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Greenhouse gas emission scenarios in nine key non-G20 countries: An assessment of progress toward 2030 climate targets

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ABSTRACT

This study compares greenhouse gas (GHG) emissions projections in 2030 under current policies and those under 2030 mitigation targets for nine key non-G20 countries, that collectively account for about 5 % of global total emissions today. These include the four largest non-G20 fossil CO_2 emitting Parties to the UN climate convention pre- Paris Agreement (Iran, Kazakhstan, Thailand and Ukraine) and one of the largest land-use GHG emitters in the world (Democratic Republic of the Congo). Other countries assessed include major economies in their respective regions (Chile, Colombia, Morocco and the Philippines). In addition to economy-wide GHG emissions projections, we also assessed the projected GHG emissions peak year and the progression of per capita GHG emissions up to 2030. Our GHG emissions projections are also compared with previous studies.

On economy-wide GHG emissions, Colombia, Iran, Morocco, and Ukraine were projected to likely meet or significantly overachieve their unconditional 2030 targets with existing policies, while DRC and Thailand would come very close to their targets. Kazakhstan and the Philippines would need to strengthen their action to meet their targets, while Chile recently raised its 2030 target ambition. Only Colombia and Ukraine are projected to have peaked their emissions by 2030. Per capita GHG emissions excluding land-use under current policies were projected to increase in all countries from 2010 levels by 8 % to over 40 % depending on the country. While the impact of the COVID-19 crisis on 2030 emissions is highly uncertain, our assessment on the target achievement would not change for most countries when the emission reductions estimated for 2020 in the literature were assumed to remain in 2030.

The findings of this study highlight the importance of enhanced and frequent progress-tracking of climate action of major emitters outside G20, as is currently done for G20 members, to ensure that the global collective progress will become aligned with the pathways toward Paris climate goals.

1. Introduction

Under the Paris Agreement, countries have committed to holding warming increase to well below 2 °C and pursue efforts to limit it to 1.5 °C above preindustrial levels by the end of the century (UNFCCC, 2015). To achieve this goal, global emissions must peak as soon as possible and reach net zero within the 21st century. However, post-2020 national mitigation commitments submitted as Intended Nationally Determined Contributions (INDCs) in the lead-up to the 2015 Paris climate conference are collectively insufficient to meet the temperature goal, leading to a median warming of 2.6–3.1 °C by 2100 (Rogelj et al., 2016). The global ambition and action on greenhouse gas (GHG) emissions reductions, therefore, must ramp up urgently.

Countries also agreed to improve their commitments over time and

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to update every five years their post-2020 targets, which turned from INDCs to Nationally Determined Contributions (NDCs) following the ratification of the Paris Agreement. This 'ratchet mechanism' intends to move commitments towards what is needed for the Paris Agreement. Assessment of countries' progress towards their NDCs or INDCs (hereinafter NDCs, unless mentioned for countries that have not ratified the Paris Agreement) is an essential part of the ratchet mechanism; countries on track to meet or overachieve their current NDCs are well positioned to raise their NDC ambition and countries that are not on track and show limited progress in time need to urgently strengthen their action. For this purpose, to obtain up-to-date knowledge on how countries' GHG emissions would develop in the future under existing policies is important.

Most studies published to date on countries' progress towards their NDCs or the transition towards the Paris long-term goal have focused on the assessment of major emitting economies, in particular G20 members (den Elzen et al., 2019; Roelfsema et al., 2020; UNEP, 2019). There is an urgent need to evaluate the progress of key countries outside G20 towards their NDCs and the transition required to achieve the Paris

Table 1
The non-G20 countries assessed in this study, their NDC targets and the rationale for their selection. The historical data were taken from IMF (2019) for nominal GDP, EDGAR emissions database (Olivier and Peters, 2020) for GHG emissions excluding land-use sector emissions, FAOSTAT (2019) for land-use sector GHG emissions, and U.S. Energy Information Administration (2020) fossil fuel production. NDC targets were taken from UNFCCC (2020) as of end-November 2020.

Country (UN region)	Share in global GHG emissions in 2017 (excluding/ including LULUCF)*	NDC target (target year: 2030 for all countries)		Rationale for the selection and other relevant background information
		Unconditional	Conditional	
Chile (America)	0.25 % / 0.04 %	Emissions excluding LULUCF: • 95 $MtCO_2e$/year, 2025 as peak year • Emissions budget of 1100 MtCO2e between 2020 and 2030 LULUCF emissions • 0.9 to 1.2 $MtCO_2e$/year sequestration of by 2030 through sustainable management and recovery of native forest; • 3 to 3.4 $MtCO_2e$/year sequestration through reforestation; • Reduce emissions from deforestation and land degradation of native forest by 25 % below 2001–2013 average.	Up to 45 % reduction in net GHG emissions (i.e. including LULUCF) below 2016 levels	• Second largest non-G20 economy in the region • OECD country • Revised NDC also commits to net zero GHG emissions by 2050
Colombia** (America)	0.31 % / 0.37 %	20 % GHG reduction below business-as-usual (BAU), including LULUCF (excluding net removals from natural forests)	30 % GHG reduction below BAU, including LULUCF (excluding net removals from natural forests)	• Largest non-G20 economy in the region • Major coal producer
D.R. Congo (Africa)	0.1 % / 0.41 %	N/A	17 % reduction below BAU (specified), including LULUCF	• One of the largest land-use GHG emitters in the world (Forsell et al., 2016; Pearson et al., 2017; Tubiello et al., 2020) • Fourth largest population in the region • Least developed country
Iran (Asia)	1.8 % / 1.8 %	4% below BAU (specified up to 2025), not clear about LULUCF coverage	12 % below BAU (specified up to 2025), not clear about LULUCF coverage	• Seventh largest energy and industry GHG emitter in the world and the largest non-G20 emitter • Among the ten largest oil producers, and the five largest natural gas producers in the world • Fourth largest oil reserves, second largest natural gas reserves worldwide (EIA, 2019a) • Has not ratified the Paris Agreement as of November 2020
Kazakhstan (Asia)	0.71 % / 0.67 %	15 % reduction below 1990 levels, including LULUCF	25 % reduction below 1990 levels, including LULUCF	• Third largest non-G20 energy and industry GHG emitter • Major fossil fuel producer (EIA, 2019b) (oil, gas and coal) • UNFCCC Annex I Party
Morocco (Africa)	0.17 % / 0.15 %	17 % below BAU (specified), including LULUCF	42 % below BAU (specified), including LULUCF	• Sixth largest energy and industry GHG emitter in the region after South Africa, Egypt, Algeria, Angola and Nigeria (all of which are fossil fuel producers)
The Philippines (Asia)	0.44 % / 0.30 %	N/A	70 % below BAU (not specified), including LULUCF	• The second largest population in the South-Eastern subregion after Indonesia • Expected to become the third largest GDP in the Southeast Asia subregion after Indonesia and Thailand by 2022
Thailand (Asia)	0.79 % / 0.79 %	20 % below BAU (specified), excluding LULUCF	25 % below BAU (specified), excluding LULUCF	• Second largest non-G20 energy and industry GHG emitter in Asia (after Pakistan) • Second largest non-G20 economy in the world (after Taiwan)
Ukraine (Europe)	0.55 % / 0.51 %	At least 40 % below 1990 levels, including LULUCF	N/A	• Largest GHG emitter in the Eastern Europe subregion after Russia and Poland (EU member state) • UNFCCC Annex I Party

* Authors' estimate based on FAOSTAT (2019) and Olivier and Peters (2020). For comparison the G20 economy with the lowest share in global GHG emissions is Argentina with 0.9 %/0.8 %.

** Colombia submitted its updated NDC in December 2020, which was not assessed in this article (Government of Colombia, 2020).

long-term temperature goal.

Against this backdrop, this article assesses the progress of selected key non-G20 countries towards their NDC targets. Emissions projections under current policies were modelled for nine countries: Chile, Colombia, Democratic Republic of the Congo (DRC), Iran, Kazakhstan, Morocco, the Philippines, Thailand, and Ukraine. These countries together comprised about 5% of total global GHG emissions including land use, land use-change and forestry (LULUCF) in 2017 (authors' estimate based on: FAOSTAT, 2019; Olivier and Peters, 2020). This article aims to address the following questions:

1) Are these countries on track to meet their NDC targets under currently implemented policies?
2) When are the GHG emissions expected to peak in these countries under the NDC targets and current policies?
3) How are per capita GHG emissions expected to develop towards 2030 under the NDC targets and current policies?

The emissions projections presented in this article are based on the data on historical GHG emissions and energy consumption, and implemented policies preceding the COVID-19 outbreak. To the extent possible, this article also discusses the potential impact of the COVID-19 pandemic on the emissions projections with currently available information.

2. Data and methods

2.1. Selection of countries

The non-G20 countries assessed in this study were selected based on the following criteria: (1) historical CO_2 and GHG emissions, (2) GDP, (3) availability of a quantified NDC emissions target, and (4) data availability to conduct a GHG emissions current policies scenario analysis (see Table 1 for data sources and Section 2.2.2 for details).

We selected countries from four major geographical regions, as per United Nations (UN) definition. Four countries from Asia region (Iran, Kazakhstan, Philippines, Thailand), two from Americas (Chile and Colombia), two from Africa (DRC and Morocco) and one from Europe (Ukraine). Iran, Kazakhstan, Thailand and Ukraine were the four largest fossil CO_2 emitters among the non-G20 Parties to the UNFCCC in 2014, when the first NDCs were being formulated in the lead-up to the 2015 Paris climate conference ; they also emitted similar amount or more fossil CO_2 emissions in 2019 than Argentina, a G20 country (Crippa et al., 2020). DRC is estimated to be one of the largest net landuse change (LUC) emitters in the world today; Colombia is also among the top ten (Tubiello et al., 2020). Chile, Colombia, Iran, and Thailand are among the top three non-G20 UNFCCC Parties ranked by their GDP (current prices) in their respective regions (IMF, 2020). Morocco is the fourth largest non-G20 fossil CO_2 emitter in Africa and was selected for the analysis over larger African emitters due to the data availability to conduct the scenario analysis.

2.2. Scenarios assessed and emissions projections

This study reports all GHG emissions in carbon dioxide-equivalent (CO_2e) terms using 100-year global warming potentials (GWPs) from the IPCC Fourth Assessment Report. We used historical GHG emissions data reported by national governments to the UNFCCC whenever possible such as national communications (NCs), biennial reports (BRs) for Annex I Parties and biennial update reports (BURs) for non-Annex I Parties, supplemented by other estimates (see S1 in Supporting Online Material (SOM) for details).

2.2.1. NDC scenario

Under the NDC scenario, countries are assumed to meet their NDC targets submitted to the UNFCCC as of November 2020 (Table 2). For the quantification of NDC target emission levels, we follow the approach of den Elzen et al. (2019); see S2 in SOM for details. We used the absolute emission levels reported to the UNFCCC by the national governments where available including NDCs and INDC documents as well as other

Table 2
Sources of baseline scenarios taken from national governments and international organisations used as the basis to develop current policies scenario projections for energy and industry GHG emissions. * denote the projections on energy-related CO_2 emissions.

Country	Source of external scenarios used for constructing current policies scenario projections	Additional policy impact calculations	Other sources reviewed
Chile	MAPS Chile (Ministry of the Environment of Chile, 2014), National Mitigation Plan's current implemented policies scenario (Ministry of Energy of Chile, 2017a)	Electromobility strategy, coal-fired power plant phase-out plan (first phase)	APERC (2019); Keramidas et al. (2020)
Colombia	Third National Communication (IDEAM et al., 2017)	Several measures with high likelihood of implementation assessed by (Universidad de los Andes, 2016)	Nieves et al. (2019); Clarke et al. (2016)
D.R. Congo	Extrapolation of historical trends* and Stiebert (2013)*, US EPA (2019) for non-CO_2 GHGs	None	Comparable studies not available
Iran	PRIMAP estimate for 2010–2017 (Gütschow et al., 2019), extrapolation of historical trends (2013–2017) up to 2030 (lower bound) and an extrapolation of the 2025 mitigation scenario up to 2030 in the Third National Communication (upper bound) (National Climate Change Office of Iran, 2017)	None	Yetano Roche et al. (2018); Moshiri and Lechtenböhmer (2015); Keramidas et al. (2020)
Kazakhstan	Third Biennial Report (Ministry of Energy of the Republic of Kazakhstan, 2017)	(GDP and emission elasticity adjustment)	Kerimray et al. (Kerimray et al., 2018)
Morocco	Third National Communication (Government of Morocco, 2016)	Inclusion of several measures listed in the 1st and 2nd Biennial Update Reports that have been implemented to date	Comparable studies not available
The Philippines	APERC (2019)*, US EPA (2019) for non-CO_2 GHGs	None	Cayamanda et al. (2017); Mondal et al. (2018)
Thailand	APERC (2019)*, U.S.EPA (2019) for non-CO_2 GHGs	Partial implementation of the Alternative Energy Development Plan (2015−36), specifically on renewable energy generation based on projections (in absolute terms) from IRENA (2017)	IRENA (2017); Chaichaloempreecha et al. (2019); Misila et al. (2017); Keramidas et al. (2020)
Ukraine	6th National Communication (Government of Ukraine, 2013)	(GDP and emission elasticity adjustment)	Long-term strategy (Ministry of Ecology and Natural Resources of Ukraine, 2017) Chepeliev et al. (2018)

UNFCCC submissions described above. Otherwise, the emission levels are calculated from base-year or business-as-usual (BAU) emissions projections data based on the aforementioned documents.

Some countries have submitted NDCs that are conditional on a range of factors, including ambitious action from other countries or provision of international finance and technical support (UNEP, 2020). This article distinguishes conditional NDCs from unconditional NDCs.

2.2.2. Current policies scenario

The current policies scenario projections assume that main climate and energy policies in place as of a certain cut-off date are fully implemented (den Elzen et al., 2019). Quantified policies include legislative decisions, executive orders (e.g. in case of the United States) and their equivalent (den Elzen et al., 2019). We did not quantify the impacts of publicly announced plans or strategies, unless they are supported by specific policy instruments.

The cut-off date for the policy information collection was end-2019, unless otherwise noted. We selected policies that were considered for emissions projections primarily based on literature research. Information sources include documents submitted by the Parties to the UNFCCC (2019d, 2019b) and other government documents. Secondary sources include publications and databases from international organisations (e.g. Asia Pacific Energy Research Centre (APERC, 2019), International Energy Agency (IEA, 2019)) and independent think tanks (Grantham Research Institute and Sabin Center, 2019; NewClimate Institute, 2019).

GHG emissions projections were developed separately for LUCUCF emissions and energy- and industrial process-related emissions. General description of the methodology for developing emissions projections can be found in Fekete et al. (2021).

LULUCF sector emissions were projected using IIASA's global land-use model GLOBIOM (Havlík et al., 2014) and the G4M global forest model (Gusti, 2010). To ensure consistency between model scenarios, the SSP2 baseline was selected as the starting point for the calculations by GLOBIOM and G4M (Fricko et al., 2017). SOM (S3) describes the tools, including the description of quantification of policy impact per policy type in detail (Fekete et al., 2021).

Energy- and industrial process-related GHG emissions projections were developed by using external sector-level reference emissions projections as the basis where available, with additional bottom-up policy impact calculations (Table 2). The sources for external scenarios include the national government submission to the UNFCCC (NCs, BRs and BURs) and international organisations and think tanks (e.g. APERC, 2019) as well as other governmental institutions for sector and GHG-specific projections (US EPA, 2019) (Table 2).

When a recently implemented policy and its expected mitigation impact was not covered in these external scenarios, the impact of that policy was added by e.g. recalculating the sector-level energy balances and emissions projected by the external scenario projections (Table 2). We also recalculated external scenario projections when the literature indicated an under- or overestimation of a deployment of certain technologies (e.g. renewable energy).

In the case of Kazakhstan and Ukraine, the baseline scenario projections from the literature (i.e. national government submissions to the UNFCCC) were found to assume higher future GDP growth rates compared to those from international institutions such as the World Bank or IMF and higher elasticity of emissions to GDP compared to historical trends. For future GDP growth rates, we replaced the values used in the original baseline scenarios with the most up-to-date projections by the World Bank and IMF. For the elasticity of emissions to GDP, we used the historically observed values; the resulting emissions projections can be considered as an extension of past trends without explicit consideration of the impact of existing policies. These projections were complemented by the projections using the IMAGE integrated assessment modelling framework (Stehfest et al., 2014) (see S4 in SOM for details).

We cross-checked our current policies scenario projections against others published in recent years (presented in last column of Table 2) whenever available. SOM (S5) provides an overview of policies considered in the assessment as well as country-specific notes on the development of current policies scenario projections.

The ranges presented for current policies scenario projections are entirely attributable to the projections for energy and industry GHG emissions. For Kazakhstan and Ukraine, they reflect projections from two different modelling approaches described above; for other countries, they reflect uncertainties on the potential impact of adopted and implemented policies (Chile, Morocco, Thailand) as well as on macro-

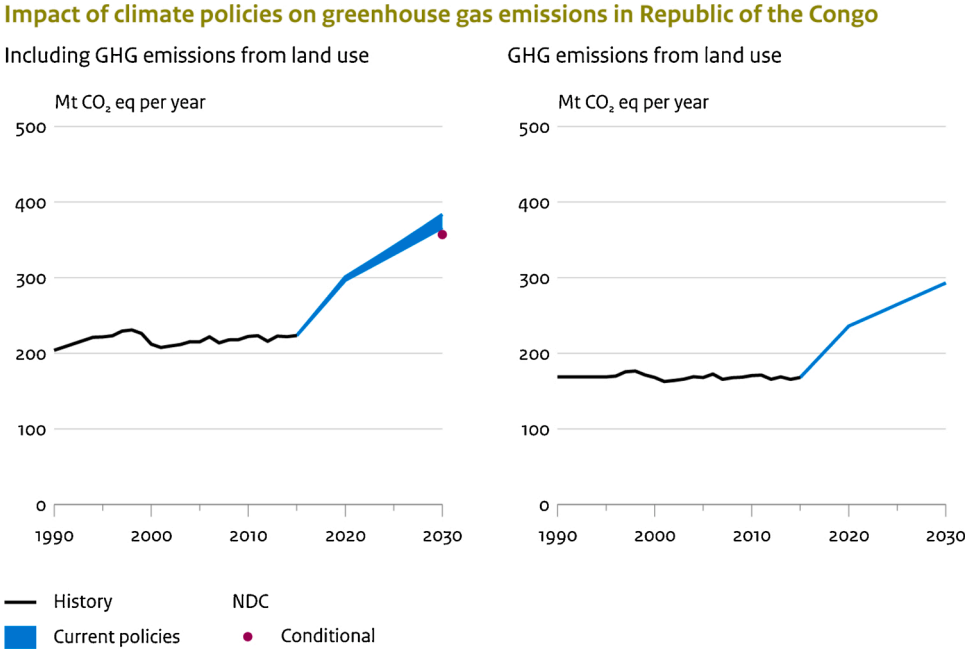

Fig. 1. Impact of climate policies on greenhouse gas emissions (left panel: all gases and sectors, and right panel: only land use (i.e. LULUCF)) in the Democratic Republic of the Congo.

economic assumptions with consideration of historical trends (DRC, Iran).

3. Results

3.1. Five major emitting countries

Our analysis finds that four of the five non-G20 emitters are projected to meet, or come close to, their NDC targets with existing policies: DRC, Iran, Thailand and Ukraine. Kazakhstan is the only country projected to clearly miss its NDC target under the current policies scenario.

3.1.1. Democratic Republic of the Congo (DRC)

DRC's NDC document estimated that around 80 % or 200 $MtCO_2e$ of the nation's annual GHG emissions are from the LULUCF sector in 2010, which is consistent with FAOSTAT (2019) used in this study. The most recent FAO estimates, however, indicate that the net emissions from forest land and net forest conversion could be as high as 600 $MtCO_2e$/year (Tubiello et al., 2020), possibly bringing DRC among the top three largest LUC emitters in the world. However, there is a high level of uncertainty related to land use emissions for DRC given that historical estimates vary from 200 to 600 $MtCO_2e$/year. Under its NDC, DRC's GHG emissions including LULUCF would increase by 94 % from 2010 levels by 2030. More than 95 % of energy supply in the DRC in 2018 was from biofuels and waste (IEA, 2020c).

In 2015, DRC introduced main policies related to the LULUCF sector to protect forest domains, promote sustainable timber management, afforestation and reforestation (COMIFAC, 2014). In 2016, a national strategy for community forest was also developed to safeguard the rights of the local people and consequently to better protect forests in the DRC (Government of the Democratic Republic of the Congo, 2016). According to the Government of the DRC (2016), this plan called for an "experimental phase" over the next five years (i.e. into 2021) to provide gradual access to an estimated area of 700,000 km^2. Community management of forests in DRC has the potential to reduce deforestation and improve the livelihood for rural communities, but its impact is still uncertain and is therefore not accounted for in our projections (Vermeulen and Karsenty, 2017).

Our analysis projects that DRC's GHG emissions under current policies in 2030 will likely come close to, but miss its conditional NDC targets (Fig. 1). LULUCF emissions are still expected to increase over time, mainly related to increase in emissions from deforestation related to the increase in cassava cultivation area and the expansion of palm oil (Mosnier et al., 2017). The country is still in its early phase of climate policy implementation; we have not identified any significant policy implemented in non-LULUCF sectors in recent years.

3.1.2. Iran

Iran is not only the largest non-G20 GHG emitter but also the largest emitter that has not ratified the Paris Agreement. It is also one of the world's main fossil fuel producers; it holds the world's second and fourth largest reserves of natural gas and oil, respectively (EIA, 2019). Limited access to international support on finance and technology due strict international economic sanctions as well as the nation's strong economic dependence on subsidised fossil fuels have hindered the nation from shifting towards a sustainable energy system (Ghadaksaz and Saboohi, 2020).

The Sixth Development Plan for 2017–2021 (Government of Iran, 2016) is Iran's main economy-wide policy strategy that includes measures to reduce GHG emissions. The plan aims for a minimum of 5 % or 5 GW of renewable energy in total installed power capacity (excluding large hydropower) by 2021. Current levels of installed renewable power capacity, however, remain low in view of this objective: by May 2019, Iran had 720 MW of installed renewable energy capacity, mostly from wind and solar (SATBA, 2019). Other 2021 targets in the Sixth Development Plan include decreasing gas flaring by at least 90 %, reducing the energy consumption in buildings by 5%, restricting vehicles not complying to the Euro 4 standard, increasing the share of railway transport, and promoting energy efficiency across various sectors.

Our analysis projects that Iran will overachieve both its unconditional and conditional INDC targets with existing policies (Fig. 2). The 2030 emissions under current policies are projected to be 22 %–37 % lower than the unconditional INDC target. The literature on Iran's GHG emissions projections in relation to NDCs is inconclusive: one the one hand, a detailed bottom-up potential assessment indicated that a 40 % reduction below a BAU could be achieved by 2030 with energy

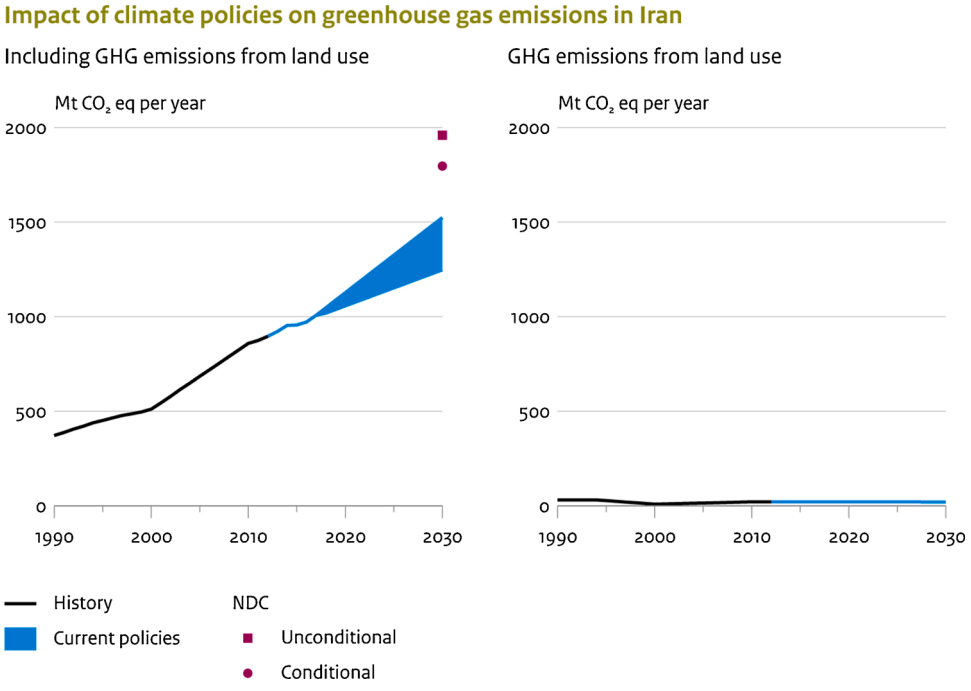

Fig. 2. Impact of climate policies on greenhouse gas emissions (CO_2, CH4 and N2O) including land use (i.e. LULUCF) in Iran.

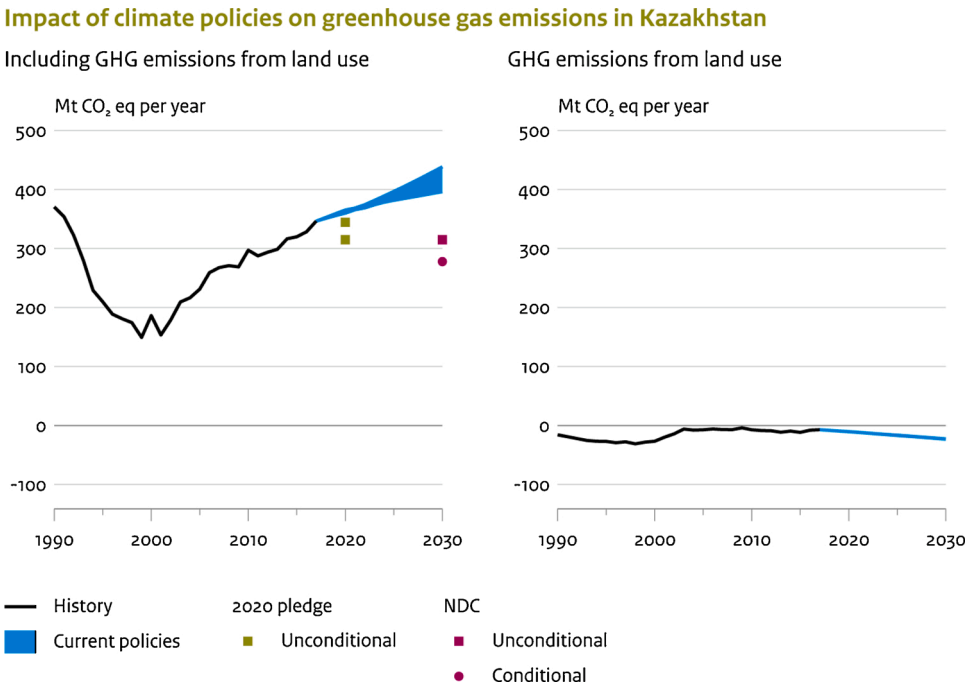

Fig. 3. Impact of climate policies on greenhouse gas emissions in Kazakhstan (left panel: all gases, including land use (i.e. LULUCF), right panel: only land use GHG emissions).

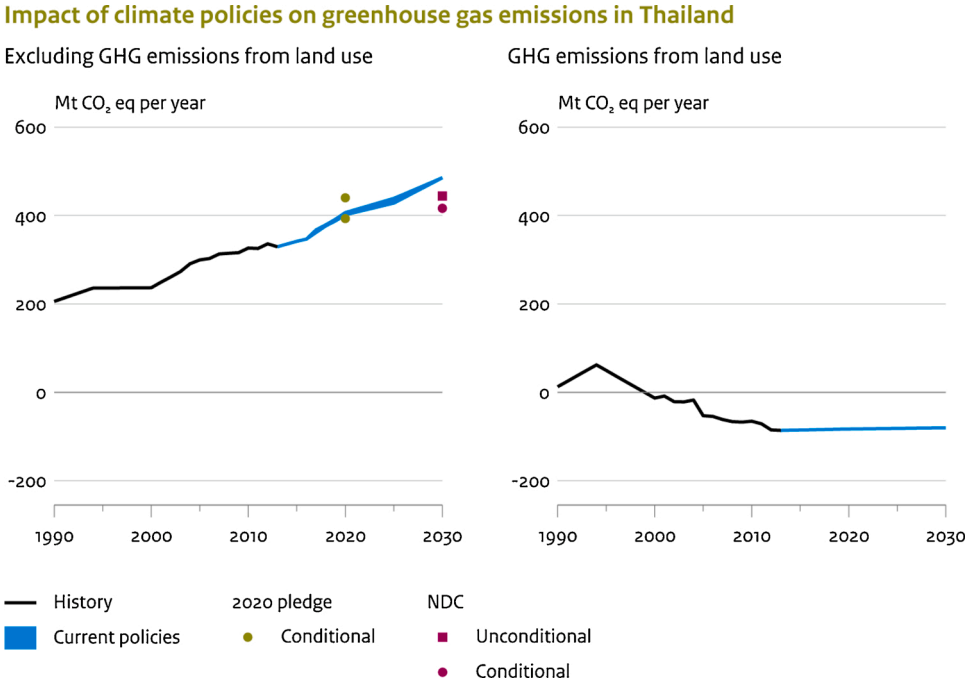

Fig. 4. Impact of climate policies on greenhouse gas emissions in Thailand (left: excluding land use (i.e. LULUCF), right: only land use).

efficiency measures alone and up to 50 % when combined with renewable energy measures (Moshiri and Lechtenböhmer, 2015). On the other hand, Keramidas et al. (2020) projected that Iran is roughly on track to meet its unconditional NDC target, which is estimated to be below 1000 $MtCO_2e$/year; the difference against our assessment can partly be explained by the different estimates on BAU emission levels and the historical emissions after 2010. Ghadaksaz and Saboohi (2020) showed that increasing the efficiency of fossil-fuelled power plants to 46 %, in addition to curbing routine gas flaring by 2030, could lead to a 6.8 % reduction below a scenario similar to BAU and meeting the unconditional NDC target.

3.1.3. *Kazakhstan*

Kazakhstan is one of the Annex I Parties to the UNFCCC. The nation's GHG emissions have plummeted by more than 50 % between 1990 and 2000, after the dissolution of the Soviet Union in 1991, but since then the emissions are steadily growing again, driven by economic growth. Kazakhstan's economy heavily relies on oil and gas industry (IEA, 2020a); about 15 % of the nation's total GHG emissions (excluding LULUCF) in 2017 were attributable to energy use and fugitive emissions

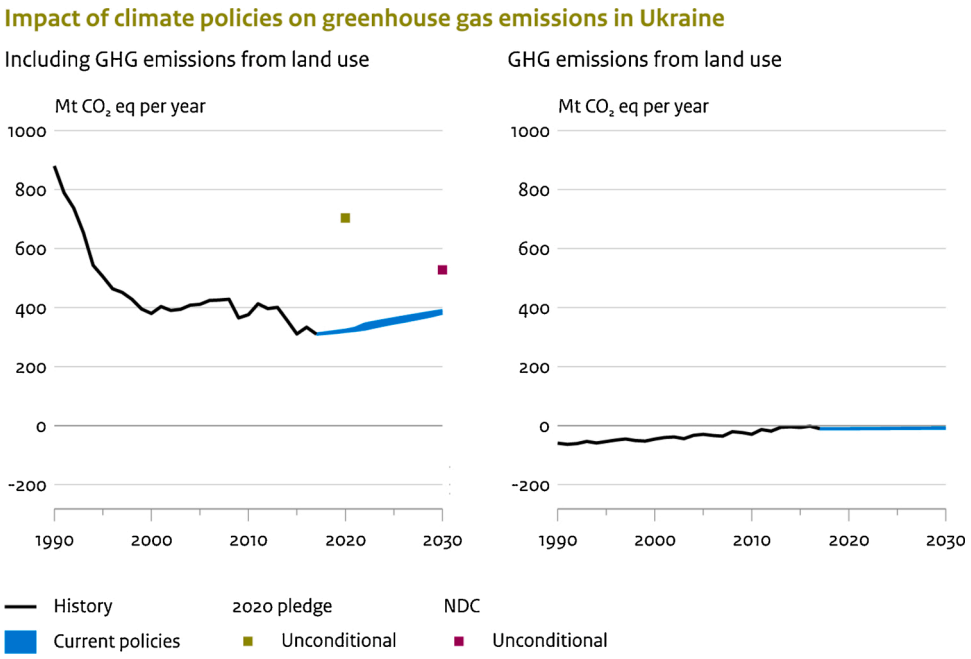

Fig. 5. Impact of climate policies on greenhouse gas emissions in Ukraine (left panel: all gases and sectors, right panel: land use (i.e. LULUCF) emissions and removals only).

related to fossil fuel extraction (UNFCCC, 2019c).

Kazakhstan is projected to likely miss its NDC target with existing policies (Fig. 3). The projected GHG emission levels for 2030 under our current policies scenario relative to unconditional and conditional NDC scenario emission levels are comparable to those under a BAU scenario assessed for GHG emissions from fossil fuel combustion in Kerimray et al. (2018). Kazakhstan is one of the few non-OECD countries alongside China that have nation-wide emissions trading scheme implemented or scheduled for implementation (ICAP, 2020a; World Bank Group, 2020). Even though the scheme was launched back in 2013, it is not fully functional yet to deliver tangible emissions reductions (ICAP, 2020b).

3.1.4. *Thailand*

The main policy strategies related to GHG emissions in Thailand include the Alternative Energy Development Plan (AEDP), Energy Efficiency Plan (EEP), Gas Plan, Oil Plan and the Power Development Plan (PDP). A new PDP for period 2018–2037 was adopted in 2019 (updated in 2020 as rev.1) (Ministry of Energy of Thailand, 2020; Thailand Board of Investment, 2020). Excluding targeted hydro power imports and demand reductions through energy efficiency, PDP2018–2037 foresees for 2037 a 14 % share of coal in total domestic generation, 62 % gas, and 24 % domestic renewables, respectively.

Our analysis projects that Thailand's emissions in 2030 are projected

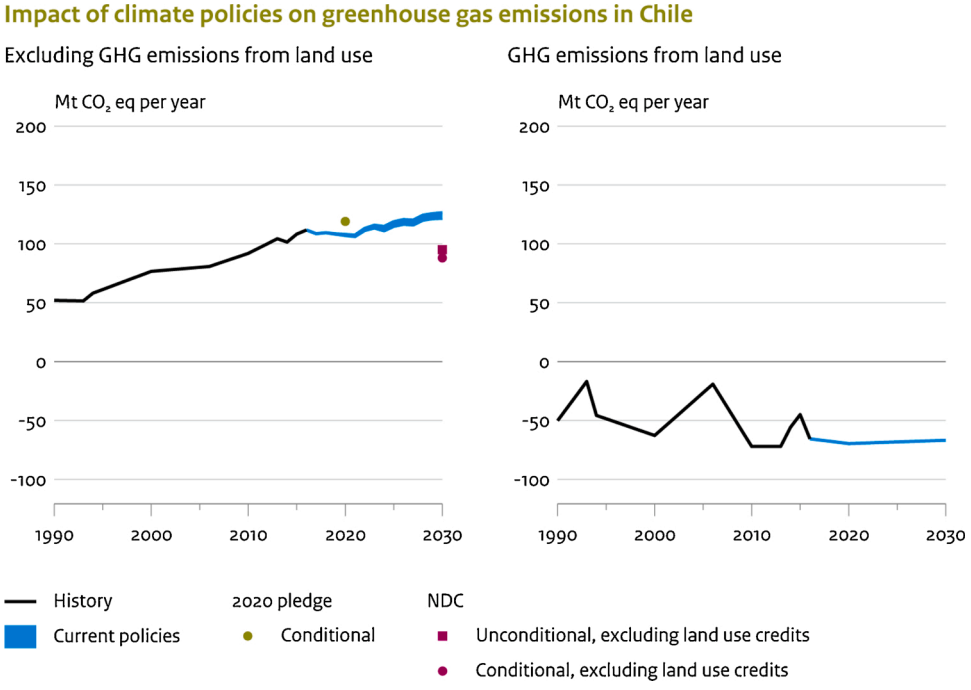

Fig. 6. Impact of climate policies on greenhouse gas emissions in Chile (left panel: excluding land use (i.e. LULUCF), right panel: only land use).

to get very close to its unconditional NDC target with existing policies (Fig. 4). Compared to our current policies scenario projections for 2030 (35–37 % coal, 45–47 % gas, 17–20 % renewables), the PDP 2018–2037 targets are distant for all power sources. Our projections are consistent with a national study that investigated the emissions reductions in the energy sector (Misila et al., 2017) as well as with the reference scenario projections (energy-related CO_2 emissions only) in IRENA (2017). Our assessment on the NDC achievement agrees with that by Keramidas et al. (2020) but our emissions growth projections (excluding LULUCF) were significantly higher (49 % compared to 22 %). Chaichaloempreecha et al. (2019), for energy-related CO_2 emissions, also projected that Thailand will meet its NDC through a full implementation of AEDP and EEP.

3.1.5. Ukraine

Unlike Kazakhstan, the other former Soviet Union country, Ukraine's GHG emissions continue to remain significantly lower than the 1990 levels (Fig. 5). The nation's economy has significantly been affected by the regional conflict against Russia (Andrusevych, 2018), which partially explains the declining emissions trends in recent years.

With its existing policies, we project that Ukraine would overachieve its NDC target significantly (Fig. 5). In December 2020, President Volodymyr Zelenskyy stated that the nation intends to update its 2030 NDC to a 58 %–64 % reduction below 1990 levels (Climate Ambition Summit 2020, 2020). Compared to the literature, though not directly comparable with the NDC, Ukraine's 2050 low emission development strategy (Ministry of Ecology and Natural Resources of Ukraine, 2017) also projected that GHG emissions from energy and industrial process sectors would be 46 % below 1990 levels in 2030 even under a reference scenario. Business-as-usual (BAU) projections for energy-related GHG emissions by Chepeliev et al. (2018), which assumed no new policies after 2015 and no fundamental changes in the energy system, are considerably higher than our projections.

Since 2009, electricity from renewable energy sources was bought on the basis of a generous feed-in tariff regulation which lead to a significant uptake of renewables but also critically affected the financial sustainability of the system (Reuters, 2020). To address this, the Electricity Market Law of 2019 (Law No. 4493) was introduced to liberalise Ukraine's national electricity market through the alignment of Ukraine's national legislation with the regulations from the European Union's Third Energy Package (Mykhailenko et al., 2019; Savitsky, 2018). Ukraine currently aims for a 38 % share of renewables and a 50 % share of nuclear energy in total electricity generation by 2035 (Government of Ukraine, 2017).

3.2. Other key non-G20 countries

On the other four non-G20 countries, Colombia and Morocco are projected to meet their unconditional and conditional NDC targets, respectively, with currently implemented policies while Chile and the Philippines are projected to fall short of their NDC targets. Note that the assessment on Colombia is based on its first NDC, which was updated in December 2020 (see Section 3.2.2 for details).

3.2.1. Chile

For Chile, the assessment result is not surprising because the nation's implementation of its updated NDC has just begun (Fig. 6). GHG emissions excluding LULUCF would plateau around 2030, later than the 2025 peaking target. Our GHG emissions growth projection between 2010 and 2030 excluding LULUCF (32 %–38 %) is higher than the reference scenario projections by Keramidas et al. (7 %) (Keramidas et al., 2020).

The Climate Action Plan 2017–2022 guides and articulates climate mitigation policies across all sectors (Ministry of the Environment of Chile, 2017). Some of the targets set in recent years include renewable electricity generation of at least 60 % by 2035 and 70 % by 2050, a two-phased plan to phase-out coal by 2040 and electrification of 40 % of the private vehicle fleet and 100 % of public vehicles by 2050 (Ministry of Energy of Chile, 2017b; Ministry of Energy of Chile, 2015; Ministry of Energy of Chile, 2019).

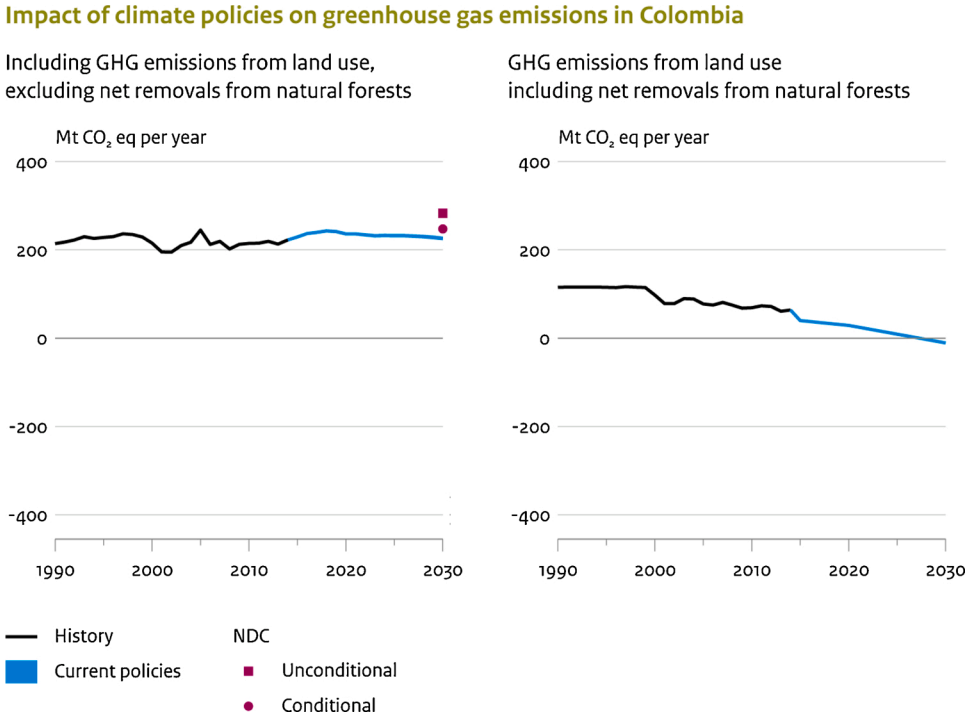

Fig. 7. Impact of climate policies on greenhouse gas emissions in Colombia (left panel: including land use (i.e. LULUCF), right panel: only land use). Note: the BAU emission projection in Colombia's NDC excludes removals from natural forests, which accounted for 263 $MtCO_2e$/year in 2010. Therefore, net removals from natural forests are excluded from the current policies scenario and NDC analysis (figure on the left) but included in the figure on the right.

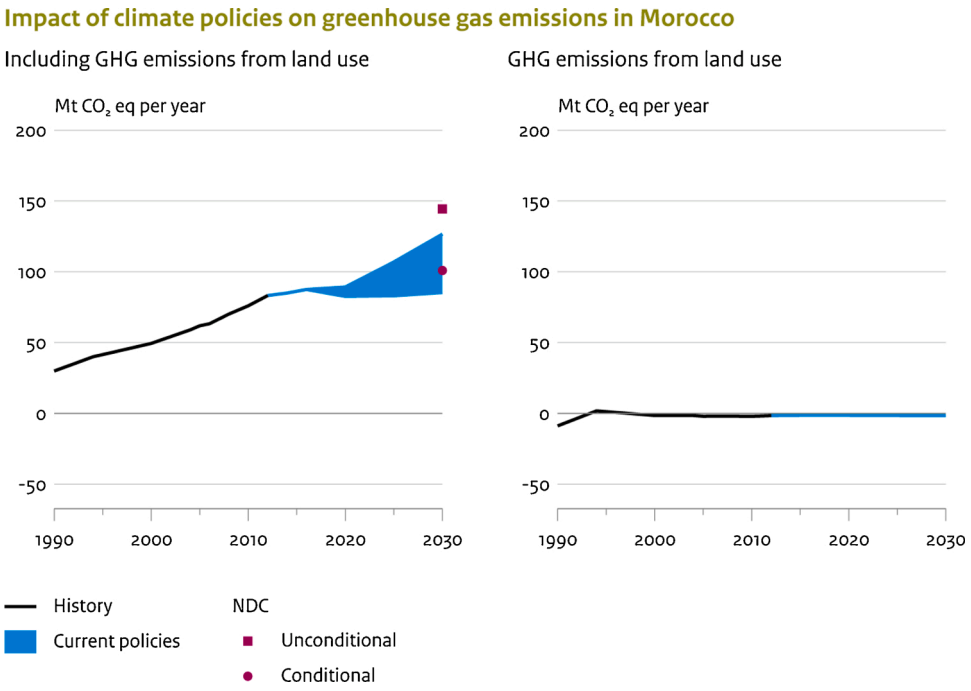

Fig. 8. Impact of climate policies on greenhouse gas emissions in Morocco (CO2, CH4 and N2O; including land use (i.e. LULUCF)).

Chile's 2050 GHG neutrality target laid out in the revised NDC is reflected in the draft Climate Change Framework Law, currently waiting for Congress approval. This draw law would set up legal and institutional framework for implementing climate change mitigation and adaptation policies.

3.2.2. *Colombia*

In December 2020, Colombia updated its NDC, which set an absolute emissions limit of 169 $MtCO_2e$/year, which equals to a 51 % reduction by 2030 compared to the BAU scenario (Government of Colombia, 2020). This article did not assess the details of the new target, in particular compared to the first NDC assessed in this article, because it was published after the cut-off date. The target update is a policy move in the right direction, as our assessment shows that the nation would likely overachieve its first NDC (Fig. 7).

Our current policies scenario projection for Colombia is similar to the 'Positive' scenario projections for energy and industry sector GHG emissions in Nieves et al. (2019), in which a technological substitution by more energy efficient and low-carbon options is accelerated, and are within the range for a current and planned policies scenario projections (fossil fuel and industrial CO_2 emissions only) reported in Clarke et al. (2016).

The government has implemented regulatory instruments to reduce emissions, including a national plan PROURE to incentivise energy

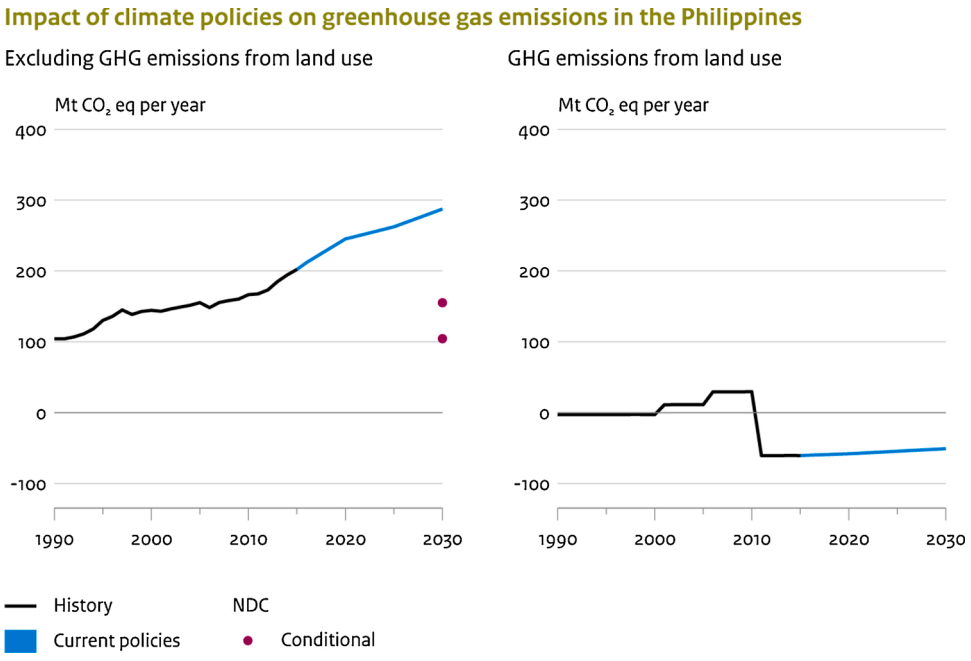

Fig. 9. Impact of climate policies on greenhouse gas emissions in the Philippines (left: excluding LULUCF), right: only land use).

efficiency in the transportation, energy, industry, and buildings sectors (UPME, 2017). Some progress has already been observed; the first auction for large scale (non-conventional) renewable energy took place in 2019. This auction was the first support mechanism in the country with significant impact and awarded 1398 MW of wind and solar power (Ministry of Mines and Energy of Colombia, 2019).

There are also moves that may lead to increase in emissions. One such move is the possible opening of fracking pilot projects (Ministry of Mines and Energy of Colombia, 2020). Another one is the deforestation reduction target of 30 % by 2022 compared to a reference scenario, which could result in a significantly higher deforestation level (250,000 ha per year) than the target level under the previous government (90, 000 ha per year) (National Department of Planning of Colombia, 2018).

3.2.3. Morocco

Morocco is one of the few countries that strengthened their targets when converting INDC into NDC. Our analysis projects that Morocco will likely overachieve its unconditional NDC target and also meet its conditional target with existing policies (Fig. 8). The emissions trends between 2010 and 2016 suggest that the 2030 emissions could be kept considerably lower than our projections.

The National Energy Strategy is the main policy strategy related to GHG emissions and includes the Morocco Solar Plan and the Morocco Integrated Wind Energy Program. With the instalment target of 2 GW for both wind and solar power by 2020 and to extend the hydropower capacity by 775 MW in addition to the 1.3 GW installed by 2010, the National Energy Strategy aims to raise the share of renewable energy in total installed power capacity to 42 % by 2020 and 52 % by 2030. The nation has made significant toward these targets but it remains to be seen if they will be achieved: installed capacities as of 2019 are 1.2 GW for wind, 0.73 GW for solar and 1.77 GW for hydropower (IRENA, 2020).

At the same time, Morocco is also expanding its coal-fired electricity generation. The installed capacity for coal grew from 2540 MW to 4280 MW between 2016 and 2018 (Badrane, 2019).

3.2.4. Philippines

For the Philippines, many factors render the Philippines' NDC emissions target highly uncertain. The BAU scenario underlying the NDC target is not specified. The last data year from the official GHG inventory being 2000, with the LULUCF sector being a large net sink, make it all the more difficult to estimate the NDC target emission levels (see S2 of SOM for further assessment).

Our assessment as presented in Fig. 9 is comparable to those from Mondal et al. (2018) on the increase in power sector CO_2 emissions (in absolute terms between 2016 and 2030), while similar to the energy-related CO_2 emissions projected by Cayamanda et al. (2017) for a scenario that considered a shift to a low-carbon electricity mix and extensive electricity savings (detailed comparison was not possible due to the lack of historical emissions data).

The Philippines has implemented distinct policies to reduce GHG emissions. The Renewable Energy Act of 2008, further laid out in the National Renewable Energy Plan, remain the main guiding policy for renewable electricity uptake (Department of Energy, 2009; Department of Energy of the Philippines, 2011). Energy efficiency targets have been set at both economy-wide and end-use sector levels (Congress of the Philippines, 2018). Moreover in 2018, even though the power sector is largely dependent on coal, the tax reform raised taxes on coal production (Department of Finance, 2017).

Table 3
Per capita greenhouse gas emissions and the emission peaking year under current policies scenario and NDC scenario in the nine countries assessed. The status of net-zero emission goals is also presented. Note: the emissions figures exclude LULUCF; figures including LULUCF are denoted with asterisks.

Country	On track to meet the NDC targets with current policies?	Per capita GHG emissions in 2030 in tCO_2e (vs. 2010 levels)		Emission peaking year		Commitment to net zero emissions goals (Energy and Climate Intelligence Unit, 2020)
		Current policies scenario	NDC: unconditional [conditional]	Current policies scenario: total emissions	NDC: unconditional [conditional]	
Chile	No (NDC was recently updated with a more ambitious one)	6.3–6.5 (+16 % to +21 %)	4.9 (-9 %) [4.5–4.9 (-9 % to -16 %)]	After 2030	By 2030 (unconditional and conditional)	Yes, net zero GHG target by 2050 submitted in the updated *NDC and Climate Neutrality Plan* of 2020 (Ministry of Energy of Chile, 2020)
Colombia	Yes (both unconditional and conditional)	4.0 (+24 % to +25 %)	5.1 (+58 %) [4.4 (+37 %)]	Around or by 2020*	After 2030 (unconditional)* Possibly by 2030 (conditional)*	Net zero CO_2 target initially announceed by President Iván Duque in 2019 (Presidencia de la República de Colombia, 2019) but remains under discussion
D.R. Congo	Close	3.0–3.2 (−11 % to -7 %; +5 % to +10 % vs. 2015 level)*	[3.0 (−14 %; +2 % vs. 2015 level)]*	After 2030*	After 2030*	Under consideration as D.R. Congo joined the *Climate Ambition Alliance* (UNFCCC, 2019a,b,c,d,e), but target remains under discussion
Iran	Yes	13.2–16.2 (+17 % to +43 %)	20.9 (+84 %) [19.2 (69 %)]	After 2030*	After 2030*	No
Kazakhstan	No	20.3–22.4 (+8 % to +19 %)	16.3–16.4 (−13 %) [14.5–14.6 (−22 %)]	After 2030*	1990 or earlier (former Soviet republic)	No
Morocco	Yes	2.1–3.1 (-11 % to +32 %)	3.6 (+52 %) [2.5 (7%)]	After 2030*	After 2030 (unconditional)* By 2030 (conditional)*	No
The Philippines	No (with large uncertainty on NDC target level)	2.3 (+31 %)	N/A [0.8–1.3 (-29% to -52%)]	After 2030	By 2030	No
Thailand	Close	6.9 (+42 %)	6.5 (+34 %) [6.1 (26 %)]	After 2030	After 2030 (unconditional) Possibly by 2030 (conditional)	No
Ukraine	Yes	9.5–9.7 (+8% to +10%)	13.1 (+48 %)	1990 or earlier*	1990 or earlier (former Soviet republic)*	No

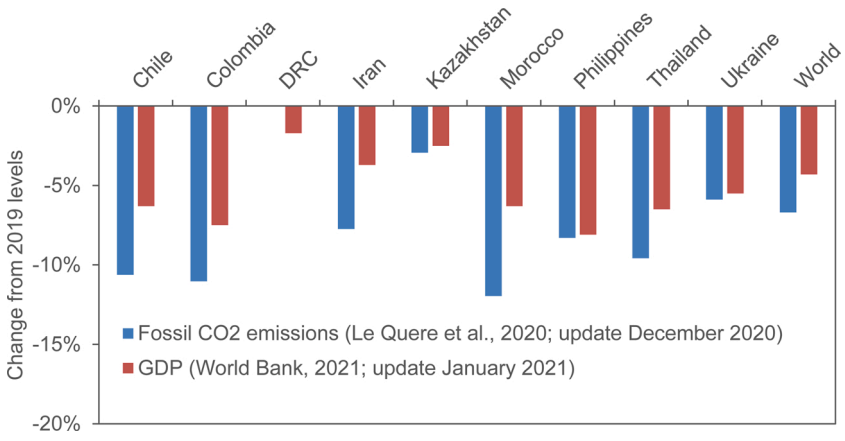

Fig. 10. Estimated changes of fossil CO_2 emissions and GDP in 2020 compared to 2019 levels in nine countries and the world (Le Quéré et al., 2020a; World Bank, 2021).

3.3. Future trends of per capita emissions and the expected peak year of GHG emissions

Based on the economy-wide current policies scenario emissions projections presented in section 3.1.1, the trends of per capita GHG emissions relative to 2010 levels and the emission peaking year were also assessed for both current policies and NDC scenarios. Historical data and projections on country-level population were taken from the UN World Population Prospects ("medium fertility case" for projections) (UN DESA, 2019). The peaking year assessment was based on the sector coverage as defined in respective NDCs. See SOM (S6) for details on the data sources and calculation steps.

3.3.1. Per capita GHG emissions

The assessment on per capita emissions excluded LULUCF except DRC where vast majority of the national energy supply is biofuels. For DRC we also present results using 2015, the modelling base year, as reference year due to the large uncertainty on the historical LULUCF emissions and their trends over time. Per capita emissions in 2030 are projected to increase from 2010 levels in most countries for both the current policies and NDC scenarios (Table 3). The overall findings for the nine countries are similar to those for non-OECD G20 members (den Elzen et al., 2019; UNEP, 2018).

Under the current policies scenario, all countries assessed except DRC are projected to increase their per capita emissions, ranging between 8 % for Kazakhstan and Ukraine to over 40 % for Iran and Morocco. The two major fossil fuel producers, Iran and Kazakhstan, are projected to emit at levels comparable to the high per capita emitters among the G20 members such as Russia, Saudi Arabia and the United States, which are also major oil producers (den Elzen et al., 2019).

For the NDC scenario, per capita emissions in 2030 are projected to be lower than 2010 levels for DRC (including LULUCF emissions), Kazakhstan and the Philippines. While this is unsurprising for Kazakhstan, it is somewhat counterintuitive for DRC and the Philippines, which are among low-income countries and low per capita emissions at around 3 tCO_2e/capita or below today. For the Philippines the NDC target level is highly uncertain, but our finding roughly agrees with that of Meinshausen and Alexander (range: 37 % reduction to 1% increase) (Meinshausen and Alexander, 2017). For DRC the historical LULUCF emissions data used in this study is similar to those presented in its NDC document, thus our result is close to what the data in the NDC document would suggest (FAOSTAT, 2019).

3.3.2. Emission peaking year

Emissions under NDC targets are expected to peak before 2030 in seven out of the nine countries assessed (Table 3). More specifically, for Colombia, Morocco, and Thailand this is only for conditional targets; GHG emissions for Kazakhstan and Ukraine have decreased by more than 50 % after 1990 by 2000, and the Philippines has a NDC target with large uncertainty. The prospects are worse for current policies scenario projections; all but Colombia and Ukraine are projected to peak their GHG emissions after 2030.

Six of the nine of the countries assessed, including four of the five major non-G20 emitters, have not committed to a long-term net-zero emission goal (Table 3, last column). These six also have not joined the UNFCCC Climate Ambition Alliance, which brings together countries that are working towards net-zero CO_2 emissions by 2050 (UNFCCC, 2019a). The projected peak years after 2030 combined with the lack of long-term net-zero goals poses a serious risk of locking in GHG emissions in the long term and thus reduce the chance of achieving the Paris climate goals.

3.4. Estimated impact of COVID-19 and responses

The COVID-19 pandemic has already had major impact on the global energy use and GHG emissions. While the world is still in the midst of the pandemic, this section discusses the possible magnitude of the impact on 2030 emissions in the nine countries based on the emerging literature.

For eight of the nine countries assessed in this study, the reductions in fossil CO_2 emissions in 2020 compared to 2019 estimated by Le Quéré et al. (2020a) range widely between 3% and 12 % (Fig. 10); on a global level, the reductions for 2020 are projected to be around 7% (range of four studies assessed: 6 %–13 %) with large differences across countries (Friedlingstein et al., 2020). The large difference observed across countries is attributable to many factors, including the level and duration of restrictions to social and economic activities, economic and industrial structure, as well as the energy mix (Enerdata, 2020; Le Quéré et al., 2020b). Thus, emissions reductions are larger than GDP reductions for most countries to a varying degree, while there are also countries with reductions similar to, or smaller than, the GDP reductions (Fig. 10). There is limited literature on the land-use sector emissions in 2020, but there are indications that deforestation activities have not slowdown during the COVID-19 pandemic and possibly increased (Daly, 2020; Fair, 2020).

The impact of the ongoing COVID-19 pandemic on future GHG emissions is highly uncertain (UNEP, 2020). Future emissions path over the next decades would be largely be affected by the extent to which low-carbon measures are incorporated in the economic responses (IEA, 2020b; Le Quéré et al., 2020b). Early estimates indicated that while 2030 emissions could take a significantly lower path than projected previously, they could also go back to pre−COVID projection levels or even slightly higher if the world pursues a high-carbon economic

recovery path (UNEP, 2020). The IEA reported that global energy-related CO_2 emissions have already rebounded strongly, with a 2% increase in December 2020 compared to the same month in 2019 (IEA, 2021).

From these recent post−COVID studies, we consider our current policies scenario projections presented in Sections 3.1 and 3.2, based on the pre−COVID data, to range on the higher side of the possible post−COVID emissions pathways. We also conducted a simplified "what-if" assessment in case the emissions out to 2030 remained below the levels projected pre−COVID. We assumed that all GHG emissions (excluding LULUCF) reduced at similar rates as CO_2 emissions in 2020 from 2019 as shown in Fig. 10, and afterwards followed similar growth trends (in absolute terms) as projected in Sections 3.1 and 3.2 out to 2030. These assumptions are in line with a "current trends" scenario presented in the 2020 UNEP Emissions Gap Report, under which emission intensity per GDP would follow similar trend as projected in pre−COVID studies (UNEP, 2020). Our assessment indicates that most countries assessed to miss their NDCs under current policies under pre−COVID projections (Chile, Kazakhstan, Morocco and the Philippines) would likely still miss their NDC targets. By contrast, Thailand would likely achieve its NDC target, when the impact of the COVID-19 pandemic is considered. Large uncertainty remains for DRC, where the majority of the emissions comes from the land-use sector.

The above findings indicate that our main conclusions on the progress towards NDCs would remain unchanged even after considering a range of possible impact of the COVID-19 pandemic on future emissions. It should be noted that the economic impact of recessions and crises was historically larger for poor countries than for rich countries (Cerra and Saxena, 2018). Since most of the countries are not high-income countries (as per World Bank definition), the long-term impact of the pandemic on GHG emissions on these countries could be significantly larger than estimated here. Furthermore, recent studies imply possible increase of emissions in agriculture and land-use sectors during the COVID-19 pandemic (Amador-Jiménez et al., 2020; FAO, 2020; López-Feldman et al., 2020; Rondeau et al., 2020; Vale et al., 2021).

4. Discussion

Our study contributes to filling an important research gap in relation to the literature on non-G20 countries' progress towards their NDC targets. The findings of study would also contribute to the assessment of the collective progress of countries in the global stocktake under the Paris Agreement, scheduled to take place in 2023.

The analytical approach used in this study is well established (e.g. Climate Action Tracker, 2019; den Elzen et al., 2019; Roelfsema et al., 2014; UNEP, 2020) but still limited in a number of ways. The most important caveat for the assessment is the impact of the COVID-19 pandemic on emissions projections, as discussed in Section 3.4. Second, whether a country would achieve its NDC target with existing policies not only depends on the stringency of the policies and the ambition level of the target, which could be assessed in the light of equity principles and many other methods (Höhne et al., 2017), but also on other factors. For example, structural factors such as demographics and macroeconomic trends affect how difficult it would be to deliver emissions reductions (UNEP, 2020).

There are also limitations related to the specific steps of calculating emissions projections: first is the use of external baseline projections for non-LULUCF sector emissions from different studies to develop current policies scenario projections. Assumptions underlying these external baseline projections (e.g. such as macroeconomic drivers, technological development, and policies considered and their projected impact on emissions), are not always explicit, and even if so, they may not always be consistent or comparable across studies. Macroeconomic assumptions are particularly important for several countries assessed in this study (e.g. economic recession in several countries, regional conflict and political instability in DRC and Ukraine, and international economic sanctions on Iran). However, we have examined underlying macroeconomic assumptions upon selecting these scenarios and applied the same policy cut-off date to the extent possible.

Second is that this article did not provide a complete assessment of national policies beyond selected energy- and climate-related policies. There is considerably less literature on implemented policies for the countries assessed in this article compared to G20 countries. This gap is partially addressed by our analysis by comparing our results with other projections in the literature on a country level. Additionally, existing policies may change and/or be abandoned for a variety of reasons, and new policies may be implemented. These factors lead to high uncertainty in the absolute emissions level in 2030. This study provides the current state of play and needs to be periodically updated.

This study did not explore how countries can reduce their GHG emissions beyond current policies scenario projections, which was outside the research scope of this article. The quantification of country-specific potential for additional GHG emissions reductions, combined with an assessment of possible policy measures, would be essential for an effective future global stocktakes under the Paris Agreement. However, tracking progress on current policies towards the achievement of their NDCs remains fundamental; it holds countries accountable to their own commitments and indicates countries that are well positioned to ratchet up their commitments in the next NDC update cycle.

There are other non-G20 countries that have equally or larger GHG emissions than the ones selected in the analysis due to not meeting one or more criteria in the country selection process. These include Egypt, Vietnam, Nigeria, Pakistan, or Bangladesh. Future research on these countries' emissions pathways would be useful contributions to both domestic and international effort toward the Paris climate goals.

5. Conclusions

This study compared GHG emissions projections in 2030 under current policies and those under 2030 mitigation targets for nine key non-G20 countries that collectively account for about 5 % of global total emissions today. Our assessment showed that Colombia, Iran, Morocco, and Ukraine were projected to likely meet or significantly overachieve their unconditional 2030 targets with existing policies, while DRC and Thailand would come very close to their targets. Kazakhstan and the Philippines would need to strengthen their action to meet their targets, while Chile recently raised its 2030 target ambition. While the impact of the COVID-19 pandemic on 2030 emissions is highly uncertain, our assessment on the target achievement would not change for most countries when we the emission reduction rates similar to those estimated for 2020 in the literature were assumed to remain in 2030.

We find a number of similarities between the nine countries assessed in this study and the G20 members, especially with non-OECD countries. First, seven of the nine countries (including Chile, an OECD country) were projected to peak their emissions only after 2030, both economy-wide and on per capita basis. Second, major fossil fuel producers Iran and Kazakhstan are projected to emit similar per capita emissions in 2030 as their non-OECD G20 counterparts (Russia and Saudi Arabia). Third, there are countries with highly inflated baselines on which the NDC targets are based upon, thus leading to large overachievement of respective NDC targets (e.g., Iran and Turkey, the latter being a G20 member). These trends are misaligned with the Paris climate goals.

Additionally, per capita emissions for the two countries with comparatively low income (DRC and Philippines) were projected to decrease between 2010 and 2030 under the NDC scenario, even though large uncertainties exist on the historical emissions data used and the quantification of the NDC targets. This calls for enhanced evaluation of climate ambition and action also for countries less studied to date, especially those with limited capacity and resources to develop GHG mitigation strategies, to ensure that their ambition and action are realistic and feasible in the light of their social, economic and political circumstances.

This study highlights the importance of enhanced progress-tracking of climate action in countries outside G20 to ensure that the global collective progress will become aligned with the pathways toward Paris climate goals. It is also crucial to continue tracking the impact of the COVID-19 pandemic on emissions on country and sector levels, as well as tracking the implementation of recovery measures to assess the potential lock-in of emissions in the longer term. Other areas for future research include, e.g., quantification of additional GHG emissions reduction potential beyond current policies scenario projections and an assessment of possible policy measures to realise the calculated potential.

Author contributions

Takeshi Kuramochi: conceptualization; formal analysis; investigation; methodology; resources; supervision; validation; writing - original draft; writing - review & editing; project administration; funding acquisition.

Leonardo Nascimento: formal analysis; investigation; methodology; resources; validation; writing - original draft; writing - review & editing.

Mia Moisio: formal analysis; investigation; methodology; validation; writing - original draft; writing - review & editing.

Michel den Elzen: conceptualization; formal analysis; investigation; methodology; resources; supervision; validation; writing - original draft; writing - review & editing; project administration; funding acquisition.

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Heleen van Soest: data curation; formal analysis; investigation; methodology; resources; validation; visualisation; writing - original draft; writing - review & editing; funding acquisition.

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Mark Roelfsema: formal analysis; investigation; methodology; validation; writing - original draft; writing - review & editing.

Niklas Höhne: methodology; supervision; validation; writing - original draft; funding acquisition.

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 material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.envsci.2021.04.015.

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