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Supporting the Paris Agreement through international cooperation: potential contributions, institutional robustness, and progress of Glasgow climate initiatives



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Many sector-level cooperative initiatives involving both national governments and non-state actors were launched around the 2021 Glasgow climate conference (COP26). However, there have been questions about whether and to what extent these initiatives could substantially contribute to achieving the Paris Agreement's goal to limit global warming to 1.5 °C. To this end, this paper examines the prospects of the 14 Glasgow sector initiatives by investigating their aggregate mitigation ambition under current national signatories and the institutional robustness of each initiative. We find that the additional emission reduction ambition of the current national government signatories would, even if fully implemented, only fill about a quarter of the emissions gap in 2030 between the aggregate of existing national targets (nationally determined contributions: NDCs) and the required emission levels consistent with keeping warming below 1.5 °C, while the institutional robustness varied considerably across the initiatives. We also find that most national government signatories did not mention Glasgow initiatives in their updated NDCs submitted after COP26. Expansion of the national government participation, national government signatories' incorporation of the initiatives' goals into their updated NDCs by setting quantifiable domestic targets, and enhanced institutional capacity are key to successful emission reduction outcomes.

In the lead-up to the 26th Conference of the Parties (COP26) to the UNFCCC held in Glasgow in November 2021, then-UK Prime Minister Boris Johnson called to world leaders to come up with ambitious commitments on “coal, cars, cash and trees”¹. As a result of the UK COP26 presidency's diplomatic effort, an unprecedented number of actors, both national governments and non-Party stakeholders committed to ambitious emission reduction goals through international cooperative initiatives, which include various “alliances”, “declarations”, “coalitions”, or “partnerships”². These initiatives aspired to bring the global warming limit of 1.5 °C in reach and to achieve global net-zero CO₂ emissions by 2050, which the Glasgow Climate Pact set as the principal ceiling for warming in the international climate negotiations^{2,3}.

The Glasgow initiatives are representative of a trend observed in recent climate summits to engage more actors in a certain sector in ambitious climate action beyond national borders to complement the formal UNFCCC process^{2,4}. There are different views on the possible contributions of these international initiatives. On the one hand, such engagements could contribute to enhancing climate ambition, particularly in terms of climate change mitigation. Earlier studies suggested a significant emission reduction potential of international climate initiatives and partnerships if fully implemented^{5,6}. On the other hand, COP presidencies and governments and leaders of initiatives have also been criticized for making promises that may look good at first glance but lack substantive commitment – especially when

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attention fades after initiatives are launched at COPs and summits^{2,7}. Indeed, global greenhouse gas (GHG) emissions continue to rise and the world is currently on track to a warming above 2.5 °C⁸, and some suggest that international climate initiatives have not been able to effectively deliver what they have committed to^{4,9}. Therefore, it is crucial to assess the Glasgow sector initiatives in terms of both their collective ambition and the institutional robustness, or institutional set-up, to obtain an enhanced understanding of their potential contributions to achieving the long-term goals of the Paris Agreement. On a country level, there are many studies that quantitatively and qualitatively assessed nationally determined contributions (NDCs) and long-term decarbonisation plans^{10–14}, but few have investigated the countries’ engagements with international cooperative initiatives and how they are related to the countries’ NDCs and long-term mitigation targets.

Against this backdrop, this paper examines the prospects of 14 major sector-level cooperative initiatives that were launched or revamped (including the update of their goals) in the lead-up to and during the COP26 and highlighted in both official and independent conference summary documents^{15,16} (see Fig. 1; Methods, and Table 3). Selected initiatives are those that focused on GHG emissions from national and non-state actors in their respective targeted sectors. We aim to obtain insights into whether the international initiatives launched around COP26 (hereinafter, “Glasgow initiatives”) would meaningfully contribute to the achievement of the Paris Agreement. We specifically focus on the participation and the potential impact of national governments. To this objective, we ask the following three specific research questions: (i) How large are the potential GHG emission reductions in 2030 resulting from the full implementation of the Glasgow sector initiatives’ sector targets? (ii) Do the Glasgow sector initiatives have a robust institutional set-up to implement their targets? (iii) To what extent the national government signatories of the Glasgow sector initiatives have incorporated the initiatives’ targets into their NDCs updated after COP26? To answer these questions, we applied both quantitative and qualitative methods, partially based on our previous research^{4,5,17}.

The 14 Glasgow sector initiatives assessed in this study are: five Glasgow Breakthrough sector initiatives (power, road transport, hydrogen, steel, agriculture), Global Coal to Clean Power Transition statement, Powering Past Coal Alliance (PPCA), No New Coal Compact, Beyond Oil and Gas Alliance (BOGA), Accelerating to Zero (A2Z) Coalition (launched as “COP26 declaration on accelerating the transition to 100% zero emission cars and vans”), Clydebank Declaration for green shipping corridors, International Aviation Climate Ambition Coalition, Glasgow Leader’s Declaration on Forests and Land Use (“Glasgow Forests

Declaration”), and the global Methane Pledge (see Table 3 for their objectives).

Results

National government signatories

We first looked at the number of national government signatories for the Glasgow sector initiatives assessed as of January 2023 based on publicly available information and their net coverage of annual global sector total GHG emissions in respective focus sectors (Fig. 1 on 12 initiatives with quantifiable 2030 goals; see Online Dataset 1 for country-and initiative-specific results). The land use sector is very well covered by the Glasgow Forests Declaration in terms of both the number of countries and the coverage of GHG emissions from the land use, land-use change and forestry (LULUCF) sector; the Global Methane Pledge also showed relatively high global emission coverage by the signatories at around 60%. These initiatives stem from the long-term efforts through the Climate and Clean Air Coalition (methane) and the New York Declaration on Forests (forestry), respectively.

By contrast, current national government signatories represent a small fraction of the energy and industry sector emissions covered by the Glasgow initiatives. The absence of China in these Glasgow initiatives is most notable. Among the initiatives assessed, China is a signatory to only two Glasgow initiatives (the Glasgow Forests Declaration and Glasgow Breakthrough on Hydrogen); it has endorsed the Glasgow Breakthrough Agenda but only the sector goal on hydrogen. China is also yet to join the Global Methane Pledge.

The lack of participation by the major emitters is more evident when seeing which countries participated in more of the 14 Glasgow initiatives. Countries with the largest participation in Glasgow sector initiatives are predominantly high-income countries including most of G7 (Canada, France, Germany, Italy, Japan, the United Kingdom, the United States of America) and the EU member states (Table 1; see Methods for data collection). By contrast, the participation of G20 countries that are not in the G7 was found to be low, with the Republic of Korea being the highest with seven initiatives. More importantly, two of the largest emitters China and India have only signed up to two and three initiatives as of January 2023, respectively.

These findings do not necessarily mean that G7 countries are more ambitious than the non-G7 G20 countries (see Online Data Set). Detailed results indicate that many of them only participate in the initiatives with targets they are more likely to be able to achieve. For example, Australia and Japan do not participate in the Powering Past Coal Alliance and the No New

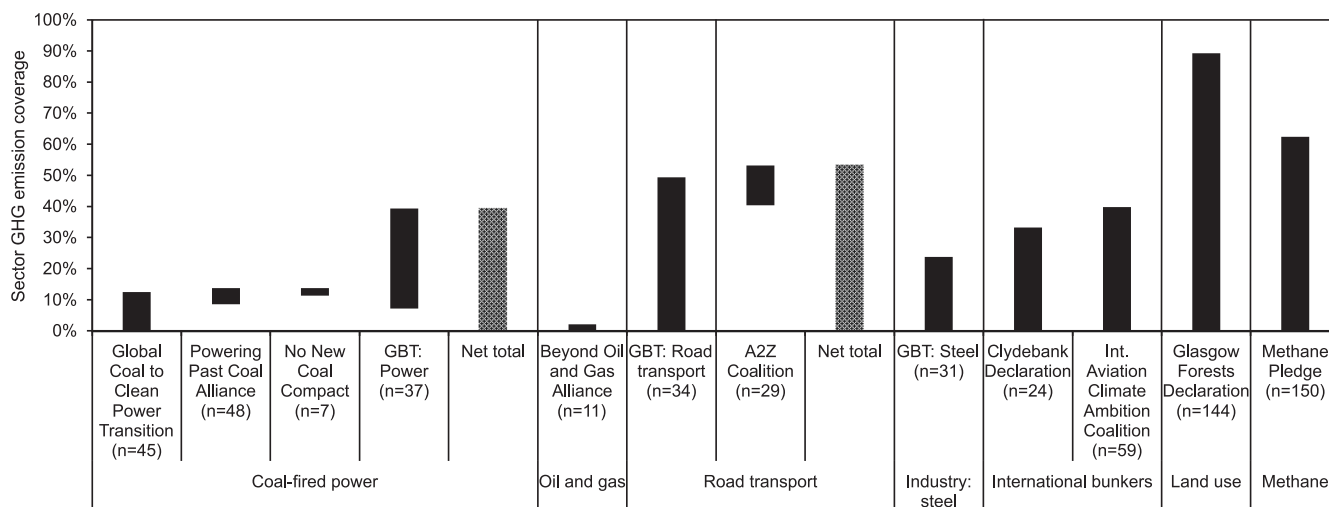


Fig. 1 | The sectoral greenhouse gas emissions coverage by the national government signatories of 12 Glasgow sector initiatives. The number of national government signatories as of January 2023 is provided in parentheses. Emission estimates are based on 2019 sector emissions for coal-based power, oil and gas

supply, road transport and steel⁵⁷, 2019 economy-wide emissions for international bunkers and 2019 methane emissions from PRIMAP-hist ver. 2.3.1⁵⁸, and 2016–2020 average deforestation-related emissions from Grassi et al.⁵³

Table 1 | Number of Glasgow sector initiatives participated by countries as of January 2023 (total number of initiatives assessed: 14)

No. initiatives	Countries
Countries with the largest number of initiatives participation (bold: G20 members, incl. EU member states)	
13	Denmark, France, Ireland, UK
12	Finland, Germany, Sweden
11	Belgium, Canada, New Zealand
10	Morocco, Netherlands, Spain
9	Italy, Japan, Norway, Portugal
8	Australia, Azerbaijan, Chile, Israel, Luxembourg, USA
Other G20 members	
7	European Union, Republic of Korea
4	Mexico, Turkey
3	India, Indonesia
2	Argentina, Brazil, China
1	Russia, Saudi Arabia
0	South Africa

Coal Compact as they both rely heavily on coal; five countries do not associate themselves with the Beyond Oil and Gas Alliance, which asks countries and subnational governments to commit to reducing oil and gas production in line with the objectives of the Paris Agreement. The findings here support an argument that side-agreements to the COP decisions like the Glasgow sector initiatives bring together mainly countries that have either fairly high confidence levels of achieving the goals due to their relatively lower costs to achieve them and/or their relatively high capacity to bear the costs^{2,18}.

On the progression of the number of national government signatories, the Global Methane Pledge was the only initiative that showed a considerable increase of signatory national governments post-COP26 (from 110 in November 2021 to 150 in November 2022). For Glasgow Breakthrough sector goals for power, road transport, steel and hydrogen, we find interesting trends in the countries' participation post-COP26. At COP27 each sector Breakthrough outlined their "priority international actions" for 2023 (hereinafter, "2023 priority actions"); there were a significant number of countries that endorsed the sector goals in November 2022 that did not support any of the 2023 priority actions. These countries include the USA for the power and road transport sectors and the Republic of Korea for the power, hydrogen and steel sectors (see Online Data Set). Some of these countries needed more time domestically to decide on their participation in the 2023 priority actions, while others may have actively declined to take part due to e.g. the limited relevance of the priority actions for their climate policy implementation or various political or diplomatic constraints.

Potential mitigation contributions by 2030

For the GHG impact quantification, we assessed in detail 12 initiatives that have set quantitative goals and could be translated into GHG emission terms. We did not quantify the impact of the Glasgow Breakthroughs Hydrogen and Agriculture, because their 2030 goals are not quantifiable in terms of GHG emission reductions. We developed two Glasgow initiatives scenarios to assess the potential GHG impact in the year 2030 of the initiatives assessed in this study and their national government signatories as of January 2023. First is the Glasgow Initiatives–Current Signatories ("Glasgow-Signatories") scenario, which assumed that national government signatories as of January 2023 would fully implement the 1.5 °C-aligned and quantifiable sector transition goals for 2030 in respective initiatives' focus sectors. The Glasgow-Signatories scenario also informs us of the extent to which the NDCs can be strengthened globally if the national government

signatories to these Glasgow initiatives would reflect the initiatives' ambition. The second is the Glasgow Initiatives–Global Ambition ("Glasgow-Ambition") scenario, which provides an indicative estimate of the fraction of the emissions gap, i.e. difference between the GHG emissions resulting from full implementation of NDCs and those consistent with the least-cost 1.5 °C-consistent emission pathways¹⁹, the Glasgow initiatives collectively aspire to fill by 2030.

The potential impact estimates for the Glasgow initiatives scenarios were assessed by quantifying how much of the emissions gap between the baseline NDC (BL-NDC) scenario and the benchmark 1.5 °C (BM-1.5) scenario would be filled by the initiatives' signatories, assuming the initiatives aim for 1.5 °C-aligned sectors that they target. The BL-NDC scenario assumed full implementation of both unconditional and conditional Nationally Determined Contributions (NDCs) and other announced targets as of mid-2021 (see methods for detailed scenario description and underlying assumptions). Both the BL-NDC and BM-1.5 scenarios were developed based on IEA²⁰ for energy and industry CO₂ emissions and other external scenarios for other sectors and non-CO₂ gases (see Methods for detailed description). Country-specific projections were developed for eight major emitting countries for energy CO₂ emissions, industry process-related CO₂ emissions and non-CO₂ emissions and for 99 countries for the land-use sector (see Methods and Supplementary Methods for details).

Global GHG emissions were projected to reduce from 53 GtCO₂e in 2019 to 49 GtCO₂e in 2030 for the BL-NDC scenario and to 33 GtCO₂e for the BM-1.5 scenario (Fig. 2; left panel). The BL-NDC scenario projections are on the lower end of the range derived by UNEP²¹ but are similar to the most recent external projections^{22,23}; the BM-1.5 scenario projection is on the upper end of the range derived from scenarios reviewed by the IPCC AR6 that limit warming to 1.5 °C with a 66% chance by 2100²⁴ but is identical to the median estimate²¹. Following the definition of the UNEP Emissions Gap Report²¹, the emissions gap in 2030 between BL-NDC and BM-1.5 scenarios is estimated to be 16 GtCO₂e.

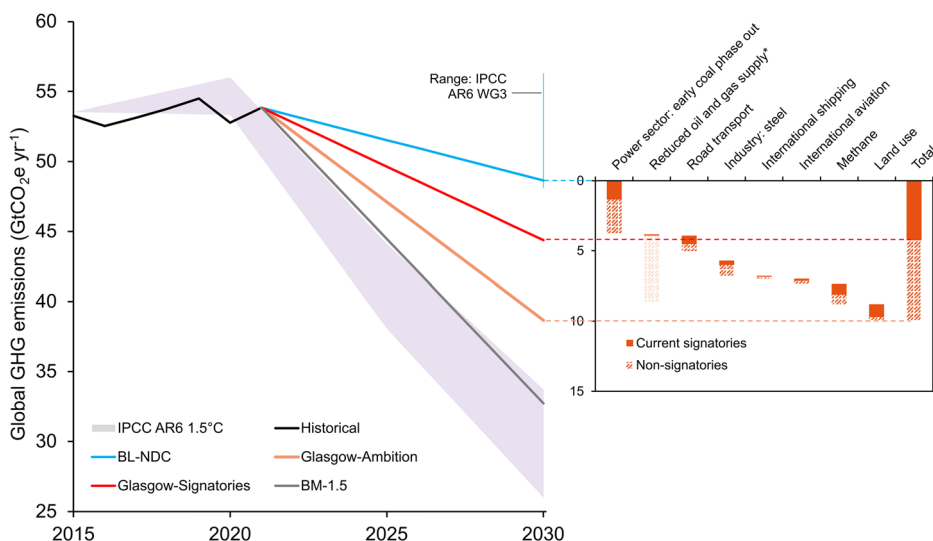
If we assume that all countries around the world participate in the 14 Glasgow sector initiatives assessed in this study and fully deliver, the Glasgow-Ambition scenario emission projections show that the initiatives could altogether fill 65% (10 GtCO₂e) of the 16 GtCO₂e 2030 emissions gap, if the sectors and emission reduction measures indicated by the initiatives themselves are rolled out globally and fully delivered (Fig. 2). The largest potential reductions were found in the power sector, followed by methane, land use, and road transport.

Full implementation of the initiatives' goals for 2030 by the national government signatories as of January 2023 as represented in the Glasgow-Signatories scenario is projected to fill about 4 GtCO₂e of the 16 GtCO₂e emissions gap (Fig. 2). About a quarter of the projected emission reductions under the Current Signatories scenario were found in the land-use sector alone, where we observed a large number of signatories in the Glasgow Forests Declaration.

Another partial explanation for the limited emission reduction potential of the Glasgow-Signatories scenario is that a considerable number of signatory countries already had sector targets under their NDCs that were equally ambitious as the Glasgow initiatives imply even before signing up for them. Glasgow initiatives are all aspired to limit warming to 1.5 °C, but the magnitude of the challenge of implementing 1.5 °C-compatible sector actions differs significantly across countries. One example is the Powering Past Coal Alliance, in which many signatories had limited reliance on coal-fired power anyway when they joined the alliance¹⁸ (Fig. 1).

Nevertheless, full implementation of the Glasgow-Signatories scenario could reduce global GHG emissions to 44 GtCO₂e in 2030, which is in line with a warming of 2 °C in 2100 (66% chance)²¹. The results also suggest that the collective ambition of countries to reduce GHG emissions for 2030 under current NDCs could be strengthened by another 4 GtCO₂e if the national government signatories reflect the initiatives' ambition in their updated NDCs.

Fig. 2 | Potential GHG emission reductions resulting from full implementation of the selected Glasgow sector initiatives. (Left) Emission projections for the two Glasgow initiatives scenarios, in comparison with the baseline NDC scenario and the benchmark 1.5 °C scenario. The projection ranges from the IPCC AR6 WG3 scenario groups are presented as a shaded area for the 1.5 °C-consistent pathways (66% chance with limited or no overshoot: 10th–90th percentile) and as bars for the baseline NDC scenarios (low: 10th percentile for conditional NDCs, high: 90th percentile for unconditional NDCs). (Right) Coverage of the emissions gap between the reference NDC and the benchmark 1.5 °C scenarios addressed by the 14 Glasgow initiatives. *Due to overlaps with other sectors and very broad sector coverage, we only use the current membership of initiatives in this sector as additional impact. The impact shown here illustrates the sector’s significance.



Glasgow sector initiatives in updated NDCs

For the Glasgow sector initiatives to maximise their potential impact, it is important that more national governments join the initiatives and that the signatories strengthen their commitment to the initiatives’ goals by incorporating them into their national commitments. We, therefore, examined whether national governments have incorporated the initiatives’ goals in their NDCs that were submitted after COP26 (see Methods, “Glasgow initiatives in updated NDCs”). We identified 38 updated NDCs submitted to the UNFCCC registry between December 2021 and January 2023²⁵, 34 of which have signed up to at least one of the 14 Glasgow sector initiatives assessed in this study. Among the 34 countries, the UK as the COP26 presidency was the only country that referred to all initiatives launched at COP26. For the rest, only one country referred to the Glasgow Breakthroughs (Dominica), the Glasgow Forests Declaration (Vietnam) and the Global Coal to Clean Power Transition (Vietnam), and four countries to the Global Methane Pledge (Micronesia, Republic of Korea, and Vietnam) in their respective updated NDCs.

Institutional robustness

While the above findings indicate considerable GHG mitigation potential of Glasgow initiatives, progress against targets is far from guaranteed. Scholars have argued that transparency and capacity are necessary for achieving effectiveness of initiatives with non-state actors, e.g., partnerships for sustainable development^{26,27}, and international cooperative climate initiatives^{17,28}. In regime and governance studies, institutional robustness is conceptualized as endurance or stable organizational characteristics that are subject to only slow modifications over time^{29–31}. This understanding of institutional robustness has previously been applied to the study of transnational climate action to determine the credibility and capacity of institutions to deliver on climate commitments, for instance by leveraging resources, or by ensuring broader legitimacy^{4,28,32,33}.

As many factors may contribute to credible delivery on commitments, operationalizations of institutional robustness vary and are often constrained by the availability of data. This study particularly focuses on capacities and institutional characteristics of cooperative initiatives; we assessed the 14 Glasgow initiatives against the following six indicators (see Methods “Institutional robustness indicators” for the rationale in the selected indicators and Supplementary Table S-2 for coding details): (i) Secretariat: a dedicated secretariat or employed staff that can be contacted; (ii) Governance structure: organizational arrangements or organizational charts are made explicit, detailing decision-making and reporting structures; (iii) Budget: the budgets to implement activities are explicitly mentioned; (iv) Openness of membership: initiatives invite other/new actors join as a

member, allowing for the scaling of initiatives and their impacts and outcomes; and (v) Monitoring: initiatives have monitoring frameworks, and (vi) Publication: regular progress reports or GHG emissions reports.

Institutional robustness indicators give a necessary – if minimal – view of whether initiatives have the capacity, and credibly make progress towards achieving desired mitigation impacts. Our analysis of institutional robustness indicators shows gaps that likely hinder the achievement of mitigation potential (Table 2; also see Supplementary Results for detailed assessment results). First, among indicators included in our analysis, we find very little data on the budgets of initiatives. This may point to a lack of transparency, rather than the absence or shortage of budgets. In some cases, information on budgets may be noted on websites other than those of the initiatives, themselves. One example is the Global Methane Pledge, the budgetary contributions of which are mentioned in a press release on the US State Department website³⁴. Due to a lack of data, however, our current analysis cannot determine the budgetary disposition of the other Glasgow initiatives.

Second, the achievement of mitigation potential depends on the ability of initiatives to engage broader participation, including more country signatories. While most initiatives in our sample explicitly invite more actors to participate, there is a lack of clarity of whether such an arrangement exists for the International Aviation Climate Ambition Coalition and the Glasgow Forests Declaration.

Third, despite having much potential within their respective sectors, the International Aviation Climate Ambition Coalition, the Glasgow Forests Declaration, and the A2Z Coalition have remained largely declarative, with limited capacity to coordinate, support, or implement, activities (Table 2). Except for the Clydebank Declaration, such declarative initiatives have also not indicated monitoring arrangements, nor do they explicate processes to encourage wider participation. Our evaluation of the institutional robustness of these initiatives, covering the period until July 2023, may still have overlooked connections and overlaps with prior initiatives, as these were not yet evident during our analysis. These declarative initiatives may still capitalize on existing institutional capacities established by earlier initiatives or evolve as continuations of pre-existing initiatives. However, in some instances, it is not clear how deep or extensive connections are between new and existing initiatives, and whether new initiatives amount to more and more ambitious action. For example, while the Glasgow Forests Declaration was introduced as a new initiative, it has since aligned with the Forest Declaration Assessment, an independent body that tracks the progress of global forest commitments³⁵.

Other declarations may resurface as new initiatives during upcoming climate conferences, supported by clearer commitments and institutional frameworks. However, the lack of transparency about the relation between

Table 2 | Institutional robustness indicators for international cooperative initiatives (re)launched at COP26 in Glasgow

Initiative	Dedicated staff/ secretariat	Transparent organizational governance structure	Transparent budget	Openness of membership	Explicit monitoring arrangement	Publications (general/ emissions reporting)
Glasgow Breakthroughs: Power, Road Transport, Steel, Hydrogen, Agriculture						
Beyond Oil and Gas Alliance (BOGA)						
Global Coal to Clean Power Transition (GCCPT)						
Powering Past Coal Alliance (PPCA)						
No New Coal Compact (NNCC)						
Accelerating to Zero Coalition (A2Z)						
Clydebank Declaration						
International Aviation Climate Ambition Coalition						
Glasgow Leader’s Declaration on Forests and Land Use *						
Global Methane Pledge						

Notes: The research on all initiatives was conducted with the data cut-off date of end-July 2023. Changes to the initiative after this period may affect the results shown.

* The initiative has since 2022 been associated with the Forest Declaration Assessment, an independent body that have assessed the progress of the New York Declaration on Forests³⁵

new and existing initiatives raise questions about the additionality of new announcements. Continuing with the example of the Glasgow Forests Declaration: this initiative shares its aim with the earlier New York Declaration of Forests (NYDF) to stop and reverse the loss of forests and degradation of land by 2030, but we found no indication about how the Glasgow Forests Declaration would build on, or associated with, the previous efforts under the NYDF^{36,37}. Overall, these declarative initiatives represent about 40% of the estimated 4 GtCO₂e mitigation potential for the initiatives’ signatories in 2030. This potential, however, would very unlikely be achieved – even in part – if they fail to develop beyond their declarative nature and gain the resources and capacities to develop and implement targets beyond those under existing initiatives.

Fourth, the Glasgow Breakthroughs on Power, Road Transport, Steel, Hydrogen, and Agriculture; Powering Past Coal Alliance; Beyond Oil and Gas Alliance (BOGA); and the Global Methane Pledge, are among the most robust in terms of institutional robustness indicators. This may partly be attributable to the fact that established and experienced institutions such as the Clean Energy Ministerial and the Mission Innovation are taking stewardship^{38–40}. Dedicated secretariats and dedicated staff, explicit delineations of roles and responsibilities, contribute to these initiatives’ capacity to manage and implement activities. These initiatives also make monitoring arrangements explicit and encourage wider participation, to possibly increase their impact. They represent roughly half of the estimated 4 GtCO₂e mitigation potential in 2030 among the initiatives analysed. The indicators assessed here suggest that these initiatives meet minimal criteria for institutional robustness, making them more likely to realize (parts) of their mitigation potential. However, the full realization of their potential is by no means guaranteed. Scrutiny of achieved emission reductions is necessary. Currently, only the Glasgow Breakthroughs on Power, Road

Transport, Steel, Hydrogen, and Agriculture, and the Global Methane Pledge have reported emission reductions.

Discussion

This article is one of the first independent research to take stock of the Glasgow initiatives after they were launched. The Glasgow initiatives have brought together many national governments and non-state actors to accelerate low-carbon transition across sectors, and they should be commended for the effort made thus far. However, our assessment has shown that the total GHG mitigation potential expected from the current signatories would only fill a fraction of the emissions gap in 2030 even if fully implemented, and the institutional robustness of the Glasgow initiatives varied substantially. Due to the combination of the lack of participation by the key sector players and emitters, limited evidence of follow-ups by signatory countries through national pledges, and scant institutional capacity of many initiatives, especially with those that are declarative in nature, our results indicate that the contribution of the Glasgow initiatives on the ambition-raising and actual emission reductions by 2030 would be limited if the status quo continues.

The findings of this study should be understood with several limitations related to the research scope and methods. First, this study assessed the potential GHG emission impact of the Glasgow initiatives based on the participation of national governments and their potential impact on their respective territorial emissions. Climate action of major economies may have both political and economic impacts beyond their territorial borders. A few of the initiatives assessed in this study focus on low-carbon technology deployment and also have subnational governments and companies as participants (e.g. A2Z Coalition); suppliers of certain technologies could be concentrated in (less than) a handful of countries⁴¹. While

their participation to these initiatives seem to have been limited so far, an increasing number of subnational and corporate actors are expressing their intent to contribute to achieving global net zero emissions^{42,43}. The collective potential mitigation impact of the initiatives may extend beyond that estimated for national policies when their contributions are also considered⁴⁴.

Second, international cooperative initiatives are also active in GHG-emitting sectors that are not covered by the Glasgow initiatives assessed in this study⁵. The UNFCCC's high-level climate champions also announced in November 2022 that the cement and buildings sectors will be added to the Glasgow Breakthrough Agenda from 2023; signatories were not clear as of July 2023³⁸. Moreover, financial sector initiatives announced around COP26 including the Glasgow Finance Alliance for Net Zero (GFANZ) and the eight alliances that comprise it, such as the Net Zero Asset Owners Alliance, could potentially deliver significant emission reductions through realignment of financial flows⁴⁵.

Third, this study only assessed the target ambition and the institutional robustness, which are only the first two stages of the causal chain of progress of climate action, from target-setting to eventual behavioural and environmental impacts⁴⁶. Future research should also assess the implementation of Glasgow initiatives by assessing their annual activities and outputs, as well as substantive changes in policies and actions of the signatories.

Fourth, a country not being a member of a Glasgow initiative does not necessarily mean that the country lacks climate ambition. For example, South Africa is not a signatory to any of the 14 Glasgow initiatives assessed in this study, but it has set up the Just Energy Transition Partnership (JET-P) with the United States and a few European countries to accelerate the decarbonisation of its economy; The South African JET-P covers energy, electric vehicle and green hydrogen as priority sectors⁴⁷.

It is important to also note that these international initiatives and partnerships like the Glasgow initiatives may contribute to broader global climate governance. A study on "climate clubs", a small group of countries that participate in coordinated international climate action outside the UNFCCC process, suggest that they may help prevent national government club members from scaling back their climate action, rather than boosting it, in a sustained manner³⁹.

Going forward, three policy-relevant recommendations can be drawn from our findings. First, the Glasgow initiatives should continue their efforts to increase the number of national government signatories. Especially for countries that made net zero emission pledges for 2050 or earlier, signing up for these initiatives can serve as a litmus test for their seriousness on shorter term action. We have also shown that there are many countries, even among the G7 and the EU, that have not signed up for several of the Glasgow initiatives assessed in this study (Table 1). Second, it is crucial that the national government signatories reflect the initiatives' goals in their enhanced NDCs to realise the country's full GHG mitigation potential⁷. The next NDC update round in 2025 offers these countries a prime opportunity to demonstrate their genuine intent for higher ambition. In this regard, the signatories of the Global Methane Pledge are reporting the status of domestic policy implementation in line with the Pledge's goal³⁴. We expect these follow-up actions to take place also in other initiatives. Third, the mobilization and orchestration of initiatives need to be credible, demonstrating robust governance capacity and arrangements; and need to demand follow-up, especially among declarative initiatives.

Initial declarations and pledges through the Glasgow initiatives need institutionally robust arrangements to subsequently direct efforts, capacities, and resources towards implementation. While declarations have contributed to a "positive storyline" that showed broad (virtual) engagement by all stakeholders during COP26⁴⁸, we initially have seen too little action by important sectors. Similarly, the growth of net-zero commitments by both individual actors and through initiatives such as the A2Z Coalition and the UNFCCC Race to Zero campaign will need to be substantiated by efforts, capacities and resources. A hopeful development in this regard is the growing attention to accountability and integrity of climate initiatives. For instance, initial steps have been taken towards the development of integrity

standards, incl. by the International Organization for Standardization⁴⁹, the UN High-Level Expert Group Net Zero Emissions Commitments of Non-State Entities⁵⁰ that include robustness standards. Demands for integrity and robustness need to keep up with the growing trend of climate action through cooperative climate initiatives, to prevent inflated and misleading expectations vis-à-vis their mitigation potential.

We note the considerable variance in prospects for real impact among Glasgow initiatives. Considering their mitigation potential and relatively robust and transparent institutional arrangements, prospects for the delivery of actual mitigation of GHGs seem more promising for initiatives such as the PPCA, the Global Methane Pledge and the Glasgow Breakthroughs on Power, Road Transport, Steel, Hydrogen, and Agriculture. Yet, much will depend on these initiatives to widen participation and generate impacts at scale within their sectors.

Methods

Initiatives assessed and their national government signatories

The 14 Glasgow sector initiatives assessed in this study and their main goals are summarised in Table 3. Information about the national government signatories of the 14 Glasgow initiatives was collected from the initiatives' respective websites using Internet Archive for periods end-November 2021 and end-January 2023. Raw data are available as an Online Data Set. For the Glasgow Breakthroughs, we considered the endorsement of sector-specific Breakthrough goals rather than the endorsement of the umbrella Glasgow Breakthrough Agenda⁵¹. China, for instance, has endorsed the Glasgow Breakthrough Agenda as a whole but on a sector level, it only participates in the hydrogen agenda. We also assumed that, for the emission scenario analysis, the national governments that endorsed sector-specific goals at COP26 remain as participants even if they did not sign up for the priority international actions announced at COP27.

To identify the mentions to the Glasgow initiatives in updated NDCs submitted between December 2021 and January 2023, we first applied the following keyword search strings: "Glasgow", "COP26", "COP 26", "Breakthrough", "declare", "Global Methane Pledge", "clean energy", "beyond oil" and "powering past". We then manually reviewed the NDCs that contained any of the keywords above to identify specific mentions of the Glasgow sector initiatives and their targets.

Emissions scenario assessment

For the emissions scenario assessment, all GHG emissions figures presented in this report were aggregated with 100-year global warming potential (GWP) values of the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Global and national GHG emissions totals include emissions from land use, land-use change and forestry (LULUCF) unless stated otherwise (further details on the methods and data are presented in Supplementary Methods).

The GHG emission projections of the BL-NDC and BM-1.5 scenarios were developed using the energy and industry CO₂ emission projections of the World Energy Outlook 2021 (WEO2021) as the basis²⁰. The BL-NDC scenario was based on the WEO2021 Announced Policies Scenario, which assumes that all climate pledges by national governments around the world including NDCs would be fully achieved. Country-level projections were developed for Brazil, China, EU27, India, Indonesia, Japan, Mexico and the USA. The BL-NDC scenario considers the impact of the COVID-19 pandemic on 2020 emissions and, to a limited extent, on future emissions, while the impact of the Russian invasion of Ukraine is not considered. The BM-1.5 scenario was based on the WEO2021 Net Zero Emissions by 2050 (NZE) Scenario. The WEO2021 NZE scenario considers a range of emission reduction measures including: behavioural changes, energy efficiency, technology switch (for both supply and demand in case of energy), fuel switch, and tailpipe measures. Because the country-level projections were not available for WEO2021 NZE, we downscaled the NZE Scenario's global projections by applying the country-, sector- and fuel-level shares derived from the WEO2021 Sustainable Development Scenario, which assumes net-zero CO₂ emissions around 2070 and is consistent with a warming of "well

Table 3 | Fourteen Glasgow sector initiatives selected for the assessment in this study

Sectors and areas	Initiative	Main goals
Energy supply	Glasgow Breakthroughs: Hydrogen ^a	The Breakthrough aims to make affordable renewable and low-carbon hydrogen globally available by 2030.
	Beyond Oil and Gas Alliance (BOGA)	BOGA's core members are committing to end new concessions, licensing or leasing rounds and to set a Paris-aligned date for ending oil and gas production.
Power	Global Coal to Clean Power Transition (GCCPT) statement	GCCPT signatories pledge to rapidly scale up their deployment of clean power generation and energy efficiency measures in their economies. GCCPT aims to: <ul style="list-style-type: none"> - To rapidly scale up technologies and policies in this decade to achieve a transition away from unabated coal power generation in the 2030 s (or as soon as possible thereafter) for major economies and in the 2040 s (or as soon as possible thereafter) globally - To cease issuance of new permits for new unabated coal-fired power generation projects (New' coal-fired power generation projects are defined as coal-fired power generation projects that have not yet reached financial close), cease new construction of unabated coal-fired power generation projects and to end new direct government support for unabated international coal-fired power generation
	Powering Past Coal Alliance (PPCA)	PPCA members commit to accelerating the transition from coal to clean energy, grounded in the objectives of the PPCA Declaration. We assume PPCA aims for unabated coal phase-out by 2030 for OECD countries and the EU, and by 2040 for the rest of the world, as implied in its Declaration. Although launched in 2017 already, PPCA was included in the analysis as it pushed for or collaborates with various other initiatives during COP26 (among which GCCPT and NNCC), and had 28 new members during COP26.
	No New Coal Compact (NNCC)	NNCC signatories pledged to no longer build coal power plants
	Glasgow Breakthroughs: Power	The Breakthrough aims to make clean power the most affordable and reliable option for all countries to meet their power needs efficiently by 2030.
Industry	Glasgow Breakthroughs: Steel	The Breakthrough aims to make near-zero emission steel the preferred choice in global markets, with efficient use and near-zero emission steel production established and growing in every region by 2030.
Transport	Glasgow Breakthroughs: Road transport	The Breakthrough aims to make zero-emission vehicles the new normal by making them accessible, affordable, and sustainable in all regions [by 2030].
	Accelerating to Zero (A2Z) Coalition	Initiatives' signatories commit to rapidly accelerating the transition to zero-emission vehicles. Signatories will work towards all sales of new cars and vans being zero emission globally by 2040, and by no later than 2035 in leading markets. The declaration also recognises that "a sustainable future for road transport will require wider system transformation, including [...] public and shared transport".
International bunkers	Clydebank Declaration	The signatories of the Declaration are to support the establishment of green shipping corridors – zero-emission maritime routes between 2 (or more) ports.
	International Aviation Climate Ambition Coalition	Coalition members are to advance ambitious actions to reduce aviation CO ₂ emissions at a rate consistent with efforts to limit the global average temperature increase to 1.5 °C.
Land use	Glasgow Leader's Declaration on Forests and Land Use ("Glasgow Forest Declaration")	The Glasgow Forests Declaration's signatories are to conserve forests and other terrestrial ecosystems and accelerate their restoration
	Glasgow Breakthroughs: Agriculture ^a	The Breakthrough aims to make climate-resilient, sustainable agriculture the most attractive and widely adopted option for farmers everywhere by 2030.
Non-CO ₂ GHGs	Global Methane Pledge	Participants joining the Pledge agree to take voluntary actions to contribute to a collective effort to reduce global methane emissions by at least 30% from 2020 levels by 2030

^aWe did not quantify the impact of the Glasgow Breakthroughs on Hydrogen and Agriculture, because their 2030 goals are not quantifiable in terms of GHG emission reductions. The selection was based on: COP26 Presidency and Carbon Brief^{5,16}. See Supplementary Results for the URLs of the initiatives' web pages.

below 2 °C²⁰. For countries not represented in WEO2021 (Indonesia and Mexico), emission projections were taken from APERC⁵². Emission projections for non-CO₂ GHGs (CH₄, N₂O, F-gases) were taken from corresponding scenarios in Keramidas et al.²². To enable a comparison of our scenario results with those of integrated assessment models (IAMs), global total LULUCF emissions calculated above based on NGHGs were further harmonized following the approach of Grassi et al.⁵³ for the entire modelling period to reconcile the accounting differences between NGHGs and bookkeeping models on which the IAM land-use sector emissions are based. We assumed the discrepancy between NGHGs and bookkeeping models, which is mainly due to the different definitions of managed land and anthropogenic forest sinks to be 6.5 GtCO₂ for harmonisation, based on UNEP¹⁹. Further details, including the description of emission projections for industrial process-related CO₂ and F-gas emissions, can be found in the Supplementary Methods.

For the LULUCF sector, emission projections for the BL-NDC and BM-1.5 scenarios were first developed based on national GHG inventories (NGHGs). The BL-NDC scenario projections were developed in three steps. First, we updated the 2016 NDC scenario estimates of 2030 LULUCF

emissions with Forsell et al. (modelling base year: 2005) with the updated NDC estimates as of 2021 assessed by den Elzen et al. per country^{10,54}. Second, the estimated NDC target emissions based on Forsell et al. and den Elzen et al. were then harmonised with 2005 emissions based on Grassi et al.⁵³ to reflect the latest country-reported emission estimates⁵³. Third, the 2030 projections of countries with high LULUCF emissions or large differences between 2005 and 2030 emissions levels were cross-checked directly with NDCs and replaced in cases of large discrepancy. Further details about the quantification of the BL-NDC scenario on both country and global levels can be found in Supplementary Methods.

The Glasgow Declaration on Forests does not specify if its goal is to achieve gross zero or net zero deforestation, which would have major implications on future emissions⁵⁵. For the BM-1.5 scenario, therefore, we assumed that the countries (for the Glasgow-Signatories scenario, only the signatories) with positive net forest emissions based on NGHGs would reach net zero in 2030, while those with negative net forest emissions in 2020 will remain at current levels. The resulting net global forest emissions are negative, but gross deforestation emissions are not eliminated by 2030; this is consistent with the top-down 1.5°C emission pathway results reported in

Roe et al.⁵⁶. Due to uncertainties about the initiatives' impact, we assumed emissions from organic soils (except peat-related emissions in Indonesia; see Supplementary Methods) and other LULUCF remain constant until 2030.

All 12 initiatives quantified are assumed to contribute to reducing emissions of the targeted (sub)sectors in line with 1.5 °C. In this study, the emission reduction potential of initiatives is therefore calculated as the difference between the sectoral emissions under the BL-NDC scenario and the sectoral emissions under the BM-1.5 scenario. For energy and industry sectors, we assumed in the Glasgow-Signatories and Glasgow-Ambition scenarios that the Glasgow initiatives collectively cover the entire range of measures considered under the WEO2021 NZE scenario; initiatives that focus on the deployment of specific technologies also either explicitly refer to energy efficiency or involve partner organisations that focus on energy efficiency. We accounted for increased or decreased electricity demand resulting from sectoral measures (see Supplementary Methods). Potential emission reductions for all remaining signatory countries under the Rest of World country group were proxied using their 2019 share of global GHG emissions in the targeted sector. These shares are based on a combination of IEA's sector emissions data⁵⁷, PRIMAP-hist^{53,58}. For the land sector, the Glasgow-Ambition scenario projections are identical to the BM-1.5 scenario projections. The calculations for the Glasgow-Signatories scenario follows the same steps as in the other two scenarios but only done for the signatory countries of the Glasgow Forests Declaration. A comparison of our scenario results with the literature and limitations of our emission impact quantification methods are discussed in the Supplementary Methods.

Institutional robustness assessment

The institutional robustness assessment conducted in this study assumes that international cooperative initiatives require the capacity to steer, implement, and grow to deliver meaningful contributions to GHG emission reductions. For instance, a secretariat and dedicated staff, and clear delineations of roles and responsibilities, can help steer an initiative towards achieving its goals by convening members, resolving disputes, and facilitating collaboration and the implementation of activities⁵⁹. Indeed, empirical studies suggest that initiatives that feature secretariats are more likely to be effective compared to those that do not^{4,26}. Similarly, dedicated budgets can contribute to the long-term viability of an initiative⁴⁶. Indeed, the securement of funding can be particularly challenging for multistakeholder partnerships compared to government programmes with similar aims to contribute to public goods⁵⁹. Initiatives can facilitate growth through institutional openness, or clear procedures for it to encourage wider participation and generate impacts at scale⁶⁰. Finally, monitoring arrangements are widely regarded as an important component in achieving progress among non-state initiatives⁶¹. Such arrangements, at the very least, should demonstrate that initiatives follow up on their targets and commitments, providing accountability and transparency^{59,62}. Regular monitoring and reporting allow for external parties to praise successes but also to critique failures, thus incentivizing them to perform better over time⁶⁰. However, scholars have also pointed out that transparency of actions is an important condition for learning by demonstrating what works and what does not, both for the initiative and initiatives' members themselves and for others (broader public or other stakeholders)⁴⁶. Transparency also helps to build trust, for instance among donors and investors, possibly helping to attract additional funding, and new partners⁶³.

The data required for the institutional robustness assessment were collected through the Climate Cooperative Initiatives Database^{17,64}. C-CID collects data from publicly available sources (including reports, websites, and official documents) on various aspects related to the initiatives' goals, organizational characteristics, functions, and outputs⁴. The cut-off date for data collection was the end of July 2023. The analysis of governance indicators provides an important complement to our analysis of climate mitigation impact of initiatives, as it informs us about the likelihood of whether

scenarios (global or current membership) may be achieved. Yet, even when initiatives demonstrate progress through our governance indicators, eventual impacts and outcomes cannot be guaranteed.

Data availability

All datasets generated and/or analysed during the current study that are not presented in the Supplementary Material are available from the corresponding authors upon reasonable request.

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Author contributions

T.K. led the production of the study. T.K., A.D., S.C., and S.S. contributed to the study's conceptualisation and design. T.K., A.D., S.S., and N.P. conducted data collection and analysis. All authors contributed to the drafting and editing of the manuscript. T.K. and S.C. led the funding acquisition process.

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Competing interests

The authors declare no competing interests.

Additional information

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