policies together. The emission levels are compared to global emissions resulting from the full implementation of the NDCs based on den Elzen et al. (2016) (arrow), and global GHG emission levels consistent with meeting 2°C with probability of at least 66% (Van Vuuren et al., 2017).

Figure 1 shows the global emission reductions in the good practice policy scenario for all policy areas, and compares the results corrected for overlap to the impact from individual implementation in the table at the bottom (individual policies). The single largest impact on global emissions compared to the current policies scenario comes from increasing renewable electricity in the 'electricity supply' sector. Other sectors with significant emission cuts are the reduction of F-gases, reduced flaring and venting in the oil and gas production sector, and improved energy efficiency in the industry sector.

The results are compared with NDC and 2°C pathways from the IMAGE model. The global implementation of the good practice policies scenario goes beyond the impact of NDC implementation, which is projected by den Elzen et al. (2016) to be in the range of 53.4 to 55.9 $GtCO_2e$. In addition, the emissions gap in 2030 with the cost-effective 2°C least-cost pathway from IMAGE,[1] is projected to narrow from 19.8 $GtCO_2e$ in the current policies scenario, to 9.7 $GtCO_2e$ in the good practice policies scenario.

3.2. Sector results

The results of the good practice policies scenario per sector are shown in Figure 2, in terms of sector indicator projections. Some efficiency indicators are presented in terms of GDP and population, and not in terms of physical units (e.g. tonnes of produced material), as these do not allow for comparison across different industrial or residential processes (Patterson, 1996). The impacts on GHG emissions presented in this section are based on individual implementation of each (sector) policy action.

Scaling up the impact of successful renewable energy policies in the electricity supply sector was projected to increase the renewable share by 2030 from 30% in the current policies scenario to 45% in the good practice policies scenario (see Figure 2a). Implementation on a global scale was projected to reduce emissions by 4.0 $GtCO_2e$ by 2030. This projection is just below the mitigation potential indicated in the United Nations Environment Programme (UNEP) Emissions Gap Report 2014 (UNEP, 2014) of 5 $GtCO_2e$, but is at the low end of the

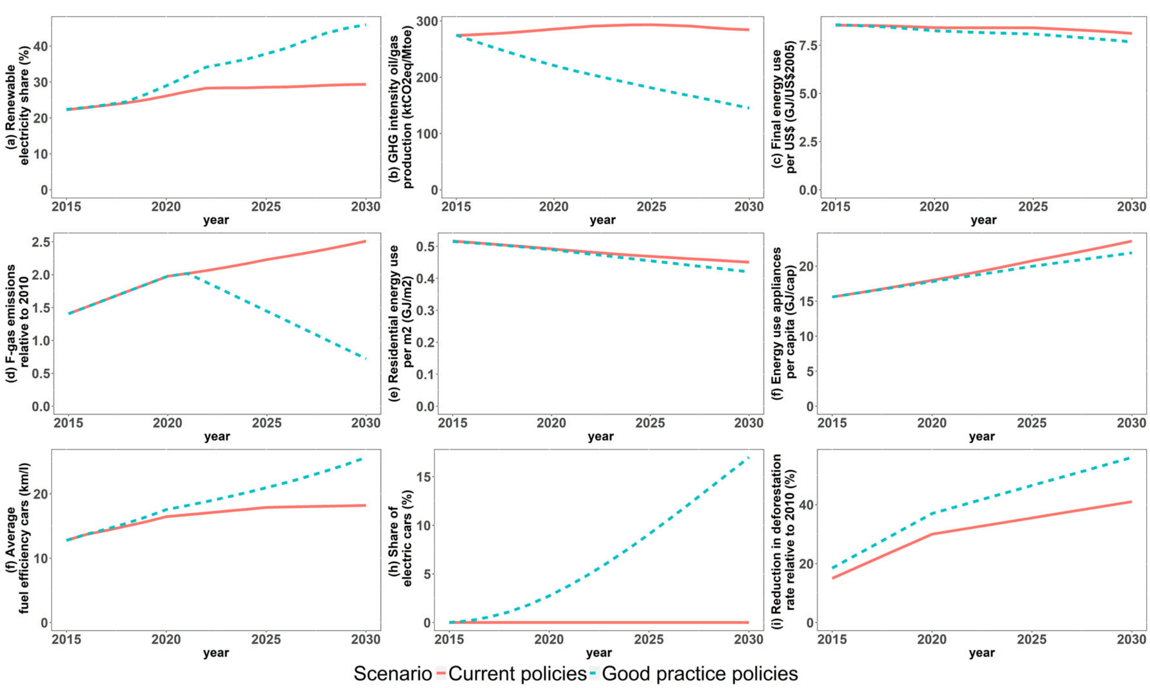

Figure 2. Sector impact indicators for a) increase renewable electricity share, b) reduce flaring and venting, c) enhance energy efficiency in industry, d) reduce F-gas emissions, e) enhance energy efficiency of building envelope, f) improve efficiency of appliances and lighting, g) improve fuel efficiency of cars, h) support electric cars charged with renewable electricity, i) reduce deforestation (starting in 2010).

potential in the 2°C scenario from the 'Decarbonising development' report (World Bank, 2015) and the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (Working Group III) (2014). These reports indicate a 30% renewable electricity share by 2025 and a 35% share by 2030.

Replicating the impact of Norway's policy in the oil and gas production sector was projected to decrease energy intensity in this sector from 285 ktCO_2e/toe in the current policies scenario to 115 ktCO_2e/toe by 2030 in the good practice policies scenario (see Figure 2b). This was projected to result in 1.1 GtCO_2e emission reductions by 2030 relative to the current policies scenario.

The impact of global implementation of industrial efficiency policies was estimated to slightly decrease energy intensity from 1.3 kWh/Industry Value Added (IVA) (US$(2005)) in the current policies scenario to 1.2 kWh/IVA (US$(2005)) in the good practice policies scenario (see Figure 2c). The reductions relative to current policies in terms of GHG emissions were projected at 1.0 GtCO_2e by 2030. If we compare the results for the good practice policies scenario in terms of final energy demand with the 2°C scenarios presented in the AR5 IPCC (2014) WGIII report, the final energy reductions in the industry sector relative to the current policies scenario (approximately 15%) are at the lower end of the IPCC 2°C pathways range.[2]

Implementation of the good practice F-gas reduction target on a global scale was projected to result in a decrease of global F-gas emissions by 70% relative to 2010 (see Figure 2d). This is a reduction of 1.6 GtCO_2e by 2030, relative to the current policies scenario. The projected reductions were in line with the global mitigation potential at €20/tCO_2e presented in Schwarz et al. (2011). In addition, these reductions were in line with the emission reduction in the 2°C scenario from Labat et al. (2015).

Implementation of measures to enhance the energy efficiency of new buildings in the residential sector was projected to lead to a decrease in energy consumption from (existing and new) residential buildings per square metre from 0.45 GJ/m^2 in the current policies scenario to 0.42 GJ/m^2 (see Figure 2e). As a result, GHG emissions were projected to reduce by 0.4 GtCO_2e by 2030.

Replicating the policy impact from improving appliance efficiency and lighting was projected to lead to indirect (from electricity) GHG emission reductions of 0.6 GtCO_2e by 2030, while the impact on direct (from fuels, heat) emissions was negligible. The impact of these policies on per capita electricity consumption (see Figure 2f) was small because of the relatively small size of the residential sector compared to population size.

The two presented policy areas described above are both in the residential buildings sector. The aggregated final energy reductions (in percentages) in this sector relative to the current policies scenario were somewhat below the IPCC 2°C range from Lucon et al. (2014) (AR5 WGIII report), but the latter also includes reduction measures from the commercial buildings sector.

Good practice fuel efficiency standards for cars could improve fuel efficiency of the car stock by 2030 to 25.7 km/l (see Figure 2g), from a global average of 12.8 km/l in 2015. The GHG emissions by 2030 in the good practice policies scenario were projected to reduce emissions by 0.6 GtCO_2e by 2030. Already under the current policies scenario, fuel efficiency of cars increased relative to a no-policy baseline, as many countries have implemented these standards. The projected fuel efficiencies in this study are around those of the IEA 2°C scenario (IEA, 2012) by 2030.

The share of electric cars increased to 19.5% by 2030 in the good practice policy scenario. This share was zero in the current policies scenario (see Figure 2h). The projected GHG reductions from this good practice policy was 0.7 GtCO_2e by 2030 relative to the current policies scenario.

Replicating the impact of successful policies on deforestation was projected to reduce global LULUCF emissions by 0.7 GtCO_2e in 2030 relative to the current policies scenario. Overall, the policy leads to an overall 55% reduction of the global deforestation rate by 2030 relative to 2010, while the current policies scenario lead to an overall 40% reduction of the global deforestation rate relative to 2010 (see Figure 2i). This deforestation rate is still substantially higher than the 84% reduction of the global deforestation rate by 2030 relative to 2010 in the 2°C scenario obtained from Popp et al. (2017).

4. Discussion and conclusions

We conclude that considerable emission reductions globally are possible if the impact from successful policies evaluated in this article were to be replicated in different parts of the world. This could keep global emissions by

2030 close to the level of those in 2010, and would considerably narrow, but not fully close, the emissions gap by 2030 with the 2°C pathway. The largest sector contributors to narrowing the gap based on our approach are the electricity sector, F-gases, flaring and venting in the oil and gas sector, and industry efficiency.

One question that arises from our study is to what extent policies are replicable to other countries, given different country circumstances. Policies that have been successfully implemented in some countries were the starting point of our analysis. Although our approach comes closer to what can realistically be expected from implementation of the NDCs or 2°C pathways than more theoretical, 'not-real-world-proven' assessments, we identify at least two main shortcomings. First, we do not take full account of country-specific circumstances that affect local implementation success. This could be improved by defining sector policy targets more in line with bottom-up national priorities and circumstances. More research into country needs and priorities, as for example done in Bataille et al. (2016), would support this. In addition, research into successful policies at lower aggregation levels of sectors, for example the cement and steel industry sector, would contribute to this improvement.

Second, rather than the implementation of these policies, our focus is on replicating policy impact trends and their aggregate impact on GHG emissions. For this, we use the integrated assessment model IMAGE, which does not allow for assessment of socio-economic or governance aspects. Other models and methods, which could be linked to IMAGE, would be needed to begin resolving this issue.

The policy literature may provide some valuable guidance on replicability, that is, the possibility of 'policy learning' and 'policy transfer'. Policy learning is a voluntary process where policymakers draw lessons from policy implementation in other countries, while policy transfer goes one step further and is often done in the context of (indirect) coercion, especially in the context of trade agreements, or via international institutes such as the World Bank or the International Monetary Fund (IMF) (Hadjiisky et al., 2017). Globalization and the rapid growth in communication technologies may also lead to policy convergence (Evans & Davies, 1999).

In order to work with more realistic assumptions on policy transfer, we turn to Dolowitz and Marsh (1996, 2000), who identify complexity of the policy landscape, insufficient information about policy content, lack of insight into the success of the policy, and differences between the economic, social, political and ideological contexts as barriers to policy learning and transfer that need to be taken into account for other countries. For example, with regard to the case cited in the introduction to this article, namely, ETS policy transfer from the EU to China, lessons from the EU were transparently documented and pilots were run in China 'reflecting a more Chinese style of policymaking' (Gippner, 2016). In China's nationwide ETS, which is under development, the output-based allowance allocation method 'mirrors the nature of China's national emissions target' (Jotzo et al., 2018).

In closing, the results in this article on the global impact of replicating policy impact might encourage countries to learn from others that have implemented successful policies and to actively pursue policy learning. Also, this study is a first approach towards a more bottom-up, realistic use of integrated assessment models. Further research could include more policies addressing other sector activities or (sub-) sectors, giving more opportunities for further reductions. But, at the same time, more research will be needed to further improve realistic emission pathways, by addressing specific country circumstances, accounting for implementation barriers and identifying important factors for policy learning.

Notes

1. At least 66% probability of staying below 2°C, and starting with cost-optimal implementation in 2020 from emissions levels implied by national pledges under the 2010 Cancun Agreements.
2. Although the IPCC range is presented as reduction relative to baseline, the 'current policies scenario' in our study does not include many industry policies.

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