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Sharing the decarbonisation effort: getting Eastern Mediterranean and Middle East countries on the road to global carbon neutrality

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ABSTRACT

To achieve the Paris Agreement's goals of keeping the global temperature rise well below 2 °C, or even better below 1.5 °C, relative to pre-industrial levels by the end of this century, countries need to make fair and ambitious contributions to reducing their greenhouse gas emissions. Here, three clusters are proposed that encompass fourteen approaches derived from three main equity principles to determine equitable national emission allocations in the year 2030 for the seventeen countries in the Eastern Mediterranean and Middle East (EMME) region. The allocations are compared with the Nationally Determined Contributions of each country in order to assess the degree to which current EMME climate change mitigation targets are sufficient. The results suggest two approaches that may be considered both realistic and fair, although with the caveat that both rich and poor EMME countries may still have reason to resist the allocations indicated by these approaches. One of these two approaches relates to the principle of responsibility and the other relates to a combination of capability and responsibility. Both require emissions in the EMME region to drop by nearly 50% by 2030 as compared to 2019 levels so as to be in line with a 1.5 °C warming scenario.

Key policy insights:

- The fairness of global decarbonisation efforts is foundational to climate change mitigation discussions.
- Achieving equitable emission reduction targets requires consideration of factors such as realism, which are less often discussed than those that are purely socioeconomic.
- Realistic and fair emissions abatement targets that reflect the equity principles of responsibility and capability should be identified and country-specific responses taken accordingly.
- The significant heterogeneity among EMME countries makes it particularly challenging to allocate emissions abatement targets in a fair and politically acceptable way.
- Nationally Determined Contributions (NDCs) of EMME countries are not aligned with required emissions abatement targets.

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1. Introduction

The climate emergency is one of the most important challenges for modern society (Gills & Morgan, 2020; IPCC, 2021). A transition to low carbon economies can mitigate the impact of climate change but requires investments at an unprecedented pace and scale (IPCC, 2018; United Nations Environment Programme, 2020). According to

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the Intergovernmental Panel on Climate Change (IPCC, 2021), to limit global temperature rise to 2 °C relative to pre-industrial levels, global net anthropogenic carbon dioxide (CO_2) emissions should decrease by about 25% from 2010 levels by 2030 (10–30% interquartile range) and reach net-zero by 2070 (2065–2080 interquartile range) (IPCC, 2018). Keeping in mind the inherent uncertainty in climate projections, to achieve no or limited overshoot of 1.5 °C, a 45% CO_2 emissions decrease from 2010 levels is required by 2030 (40–60% interquartile range), while emissions should drop to net-zero by around 2050 (2045–2055 interquartile range). These figures are consistent with net-zero CO_2 targets that use 2019 emissions as the baseline (IPCC, 2023).

In the European Union, the European Green Deal aims to achieve a carbon-neutral regional economy by 2050 (European Commission, 2019), and other governments around the world (e.g. Canada and South Korea) are following the same strategy. However, not all regions and nations share the same level of ambition. One such example is the region of the Eastern Mediterranean and Middle East (EMME)[1], which is the focus of our paper. In 2019, the EMME region hosted 5.5% of the global population, produced 4.9% of the world's economic output but generated more than 8% of global carbon dioxide emissions. Most EMME countries emit much more carbon dioxide per capita than the world average due to their dependence on fossil fuels. onsidering their population trends and economic growth prospects, almost all EMME countries are far off the trajectory required to stabilise the global climate in line with the objectives of the Paris agreement on climate change. This is confirmed by the official projections from major economies in the EMME region, such as Saudi Arabia and Turkey (United Nations Environment Programme, 2019), and hence planning this transition at a national level is identified as a priority by policy makers as well as the academic community (Fujimori et al., 2021). Section 1 of the Supplementary Material (SM) provides an overview of the current status of carbon dioxide emissions, carbon intensity and income levels in the EMME countries.

Several studies have investigated the required level of action that each country would need to undertake to achieve the Paris Agreement targets and the equivalent implications based on global fairness. However, insights are needed to understand the equity dimensions of any low-carbon transition required to achieve the global warming targets at a national level (Carley & Konisky, 2020; DeAngelo et al., 2021; Pye et al., 2020). In the literature, fairness is often discussed around equity principles, and different effort-sharing approaches have been used to determine: (i) emission allowances or required emission reduction targets over time (Den Elzen & Höhne, 2010; Höhne et al., 2014; Meinshausen et al., 2015; Pan et al., 2017; Rajamani et al., 2021; Raupach et al., 2014; Robiou du Pont et al., 2017; Tavoni et al., 2015; van den Berg et al., 2020); (ii) carbon budgets[2] (Kuramochi et al., 2016; Raupach et al., 2014; van den Berg et al., 2020), and (iii) carbon dioxide removal (CDR) quotas (Pozo et al., 2020). The IPCC Fifth Assessment Report (AR5) (Clarke et al., 2014; Fleurbaey et al., 2014) grouped the effort sharing approaches into three basic definitions of equity principles, which are also mentioned in the latest IPCC Sixth Assessment Report (AR6) (IPCC, 2023): (i) ***responsibility***, which concerns the current and the historical contribution to global emissions; (ii) ***capability***, which sometimes in literature is referred to as 'ability to pay for mitigation' or as 'emission intensity approach' (Miketa & Schrattenholzer, 2006; Pan et al., 2017) – according to the former the least capable countries could have a less ambitious reduction effort, often described by GDP or income, and according to the latter abatement is calculated based on emission intensity improvements; (iii) and ***equality***, which concerns equal rights per person and usually translates into equal emission allowances per person (Pan et al., 2014). A further category identified in the literature, called 'blended sharing principle' (Raupach et al., 2014) utilises different combinations of these basic principles such as responsibility-capability-need (Baer et al., 2009), which combines responsibility and capability, and equal cumulative emissions per capita, which is a composite of responsibility and equality (Höhne et al., 2014).

In this context, this paper investigates 2030 country-level CO_2 emission targets for the seventeen countries of the EMME region to support the Paris Agreement goals. This work adds to the literature of effort-sharing approaches by investigating fourteen effort sharing alternatives, based on three different clusters of approaches and proposing equitable national emission allocations. Our focus on the EMME countries reflects that, although the region is projected to suffer disproportionately from climate change impacts, it has hardly been analysed to date. At the same time, this analysis sheds light into the challenges faced at a global level. The region consists of a diversity of nations – rich and poor, more and less industrialised, some very rich in fossil fuel reserves and others without local fossil resources, some whose emissions have grown recently while others had a stronger contribution to historic emissions, and even some very fragile states,

such as Palestine and Syria. The region is also heterogeneous in climate policy ambition – it includes European Union member states with ambitious climate targets (i.e. Cyprus and Greece); countries with modest pledges; and even nations that have not yet ratified the Paris agreement. Therefore, it is extremely challenging to attempt to design a trajectory to carbon neutrality for such a diverse group of countries; this diversity also highlights the challenges that the global community is facing in achieving its decarbonisation ambitions. Although there are several studies in the literature studying regional-level emission allocations for the Middle East region (DeAngelo et al., 2021; Höhne et al., 2014; Pye et al., 2020; Robiou du Pont et al., 2017; Tavoni et al., 2015), to our knowledge, this paper provides the first evaluation of national emission allocations for the seventeen countries in the broader EMME region. This paper utilizes transparent and rigorous analysis to provide guidance on setting realistic and fair emissions targets based on national circumstances.

The first section of the paper sets the context of the analysis. Section 2 of the paper describes the methodology developed to address a diverse set of effort-sharing approaches, while a set of quantitative criteria to evaluate the degree of realism and fairness for each approach are also proposed. Section 3 presents the results of the analysis, compares the estimated national emission reduction ranges with national pledges, and provides an evaluation of realism and fairness for each approach. The paper concludes in section 4 with policy-relevant remarks and insights.

2. Methods

The methodology adopted in this paper assesses multiple plausible effort-sharing approaches, which are supported by a comprehensive list of criteria and that can be applied to set country-specific CO_2 emission targets. In this regard, it pursues in various scenarios a 'blended sharing principle' similar to that of Raupach et al. (2014), who combine two alternative effort sharing criteria. The work utilises a more extensive blended sharing principle and experiments with combinations of up to four criteria to test alternative allocations of the emission abatement effort. In addition, the outcomes of these approaches are further verified in terms of the degree of 'realism' and 'fairness' that characterise each of them. In essence, the set of approaches analysed provides a range between the least and most aggressive mitigation targets to be pursued by each country, keeping the EMME region aligned with the Paris Agreement's climate targets. This also allows a comparison of the required trajectory of emissions against the NDC pledges and, hence, the expected emission trajectory of each country up to 2030 in order to estimate the gap in required decarbonisation efforts.

2.1. Data and indicators

The different data and indicators used to explore potential CO_2 abatement in EMME countries include population, current (2019) and cumulative (1750–2019) CO_2 emissions (from fossil fuels and industry, excluding land use change), Gross Domestic Product (GDP) and carbon intensity. The main contributors of current and cumulative CO_2 emissions as of 2019 are the three most populous countries in the region – Turkey, Saudi Arabia and Iran – while the smallest contributors are Palestine and Cyprus. In terms of per capita CO_2 emissions, Bahrain, Kuwait and Qatar are the highest, while Palestine is again the smallest contributor. The ranking remains essentially the same also when cumulative CO_2 emissions per capita are observed, i.e. accounting for the historical carbon emissions during 1750–2019, divided by the population of 2019. In terms of economic output, Iran, Turkey and Saudi Arabia have the largest national GDPs, while the countries with the largest GDPs per capita are the United Arab Emirates (UAE), Israel and Qatar. Looking at the volume of emissions per unit of GDP, illustrated by the carbon intensity of the economy, Iraq, Iran and Syria are the most carbon intensive, while Israel and Palestine are the least carbon intensive. Section 1 of the SM gives an overview of the data used for the analysis and the ranking of the countries in the EMME region based on the different indicators discussed.

2.2. Effort sharing approaches

A comprehensive set of effort sharing approaches was developed using the data and indicators described in Section 2.1. As a first step, the global CO_2 emission targets in absolute values and per capita for 2030 are

estimated as seen in Table 1. These calculations were based on the targeted reduction of at least 25% and 45% of world CO_2 emissions by 2030 compared to 2010, as mentioned in the introduction for the 2 °C and 1.5 °C targets, respectively. In addition, the equivalent targeted emission reduction of global CO_2 emissions by 2030 was calculated as compared to 2019.[3] Absolute and per capita emissions were then used in different approaches to determine CO_2 emission reduction targets for each country in the EMME region. The reference point for the different approaches presented in this report is the most recent year for which consistent data are available, which is the year 2019 (Our World in Data, 2021). The year 2030 was chosen as a convergence period instead of 2050 or 2100, as emissions reductions achieved by 2030 will largely determine whether net-zero emissions in 2050 would result in achievement of the Paris Agreement goals. This also serves to highlight the urgency for climate action in the region.

To allocate the decarbonisation effort among the countries of the EMME region, three alternative clusters of approaches were developed. It should be noted that even though EMME countries do not participate as a coalition in global climate negotiations, several of the approaches set an initial constraint that the global average emission reduction aligned with the 2 °C and 1.5 °C global warming targets must be achieved for the region. This is done as EMME countries have highly diverse socioeconomic conditions and hence offer an ideal subset of nations upon which effort sharing approaches can be tested. The core of each alternative approach lies in the methodology used to calculate the CO_2 emissions abatement for each of the EMME countries.

Cluster 1 (Equal per capita emissions): The first cluster consists of a single approach (approach1.1), in which the required CO_2 emissions abatement for each country is calculated by assuming that all countries in the region would converge to the same per capita emissions level by 2030. This is equal to the global per capita emissions level for 2 °C and 1.5 °C global warming targets that are presented in Table 1. Even though it may be difficult for countries in the region, which have such diverse socioeconomic conditions, to converge to the same emission level, this effort-sharing approach is included for comparative purposes.

Cluster 2 (Historic trends dictate targets): In the second cluster, a set of approaches has been investigated. Two subcategories are identified based on the calculation of the total required CO_2 emissions abatement done either (i) on a global scale (approaches 2.1–2.4) or (ii) for the EMME region (approach 2.5). In each of these approaches, the calculated total required CO_2 emissions abatement is allocated by country based on each country's historic contribution to each of the respective indicators considered. The rationale behind calculating the total required CO_2 emissions abatement on a global scale is that the EMME countries should follow the same methodology as countries from other regions. Even though this approach may be difficult to realize, it is nonetheless important to consider. However, there are two potential limitations with this method. First, the countries that have the lowest ranking may be allocated a higher absolute reduction in CO_2 emissions compared to countries that rank higher. Second, sometimes the absolute reduction of CO_2 emissions corresponding to a specific country may be higher than the CO_2 emissions that the country generated in 2019, resulting in negative emissions required for 2030.

Cluster 3 (EMME average equals global average): Eight approaches are developed within this cluster to overcome the limitations of cluster 2. At the core of these approaches is the assumption that the EMME region's emissions reduction as a whole aligns with the required global emission trajectory. In this set of approaches, the targeted abatement in each country is only allowed to vary within a pre-defined range (i.e. 0–50%) and is determined by the ranking of the countries in the relevant indicators considered. For instance, if a country ranks high in per capita emissions, the respective country's emission target is also high. In addition, in order for the EMME region to be in line with the required global emission reduction trajectory that limits global temperature rise to

Table 1 . Emission targets according to authors' calculations based on IPCC (2021) and emissions data for 2010 and 2019.

	CO_2 Emissions (million tonnes)	CO_2 Emissions per capita (tonnes)
Maximum global emissions in 2030 to achieve the 2 °C target	24,849	2.91
Maximum global emissions in 2030 to achieve the 1.5 °C target	18,223	2.13
Reduction in global CO_2 emissions required in 2030 compared to 2019, to achieve the 2 °C target	11,589 (−32%)	–
Reduction in global CO_2 emissions required in 2030 compared to 2019, to achieve the 1.5 °C target	18,216 (−49.99%)	–

1.5 °C or 2 °C, a correction factor is applied in each scenario. The ranking for each indicator is provided in SM Table 2.[4] More information on how approaches in this cluster are implemented mathematically is provided in section 3 of the SM.

A summary of the proposed effort sharing approaches is presented in Table 2. In this Table, the last column indicates the IPCC equity principle categories most directly related to each approach. When a combination of principles is used, some principles may be emphasized more than others.

2.3. The need for realism and fairness

The wide range of effort-sharing approaches investigated in this paper comes with a caveat. The combination of indicators assessed in each case can result in targets that could be neither realistically attainable nor fairly allocated. As such, a methodology, even if qualitative or simple, is needed to assess whether the effort-sharing results are realistic and fair. The general understanding of what would constitute a realistic and fair contribution to the global understanding recognizes the need for 'common but differentiated responsibilities and respective capabilities, in the light of different national circumstances' as stated in the Paris Agreement's Article 4.3 (UNFCCC, 2016). However, there are no agreed guidelines in the literature for assessing whether a contribution is realistic and fair on a quantitative basis. Hence, a set of quantitative criteria to evaluate the notions of realism and fairness are proposed in this analysis. The threshold for each criterion is intentionally set quite high with the aim to eliminate extremes. For each approach the following simple criteria were considered with regard to the most demanding mitigation effort, which is limiting global temperature rise, relative to pre-industrial levels, to 1.5°C:

- The emission reduction target relative to 2019 emissions should not exceed 80% for any of the countries (**realism**).
- The abatement target in percentage emission reduction for any country should not be more than 50% higher than the average abatement of the whole EMME region (**fairness**). That is, the burden allocated to any particular country will not greatly exceed that of the region as a whole.
- The range of abatement targets between countries (i.e. the difference between the maximum and minimum percentage emission reduction) should be less than 80% (**fairness**).

3. Results

3.1. Effort sharing approach results

Detailed results for each of the effort sharing approaches are provided in section 2 of the SM. Using a uniform global average per capita emissions target, as in approach 1.1, allows low-income countries of the region to increase their emissions to 2030 before they start a stronger decarbonisation effort, in order to reach net-zero emissions after some decades. On the other hand, the uniform per capita emission target sets very demanding objectives for economies with currently very high per capita emission levels. In addition, this approach does not consider the historic emissions of each country and thus, does not account for each nation's responsibility in causing climate change.

Uniform per capita emissions could be said to constitute a fair approach at a global scale, but it demands a much stronger decarbonisation effort from EMME countries relative to other countries worldwide, as their average per capita emissions in 2019 (7 tonnes/capita) were much higher than the world's average (4.7 tonnes/capita). If this principle is applied in a straightforward manner, as in approach 1.1, the EMME region will have to reduce its emissions by 52% and 65% in 2030 compared to 2019 levels for the 2 °C and the 1.5 °C global warming target respectively, whereas the corresponding reductions are 32% and 50% on a global scale. Such an approach does not take into account variations in the economic structure across countries. For instance, in the Gulf Cooperation Council (GCC) countries[5], industrial GHG emissions have a higher share in the total national emissions than the rest of the EMME region (ClimateWatch, 2020). Hence, emission

Table 2 . Summary of the different approaches per cluster and their corresponding methodologies.

Cluster	Approach	Methodology used to calculate national abatement targets	IPCC equity principle
1	1.1	This approach estimates the amount of CO_2 emissions each country is allowed to emit, assuming that all countries reach the global per capita emission targets of 2030.	Equality
2	2.1	The required global CO_2 emissions abatement is calculated based on the average global emission reduction of 32% and 49.99% and then allocated to each country based on the share of their cumulative emissions to the global emissions.	Responsibility
	2.2	Half of the abatement needed to reach the global per capita emission target (approach 1.1) is added to half of the abatement that is calculated based on the share of the cumulative CO_2 emissions of each country compared to the global CO_2 emissions (approach 2.1).	Combination of Equality and Responsibility**
	2.3	Half of the abatement needed to reach the global per capita emission target (approach 1.1) is added to half of the abatement that is calculated based on each country's share in global GDP, where higher GDP leads to a higher emissions reduction target.	Combination of Equality and Capability (ability to pay)
	2.4	The average abatement of three methodologies is taken to derive the abatement: the need to reach the global per capita emissions target (approach 1.1), the share of each country's GDP in global GDP (partial scenario 2.3) and the share of each country's cumulative carbon emissions to global cumulative emissions (approach 2.1).	Combination of Equality, Capability (ability to pay) and Responsibility
	2.5	Half of the abatement needed to reach the global per capita emission target (approach 1.1) and half of the abatement that is calculated based on the share of the cumulative emissions relative to the EMME region cumulative emissions, if the EMME region is required to attain the average global emission reduction targets of 32% and 49.99%.	Combination of Equality and Responsibility
3	3.1	The EMME region should attain the average global emission reduction of 32% and 49.99% (for the 2 °C and 1.5 °C targets respectively) and total emission reductions are allocated based on each country's GDP per capita.	Capability (ability to pay)
	3.2	The EMME region should attain the average global emission reduction of 32% and 49.99% (for the 2 °C and 1.5 °C targets respectively) and total emission reductions are allocated based on each country's carbon intensity .	Capability (emission intensity)
	3.3	The EMME region attains the average global emission reduction of 32% and 49.99% (for the 2 °C and 1.5 °C targets respectively) and total emission reductions are allocated based on each country's cumulative emissions per capita.	Responsibility
	3.4	Half of the abatement needed to reach the global per capita emission target (approach 1.1) is combined with half of the abatement that is calculated based on each country's per capita GDP ranking (approach 3.1).	Combination of Equality and Capability (ability to pay)
	3.5	Half of the abatement needed to reach the global per capita emission target (approach 1.1) is added to half of the abatement that is calculated based on each country's carbon intensity ranking (approach 3.2).	Combination of Equality and Capability (emission intensity)
	3.6	Half of the abatement needed to reach the global per capita emission target (approach 1.1) is added to half of the abatement that is calculated based on cumulative emissions per capita (approach 3.3).	Combination of Equality and Responsibility
	3.7	The average abatement of four approaches is taken to allocate the required abatement: the required global per capita emissions target (approach 1.1), GDP per capita (approach 3.1), carbon intensity (approach 3.2) and the emissions per capita (approach 3.3).	Combination of Equality, Capability (ability to pay and emission intensity) and Responsibility
	3.8	The average abatement of three approaches is taken to derive the abatement: GDP per capita (approach 3.1), carbon intensity (approach 3.2), and emissions per capita (approach 3.3).	Combination of Capability (ability to pay and emission intensity) and Responsibility

reductions are more directly tied to the countries' current economic structure and are thus more difficult to achieve than in other less energy-intensive nations.

For reasons of global fairness, it is not advisable to completely ignore the uniform per capita emissions criterion. However, in order to reach politically feasible allocations, a combination with one or more additional criteria like per capita GDP, per capita cumulative carbon emissions, or carbon intensity can lead to a more balanced decarbonisation burden. Approaches 3.4–3.7 demonstrate such examples. In such a case, the EMME region would commit to stronger emission abatement than the world average, which is fair for global standards. At the same time, it would allow temporary emission increases in poorer nations of the region like Syria, Palestine and Egypt, and would put a stronger decarbonisation burden on the richest countries – which is, however, considerably smaller than the corresponding burden of the 'globally fair' allocation of approach 1.1. Although equality is important, aiming for equal per capita emissions, such as in approaches 3.4–3.7, might not be a completely fair and realistic solution given the very different starting points of each country and the strong reduction required in some countries. Approach 3.8 illustrates an example that integrates the use of historical cumulative emissions, GDP per capita and carbon intensity while excluding approach 1.1.

An alternative would be to apply for the EMME region, the same percentage reduction in 2030 emissions as required worldwide, i.e. 32% and 50% from 2019 levels for the 2 °C and the 1.5 °C global warming targets respectively. If one applies this objective in combination with a ranking of EMME countries based on per capita GDP or emissions, as done in approaches 3.1–3.3, the result is a relatively fair intra-EMME allocation that, however, does not allow poorer countries to temporarily increase their emissions up to 2030, which may thus constrain their development. It should be noted that some approaches result in significantly higher CO_2 emission reductions in the EMME region compared to what is recommended for the global targets, meaning that a higher burden is put on the EMME countries, on average, than the rest of the world (approaches 3.4–3.7).

Finally, approaches 2.1–2.5 can lead to similar results to approaches 3.4–3.7 but can also present drawbacks: they result in unrealistically high percentage reductions by 2030 compared to 2019 (as observed in approaches 2.3 and 2.5) and/or they lead to an overall reduction in EMME emissions that might not be in line with the 1.5 °C target of the Paris agreement (approaches 2.2–2.4).

It is interesting to note that the variability in allocated emissions reduction across the effort sharing approaches is less variable for some countries than for others. For instance, for the 2 °C target, the emission reduction targets for Greece range between 36 and 66%, while in the case of Palestine, these range between an increase in emissions by 458% and a reduction of 60%; similarly, the emission reduction range for Qatar is between 13 and 91%. Hence, certain countries, such as Palestine and Qatar, are likely to lobby strongly for specific approaches that are more favourable to them, while others, such as Greece, may be indifferent to the specific approach pursued.

3.2. Comparison with submitted nationally determined contributions (NDC)

While assessed effort sharing approaches provide a framework for emissions reductions, Nationally Determined Contributions (NDCs) indicate the actual emissions reduction intentions of individual countries. Hence, it is important to assess the emissions mitigations required by the approaches considered in this paper relative to planned actions articulated in NDCs as this assists in directly evaluating the realistic attainability of the estimated emission reductions.

The emission reduction pledges provided in NDCs (UNFCCC, 2021) cover the total greenhouse gas (GHG) emissions (i.e. in CO_2-eq) and are calculated either based on the expected GHG emissions in the country during a specific target year or based on the actual GHG emissions in the country in a previous reference year. To enable a more direct comparison, these data were transformed into emission reduction targets between the target year as indicated in the NDCs of each country and a common reference year. The reference year was selected based on the most recently available data on total GHG emissions, which is 2016 (Our World in Data, 2021). The data derived from the NDCs, where quantitative data were available, are shown in Table 3, along with a direct comparison with the CO_2 emission reduction ranges of the assessed effort sharing

Table 3. GHG emission reductions based on NDCs and comparison with CO_2 emission reduction ranges from the assessed effort sharing approaches. A negative percentage reduction represents an emissions increase.

	Target year	Emissions (million tonnes CO2-eq) – reference year (i.e. 2016)[a]	Emissions (million tonnes CO2-eq) – target year[b]	Percentage GHG emissions reduction between the target and reference year[c]	CO_2 Emission reduction ranges (2030)	
					2°C target	1.5°C target
Bahrain	-	-	–	–	18%–83%	29%–88%
Cyprus	2030	8.26	7.28	12%	27%–63%	43%–75%
Egypt [d]	2030	310.42	>341.7	-10%	-42%–32%	-4%–50%
Greece	2030	86.36	54.24	37%	36%–66%	55%–93%
Iran	2030	867.96	651.87	25%	16%–65%	26%–75%
Iraq	2035	191.41	262.30	-37%	14%–40%	22%–52%
Israel	2030	90.08	58	36%	26%–68%	40%–97%
Jordan	2030	35.72	30.29	15%	−19%–42%	13%–60%
Kuwait	2035	111.99	131.72	−18%	19%–87%	29%–91%
Lebanon [e]	2030	31.39	31.16 26.88	1% 14%	15%–48%	28%–66%
Oman	2030	75.98	116.49	−53%	12%–76%	19%–82%
Palestine [f]	2040	4.65	13.13 17.9	−182% −285%	−458%–60%	−309%–78%
Qatar	2030	92.26	–	–	13%–91%	21%–94%
Saudi Arabia	2030	663.58	–	–	18%–80%	28%–86%
Syria	2030	45.38	–	–	−188%–47%	−111%–74%
Turkey	2030	395.95	928.25	−134%	18%–45%	28%–63%
UAE	2030	259.22	178	31%	17%–84%	27%–88%

Notes:
[a]2016 is the year with the most recent data available on total GHG emissions (Our World in Data, 2021).
[b]Emissions in the target year as specified in the NDC submission of each country.
[c]A negative emissions reduction indicates an increase in emissions in the target year compared to the 2016 levels.
[d]Egypt's revised NDC provides emission projections for 2030 only for the electricity, oil and gas, and transport sectors, which corresponded to 43% of its total GHG emissions in 2015.
[e]Lebanon's NDC provides two GHG emission reduction scenarios with respective unconditional and conditional targets.
[f]Palestine's NDC defines two scenarios: one considering only Palestine's land as it is today, and one assuming that Palestine's land will include land that currently is controlled by Israel.

approaches. As illustrated, of the twelve countries for which quantitative information is available, only Greece, Iran, Israel, Jordan and the United Arab Emirates have set emission reduction targets that are within the calculated ranges compliant with the 2 °C warming target, while only Jordan and the UAE marginally fall within the ranges for the 1.5 °C warming target. Palestine, which projects to significantly increase its GHG emissions, also falls within the ranges for both warming targets. In addition, the UAE's third NDC submission commits to approximately 15% lower emissions by 2030 than the level committed in the country's second NDC (UAE Ministry of Climate Change & Environment, 2023).

Some countries have negative reductions, meaning that GHG emissions are expected to increase by the target year compared to the 2016 levels. The countries for which this is observed are Egypt, Iraq, Kuwait, Oman, Palestine and Turkey. This occurs because the relative reductions in NDCs are set based on the expected, or 'business-as-usual', emissions in the target year, which are estimated to increase compared to the 2016 levels. The climate targets in these countries indicate that their GHG emissions will grow significantly in this decade, but the growth will be restricted in comparison to a hypothetical case without abatement measures. For example, Turkey is expected to have an enormous increase in GHG emissions in the next decade. However, by following their climate actions as stated in their NDC, this increase is projected to be 21% less than a case without any climate mitigation actions.

By taking the percentage change between 2016 and the target year for the whole area, and considering only countries for which quantitative data are available, GHG emissions remain relatively stable. In fact, a mild decrease of 1% is noticed. This is not in line with the regional emission reductions derived in the assessed effort sharing approaches. This finding is further supported by the conclusions of previous studies, which have shown that the aggregate impact of the NDCs is insufficient to meet the 2 °C and 1.5 °C climate stabilisation targets (Robiou du Pont et al., 2017; Roelfsema et al., 2020; Rogelj et al., 2016). However, a comprehensive

comparison between the emission reduction ranges from the effort sharing approaches and the emission reduction intentions outlined in each country's most recent NDC, is not possible for all EMME countries for four main reasons:

i. Not all NDCs submissions provide quantitative data as part of the proposed mitigation actions.
ii. The emission reduction targets provided in many NDCs cover all GHG emissions, whereas the present analysis focuses on CO_2 emissions only.
iii. The most recent data on total GHG emissions are provided for 2016 (Our World in Data, 2021) while the most recent data on CO_2 emissions are available for 2019 (Our World in Data, 2021).
iv. The target year for most countries is 2030, which coincides with the target year used in the present effort sharing scenarios. However, Iraq, Kuwait and Palestine have different target years; 2035 and 2040 respectively.

More recently, several countries from the region have communicated their commitment to a net-zero emission future in official policy documents, including Greece, Israel, the UAE, Oman, Turkey, Bahrain and Saudi Arabia, while such a pledge is under discussion in Lebanon and Cyprus (Energy & Climate Intelligence Unit, 2021). In the case of Israel, the effort sharing approaches provided a range of reductions of 26–68% (50% average) for the 2 °C target and 40–97% (68% average) for1.5 °C target. Similarly, the UAE's range of emissions reduction is estimated between 17 and 84% (55% average) for the 2 °C target and 27–88% (67% average) for the 1.5 °C target; thus, only marginally falling within the range for the 1.5 °C target even after accounting for a more ambitious target in the country's third NDC. As such, considering their NDC emission reduction pledges, Israel and the UAE may need to revise their medium-term (i.e. 2030) mitigation efforts if they are to achieve their net-zero 2050 aspirations.

Similar to Israel and the UAE, Turkey has a 2050 net-zero target that is unlikely to be attained without increased mitigation efforts. At the present time, Turkey is expected to more than double its emissions by 2030. This finding agrees with assessments that existing climate policies in Turkey and the UAE are critically insufficient and highly insufficient, respectively (Climate Analytics and NewClimate Institute, 2023). We revisit this issue in the conclusions when noting that countries with net-zero aspirations but insufficient 2030 carbon mitigation commitments may need to take accountability for carbon management and mitigation approaches that presently are not cost-competitive. These particularly include negative emissions approaches like direct air capture of carbon or bioenergy with carbon capture and storage (BECCS) for EMME countries that have significant biomass potential.

3.3. Assessment of realism and fairness

The results from the effort sharing approaches of the 1.5 °C case were evaluated against the realism and fairness criteria established for this work in order to assess the scenarios most likely to succeed. Even though the criteria cannot be regarded as strict, only two approaches pass all three criteria; approaches 3.3 and 3.8 (see section 4 of the SM). Thus, the level of emission reductions estimated in these two approaches may have the best chance for success if regional negotiations on climate mitigation were to occur. It is also interesting to note that approaches 3.3 and 3.8 relate to the equity principles of responsibility and capability, in line with the wording used in Article 4.3 of the Paris Agreement and as quoted in section 2.3 of the present paper. However, according to these approaches, all countries are forced to decrease their emissions by 2030 as compared to 2019 levels. This may be difficult for low-income, developing countries, such as Palestine, or fragile states that are recovering from long periods of conflict, such as Syria. Hence, the latter part of the quote regarding the consideration of special 'national circumstances' is not fully captured.

To illustrate an indicative pathway in line with one of the two approaches (3.3) that agree with all three criteria, Figure 1 presents the emissions per capita of each country in 2019 and the target values for these emissions in 2030 according to the abatement effort, before they reach the Paris-compliant zero-emission goals in 2050/2070. The second approach (3.8) offers a very similar outlook.

Results from the effort sharing approach 3.3 indicate that the group of countries that are allocated a greater percentage level of emissions abatement correspond to countries with a high GDP per capita and high levels of

CO_2 emissions. These top five countries are Qatar, Kuwait, Bahrain, the UAE and Saudi Arabia. As such, if these countries are to align their development plans with the Paris Agreement's goals, diversification of the energy supply towards zero and low-carbon technologies is necessary. Since these countries are rich in fossil fuel reserves and are net exporters of energy, they have a greater financial capacity to pursue such a low-carbon transition, which can arguably be considered as a fair with regard to effort sharing.

4. Conclusions

The pursuit of adequate climate change mitigation action is a necessity to achieve the Paris Agreement's global climate targets, thus minimizing the impact of climate change on ecosystems and livelihoods. However, the level of emission abatement effort should reflect the socioeconomic context of each country or region, as well as its contribution to historical greenhouse gas emissions. Our analysis has considered these aspects in the methods developed and the approaches assessed, resulting in a wide array of regional and national emission reduction targets for countries in the EMME region; a region that often remains unexplored in the scholarly literature. Some of the countries have a relatively invariant contribution across approaches, while for others, the approach taken matters a great deal. Hence, our paper has provided a methodology to allocate decarbonisation effort, highlighting the need for fairness to be considered in climate discussions in EMME and globally. While we have proposed criteria to determine approaches that are fair and realistic, we note that these are open to discussion and debate. What is most important to glean from these criteria is that any approach that is deemed politically viable must consider the extent to which any individual country is impacted and the relative impacts experienced by any particular country relative to its peer group. In this study, countries in the EMME region represent the peer group, although we have noted in several instances the significant socioeconomic heterogeneity that exists among EMME countries.

Two of the approaches assessed were considered as fair and realistic in line with the three criteria of responsibility, capability, and equality; one approach relates to the principle of responsibility, while the other relates to a combination of capability and responsibility. However, additional country-specific aspects may need to be taken into account before considering either of these approaches as viable. Some countries, especially the fragile states, require particular consideration, as their present social, economic and political situations do not necessarily allow them to take immediate climate change mitigation actions aligned with their historical emissions. One notable example is Syria, where a decade of civil conflict has shattered the national economy and destroyed critical infrastructure. Therefore, in order to provide more flexibility to such low or lower middle-income countries, taking into account unique national circumstances, an additional iteration that distributes the abatement effort needed from these countries to the rest of the countries of the region may be warranted. In selected cases, emissions could potentially be allowed to increase modestly, if this can have a significant beneficial impact on the economic growth of low income and lower middle-income

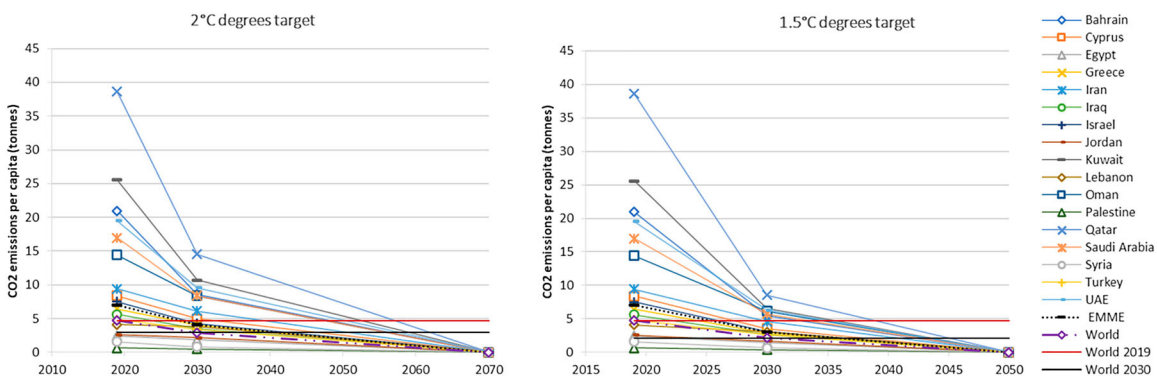

Figure 1 . CO_2 emissions per capita projections in line with the Paris agreement targets for approach 3.3. The first graph illustrates the case for 2 °C and the second graph for 1.5 °C. The corresponding global per capita emissions in 2019 and 2030 are shown with horizontal lines.

countries. We also note that for countries with emissions that are deeply ingrained in their economic structures, such as the GCC countries, the levels of decarbonisation required by 2030 in the approaches deemed fair and realistic may no longer be achievable in such a short timeframe. For such countries, a path forward, and perhaps the only viable path forward, to align with global climate change mitigation efforts may be to take a leading role in implementing Circular Carbon Economy (CCE) (Saputra et al., 2022) and/or Extended Producer Responsibility (EPR) principles (Jenkins et al., 2023). Both CCE and EPR promote carbon removal as means of achieving net-zero carbon emissions while CCE further emphasizes carbon reduction, recycle and re-use. Given that the economic structures of these wealthier countries may not allow them to radically reduce carbon emissions by 2030, these frameworks would hold them accountable for developing and implementing carbon removal and use solutions, such as point-source and direct-air carbon capture and geologic CO_2 storage. As discussed with regard to net-zero aspirations, negative emissions may be required for these countries, and others, that cannot achieve 2030 emission reductions in a manner that provides a realistic net-zero 2050 pathway.

Despite the recently updated NDCs and net-zero commitments of several EMME countries, none have yet proposed a strategy that could reduce 2030 carbon emissions by more than half relative to 2019 levels, as would be necessary to be clearly on track for achieving stated net-zero ambitions. This study, therefore, serves as notice to these countries, as well as to the global community, that their stated climate ambitions do not track with reality. Furthermore, the results show that achieving equitable emission reduction targets requires consideration of factors, such as realism, that are less often discussed than those that are purely socio-economic in nature.

The findings of this study also have a broader applicability to climate negotiations. Specifically, the EMME region can be considered as representative of the broader global context; a mix of lower versus higher income countries, resource-rich versus resource-poor countries, and carbon-intensive versus less carbon-intensive countries. The approach to be adopted in setting national greenhouse gas emission reduction targets is greatly affected by the indicators considered and countries may be more or less favoured depending on the particular method taken to allocate climate change mitigation targets. Hence, the usual criteria for determining fair share emissions reductions – equality, responsibility and capability – should be bounded by considerations of realism and fairness. As discussed in this paper, taking such an approach can help identify emissions reduction approaches that are relevant not just to the EMME, but globally as well. This said, although quantitative effort sharing approaches may theoretically provide an appropriate method to allocate climate mitigation burden, additional considerations, even if qualitative in nature, may be needed to account for unique national circumstances. Wealthier countries may ultimately need to take up portions of the burden of the allocated effort from nations with limited current capacity for climate action.

In considering the direct regional benefits that may accrue from the results of this study, a focus on coordinated climate change mitigation action may enable countries of the region to shift their current emissions trends to a lower emissions trajectory than could otherwise be possible. Regional cooperation, for instance through renewable electricity trade or technology knowledge exchange, can assist the achievement of emissions reduction targets that are fair and realistic. Similarly, financing of projects that reduce greenhouse gas emissions in countries with a lower GDP per capita, such as renewable energy facilities, energy efficiency interventions or waste management, by the richer countries of the region may provide the momentum needed to put EMME countries on a path compliant with the Paris Agreement goals. This can provide a necessary motivation for countries in the region that are not ready to rapidly and independently decarbonise for reasons already discussed. Finally, wealthier countries in the region that are unlikely to achieve the levels of emissions mitigation proposed by 2030 may take greater responsibility for developing and deploying emissions management and removal technologies that may ultimately be required for global climate change mitigation targets to be achieved. Future work may include the pursuit of such suggestions in parallel to the development of long-term energy system pathways for the EMME region, pathways that aim to operationalize a select mix of the approaches suggested here.

Competing interests

The authors declare no competing interests.

Notes

1. The EMME region as defined in this paper consists of: Bahrain, Cyprus, Egypt, Greece, Iran, Iraq, Israel, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, Syria, Turkey, and the United Arab Emirates (UAE).
2. Carbon budget denotes the maximum amount of future cumulative CO_2 emissions that are consistent with a given global warming limit.
3. Since the most up-to-date data are available for 2019, this year was used as the base year for the analysis. A future year was not chosen to reduce uncertainty around the data.
4. In cluster 3, a linear interpolation between of 0% and 50% was determined and assigned to each country based on its specific indicator rankings. For example, based on each country's GDP per capita, countries with high GDP per capita have a high percentage reduction in their CO_2 emissions, while those with low GDP per capita will be allocated a lower percentage reduction. After assigning the percentages to each country, the total emission of the region was calculated, and a correction factor (either positive or negative) was added to each country, so that the regional percentage reduction aligns with the global reduction necessary to meet the Paris agreement targets; 32% and 49.99% for the 2°C and 1.5°C targets respectively.
5. Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates

Disclosure statement

No potential conflict of interest was reported by the author(s).

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