



Strengthening global climate governance and international cooperation for energy-efficient buildings

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Abstract Buildings constitute one of the main GHG emitting sectors, and energy efficiency is a key lever to reduce emissions in the sector. Global climate policy has so far mostly focused on economy-wide emissions. However, emission reduction actions are ultimately sectoral, and opportunities and barriers to achieving emission reductions vary strongly among sectors. This article therefore seeks to analyse to what extent more targeted global governance may help to leverage mitigation enablers and overcome barriers to energy efficiency in buildings. To this end, the article first synthesises existing literature on mitigation enablers and barriers as well as existing literature on how global governance may help address these barriers (“governance potential”). On this basis, the article analyses to what extent this governance potential has already been activated by existing activities of international institutions. Finally, the article discusses how identified governance gaps could be closed. The analysis finds that despite the local characteristics of the sector, global governance has a number of levers at its disposal that could be used to promote emission reductions via energy efficiency. In practice, however, lacking attention to energy efficiency in buildings at national level is mirrored at the international level. Recently, though, a number of coalitions demanding

stronger action have emerged. Such frontrunners could work through like-minded coalitions and at the same time try to improve conditions for cooperation in the climate regime and other existing institutions.

Keywords Global climate governance · Climate change mitigation · Energy efficiency · Buildings

Introduction

The Paris Agreement (PA) in Article 2.1(a) established the objective to stabilise global temperature increase “well below” 2 °C and to make “best efforts” to stay below 1.5 °C. However, the window to achieve these objectives is closing rapidly. Buildings are a key action area in this context. As of 2019, global GHG emissions from buildings amounted to 12 Gt CO₂-eq, 21% of total global emissions. Final energy demand from buildings accounted for 31% of global final energy demand (128 EJ) and electricity demand from buildings for around 18% of global electricity demand (43 EJ) (Pathak et al., 2022).

Energy efficiency is a fundamental lever for decarbonisation of the sector. This includes, first, to enhance energy performance of buildings to minimise heating and cooling demand as much as possible, and second, to shift from fossil-fuel-based and often low efficient to renewable energy based and (super) efficient heating, cooling and cooking. So far, however, energy demand in buildings has continually increased, driven

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by building floor growth in combination with improved energy access and living standards (Cabeza et al., 2022; IEA, 2023). A rapid turnaround is therefore needed to get onto a Paris-compatible pathway.

This article seeks to analyse how global climate governance can contribute to achieving such a rapid turnaround. Global climate governance in the context of the United Nations Framework Convention on Climate Change (UNFCCC) has traditionally to a large extent focused on elaborating adequate economy-wide emission targets. Even the Paris Agreement, where parties' mitigation contributions are nationally determined, in Art. 4.4, encourages all countries to move to economy-wide targets over time. However, economies consist of sectoral systems, each supplying distinct goods and services, such as shelter and thermal comfort in the case of buildings, or mobility, energy, food provision and others. Opportunities and barriers for reducing emissions differ strongly from sector to sector. Taking these differences into account would allow global climate governance to address each sector in the way it can be most effective (Ghosh et al., 2022; Oberthür et al., 2021; Victor et al., 2019).

Especially around the Conference of the Parties (COP) to the UNFCCC in Copenhagen in 2009, there was already some discussion about the potential of sectoral approaches for global climate governance (see e.g. Barrett, 2010; Meckling & Chung, 2009; Sawa, 2010; Schmidt et al., 2008). This article goes beyond this literature in several ways. First, much of this literature focused on the industrial sector, with little consideration of other sectors. Second, much of this literature focused either on negotiating sectoral emissions targets with emerging economies or organising international technological cooperation and technology transfer along sectoral lines. An exception is Gupta and Ivanova (2009) who discuss the potential of global energy efficiency governance in connection with climate governance.

Third, the perspective on what actually the problem is and how it can be resolved has broadened over the last decade. Historically, as can be traced through the assessment reports by the Intergovernmental Panel on Climate Change (IPCC), discussions about international climate policy were to a large extent based on seeing climate change mitigation as a collective action problem where countries have an incentive to “free ride” on the efforts of others, as most climate-related benefits of mitigation

actions accrue globally rather than within the borders of those taking action. This perspective focuses on levels of GHG emissions and the enforcement capacity of international agreements to deal with free riding. Up to the fifth IPCC assessment report in 2014, the discussion of international cooperation therein (Stavins et al., 2014) focused on this perspective. Since then, a different perspective has developed that sees climate change mitigation as a transformation problem, where emission levels are the end result of a large number of transformative processes. This perspective focuses on analysing the progress in individual transformations and on how international cooperation can stimulate them (Patt et al., 2022). In addition, the knowledge of co-benefits of climate change mitigation for those taking action has significantly increased. Buildings energy efficiency in particular will bring significant savings on energy costs and other co-benefits (Thema et al., 2019).

This article therefore takes a broader look at possible means of global governance that go beyond emission targets and technological cooperation, as outlined in the next section. In addition, it takes a broad approach to international institutions. In recent years, a plethora of new inter- and transnational governance initiatives have emerged to complement the climate regime under the UNFCCC as part of a “polycentric” global climate governance (Jordan et al., 2018). This article will map the international institutions that seek to promote energy efficiency efforts in the buildings sector and analyse the extent to which this governance complex has harnessed the potential of global governance to advance efficient buildings.

To this end, this article proceeds in four steps. First, it identifies key challenges and barriers that impede energy efficiency in buildings. Second, it analyses how international institutions could *in theory*, assist with overcoming these barriers and mobilising opportunities (“governance potential”: the “Potential of global governance to address barriers and potentials” section). Third, the “Current status of global governance and international cooperation for efficiency in buildings” section assesses to what extent existing intergovernmental and transnational institutions relevant for energy efficiency in buildings have delivered on the identified governance potential *in practice*. On this basis, the “Discussion: factors impeding and promoting governance and options for

enhancement” section discusses how global governance could be enhanced.

Methods and material

Conceptual framework

Functions of global governance

The buildings sector may be the least amenable to international cooperation, given its mostly localised supply chains, lack of exposure to international trade and highly differentiated needs in relation to geography and climate (Victor et al., 2019). One may also more generally question the need for or potential of global governance on energy-related issues. Countries have historically been highly reluctant to coordinate internationally on energy policy because they see energy security as central to national security and economic development, and especially energy exporting and importing countries have widely diverging interests and compete over resources (S. Karlsson-Vinkhuyzen, 2015; Leal-Arcas & Filis, 2013; I. A. Reda, 2023; Sovacool & Florini, 2012). Also, according to the subsidiarity principle, higher levels of governance should only take action on an issue if lower levels cannot address the issue as effectively or efficiently as higher levels (Follesdal, 1998).

However, this is exactly the case not only with combating climate change, but also with moving towards a more sustainable energy system more generally. Implementation of both the Paris Agreement and Agenda 2030 is widely off track (Pathak et al., 2022; United Nations, 2023). Many countries lack capacity or are impeded by other barriers from implementing stringent climate and energy policy (Florini & Sovacool, 2009; Pathak et al., 2022). Strong and coherent governance at all levels, including the global level, is therefore required to achieve a transition to sustainable energy supply and use patterns (S. I. Karlsson-Vinkhuyzen et al., 2012; Sovacool & Florini, 2012). And, as will be discussed in the following, despite the highly local nature of the buildings sector, global governance does have various levers at its disposal which could be used to promote energy efficiency in buildings. Gupta and Ivanova (2009) note that global efficiency governance can address at least four challenges simultaneously: energy security,

energy and development, energy and environment and energy poverty. Enhancing global governance to promote efficient buildings is therefore both necessary to address the problem and has the potential to be effective.

Synthesising previous literature on the functions and effects of international governance (e.g. Bulkeley et al., 2014; De Búrca et al., 2014; Loorbach, 2010; Simmons & Martin, 2002; Stokke, 2012; Young, 1999), Oberthür et al. (2021) derive five functions of global governance that international institutions can activate to address specific problems, such as climate change. In previous work, this approach was already applied to global climate governance in five sectors, namely electricity (Hermwille, 2021), energy-intensive industries (Oberthür et al., 2021), land transport (Obergassel et al., 2021), international transport (Rayner, 2021b) and fossil fuel supply reduction (Rayner, 2021a), and also to the performance of the UN climate regime as a whole (Kinley et al., 2021).

The five functions are the following:

- **Guidance and signal:** international institutions can signal the determination of members to pursue a particular course, such as promoting efficiency and GHG reductions. These signals derive from the principles and goals that underpin international institutions and can provide direction beyond the institution in question by giving businesses, investors and other actors an indication of what policy paths countries are likely to take.
- **Rules and standards:** International institutions cannot only provide desired direction, but also require their members to take certain actions to achieve mutually agreed-upon goals.
- **Transparency and accountability:** international institutions can increase the transparency of actions taken by their members by collecting and analysing relevant data and identifying and addressing problems in the implementation of agreed rules/standards.
- **Means of implementation:** International institutions can organise capacity building, technology transfer and funding among members, including coordination efforts to effectively allocate and pool resources and clarify who should contribute how much.
- **Knowledge and learning:** International institutions can create knowledge and platforms for individual

and social learning. The goal is to create and disseminate scientific, economic, technical and policy-related knowledge about understanding and/or possible solutions to the problem at hand.

This article will employ these governance functions to analyse the following:

- First, how international institutions may in theory promote phase-out of inefficient and high-emission solutions and development and uptake of more efficient and low-emission solutions in the buildings sector.
- Second, to what extent this theoretical potential has so far been applied in practice.
- Third, how gaps could be closed, see also the following section.

In terms of the scope of institutions analysed, we follow Oberthür et al. (2021) in using the term “global governance” in a broad sense, including transboundary cooperation of various actors, which may include state and/or non-state actors and take place at varying geographical levels, from the regional to the global. “Global” is therefore not meant in the sense of requiring universal membership of an institution by (nearly) all countries. Relevant institutions may also consist of smaller subsets of countries or may even be composed solely of non-state and sub-national actors.

Options to enhance global governance

In the final step, the article discusses institutional options for closing the governance gaps identified in the previous steps. This analysis follows (Otto & Oberthür, 2022) who synthesised existing literature on the creation and development of international institutions and on this basis proposed four criteria for assessing institutional options:

- Membership refers to whether an institution includes a “critical mass” of actors as members that are needed to fill the governance gaps identified.
- Institutional strength and capacity refer to whether an institution has the competence, capacity and expertise to address the identified governance gaps. The latest IPCC assessment report discusses institutional strength in terms of regulative quality,

mechanisms to enhance transparency and accountability and administrative capacity (Patt et al., 2022). In other words, institutional strength therefore refers to whether an institution has the capacity to activate the governance functions introduced in the previous section.

- Legitimacy refers to the authority of an institution as perceived by other actors, both in terms of process (input legitimacy) and outcome (output legitimacy). This criterion is closely related to issues of membership and distribution of resources, especially in a North–South context.
- Finally, political feasibility refers to whether there is a realistic political opportunity for institutional reform or the creation of a new institution. Regarding existing institutions, this includes compatibility with the institution’s established goals and the prospects for agreement among its members. Regarding the potential for a new institution, this includes linkages to existing institutions and venues as potential starting points.

Evidence base

This study applied a mix of qualitative data collection methods. In the first step, we synthesised existing literature on the main barriers to increasing energy efficiency in the buildings sector. The aim of this synthesis is not to provide a comprehensive literature review, but to provide the basis for the subsequent steps of the analysis. The section therefore takes the most recent IPCC assessment report as key starting point, in particular the chapter on buildings (Cabeza et al., 2022), complemented by additional literature.

In the second step, we synthesised existing knowledge on how global governance might theoretically help to overcome the barriers identified in the first step. Again, the goal is not to provide a comprehensive review of the existing literature, but to lay a foundation for the empirical core of this article, the analysis of the currently existing governance complex. The mapping of options for global governance and international cooperation therefore began with a synthesis of the existing literature on global climate governance and buildings in the recent IPCC assessment report (Cabeza et al., 2022; Patt et al., 2022), complemented by additional literature and interviews.

In the third step, to analyse whether and to what extent the governance potentials identified in the previous section has so far been activated/exploited in practice, we developed a database of institutions that are relevant for energy efficiency in buildings. Following the approach laid out by Oberthür et al. (2021), to account for the strong rise of international initiatives by sub-national and non-state actors, we adopted a broad definition of international institutions. This definition includes not only formal international organisations, such as the various UN organisations, and international regimes, such as the UN climate regime, both of which are based on formal agreements among national governments. It also includes less formal transnational arrangements which include fully private arrangements as well as hybrid forms including both states and non-state actors.

We included institutions featuring in particular the following characteristics. Institutions

- must aim to realise a common purpose,
- be lasting,
- contribute to at least one of the five governance functions, and
- must have procedural rules for making and implementing decisions, including on substantive rules.

These criteria aim to delineate international governance institutions from international coalitions and lobby groups as well as ad hoc fora, platforms, projects, programmes and networks.

Applying these criteria, we first identified an initial list of potentially relevant institutions by reviewing the Global Climate Action Portal maintained by the UNFCCC Secretariat (UN Climate Change, 2023) and the “Future of Climate Cooperation” database maintained by the University of Oxford (Future of Climate Cooperation Website, 2023). The resulting list of institutions was subsequently complemented with further institutions identified through literature review. To identify which institutions meet the inclusion criteria, we reviewed their governance statements. If such statements were not available from the existing databases, we retrieved them from the institutions’ own websites.

To verify and further expand on the results of the previous steps, we conducted a series of expert interviews. Interview partners were identified by snowball sampling. An initial list of potential participants was

created by the authors based on their pre-existing contacts. During the interviews, interview partners were *inter alia* asked whether they would recommend further experts to be involved. The authors aimed to gain different perspectives, including participants from academia, governments, businesses, civil society and international organisations. In total, 20 individuals were contacted by email and 11 of them ultimately agreed to be interviewed. Details on the institutional affiliations of the interview partners are documented in Annex 1.

The interviews were semi-structured, following a set of pre-defined questions but with the flexibility to pursue emerging lines of enquiry. The interview questions were informed by the results of the desk research undertaken as outlined above and are documented in Annex 1. Interview responses were analysed qualitatively and structured according to the main topics of this article: (1) barriers to energy efficiency, (2) potential contributions of global governance, (3) current status of global governance and (4) suggestions for improving the current status. All participants agreed that their responses could be quoted by name if the quotations were shown to them in advance. These quotes are in the following referenced in the form (name, personal communication, date).

Finally, to further validate the outcomes of the analysis, interim results were presented and discussed at an online workshop that took place on 22 September 2022. Workshop participants included some of the interview partners as well as additional experts identified during the interviews.

Barriers to energy efficiency in buildings, governance options and governance gaps

Synthesis of main barriers to energy efficiency in buildings

While in the last decade, building energy intensity has decreased, according to the International Energy Agency (IEA), the decrease of building energy intensity needs to accelerate significantly in the next decade to be compatible with the objectives of the Paris Agreement (IEA, 2023). For example, the energy renovation rate of the building stock is about 1% per year, compared to the 2.5% by 2030 envisaged in the IEA Net Zero Emission scenario. In addition, energy

intensity reduction that resulted from renovation was less than 15% on average, which is far less than what is technically and often economically feasible (40–80% reduction depending on the local climate and building features) (IEA, 2021a).

Existing work has characterised incumbent buildings, construction and energy companies as an institutionalised force actively perpetuating conservative, unsustainable building practices (Gibbs & O’Neill, 2015; Lowes et al., 2020a, 2020b; F. Reda et al., 2021; Smith, 2007). Another fundamental issue is the high number of relevant actors (constructors, building product producers, building managers, architects, engineers, owners, occupants, investors, trades people, equipment manufacturers, suppliers, lenders, insurers, codes and standards setters, zoning officials, realtors and others), many of which have low degrees of capacity and knowledge about climate-friendly design options. Effective policies are therefore needed to align all of these actors towards decarbonisation (Cabeza et al., 2022; Höfele & Thomas, 2011). In addition, there is a broad range of further political and institutional, economic and financial, information and knowledge, technical, social and cultural and structural barriers. Table 1 summarises major barriers identified from literature review.

Potential of global governance to address barriers and potentials

This section synthesises existing literature on how global governance could help to overcome the barriers summarised in the previous section. As laid out in the “**Methods and material**” section, this mapping of governance options builds on the most recent IPCC assessment report, additional literature and interviews. While global agreement would make the suggested options most effective, they could also be pursued by less comprehensive coalitions of interested states, non-state and sub-national actors.

Global guidance and signals such as global targets can provide a reference point for national and local policy as well as other actors (Dai, 2010; Kinley, 2017; Morseletto et al., 2017; Rayner et al., 2021). If targets have been adopted internationally, domestic actors have more legitimacy to request that corresponding action should be taken (L. Reynolds, personal communication, 22 August 2023). They could thereby help overcome the current lack of political

commitment, lack of clear and ambitious national policies for energy efficiency as well as corresponding market uncertainty. For example, in 2015, the district court in the Hague ruled that the climate policy of the Netherlands was too weak with reference to the findings of the IPCC and required the Dutch government to strengthen its emission targets (Saurer & Purnhagen, 2016). In 2021, Germany’s Constitutional Court ruled that Germany’s climate law was too weak and directly referenced the objectives of the Paris Agreement in its justification (Bundesverfassungsgericht, 2021).

However, the objectives of the Paris Agreement apply to global temperatures and emissions. More specific guidance could arguably be provided by breaking the global mitigation objectives down to the individual sectors (Oberghassel et al., 2022; Rayner et al., 2021), such as setting targets for energy efficiency (S. I. Karlsson-Vinkhuyzen et al., 2012). The “Building to COP coalition” advocates that by 2030, 100% of new buildings must be net-zero carbon in operation and embodied carbon must be reduced by at least 40%, and by 2050, all new and existing assets must be net zero across the whole life cycle (Building to COP Website, 2022). However, such targets would probably be impossible for many developing countries to meet. Conduct-based rather than outcome-based targets could be more realistic, e.g. that a certain percentage of new building construction should be code-compliant by 2030 (S. Kumar, personal communication, 1 August 2023).

Governments could also agree on international rules and standards to help overcome the lack of political commitment and ambitious national policies. The “Building to COP” coalition argues that all countries should “include full building decarbonisation targets, concrete policies and measures and related implementation mechanisms” in their nationally determined contributions (NDCs) (Building to COP Website, 2022). Many NDCs so far relate only to economy-wide emissions. A sectoral breakdown of NDCs would help to connect the NDCs to actual national policy, policy-makers and implementers (I. Geppert, personal communication, 25 July 2022; N. Steurer, personal communication, 3 June 2022). The buildings sector does so far tend to be forgotten in NDCs (L. Reynolds, personal communication, 22 August 2023). However, substantial effort would be required to develop sectoral breakdowns in a way that is actually relevant (based on real consumption data, not modelled data) for the

Table 1 Overview of barriers to energy efficiency in buildings

Barriers	Description
Political/institutional	<ul style="list-style-type: none"> • Mismatch between long-term commitment needed given long lifetimes and investment cycles on the one hand and short-term election cycles on the other (UNEP, 2020) • Absence of clear policy signals to the market, e.g. ambitious targets, roadmaps and policy instruments such as building codes and lack of enforcement (Cabeza et al., 2022; Gaur et al., 2021; IEA, 2021a, 2022a; UN Climate Change, 2021) • Permitting installation of fossil-fuel heating in new buildings and replacement in existing buildings (Loves et al., 2022) • Subsidies for fossil fuels and fossil boilers have significantly delayed the transition towards renewable-based heating and cooling (IRENA et al., 2020; Vikkelsø & Boye Olesen, 2021) • Low or area-based energy prices for residential use creating little incentives for saving, e.g. in China (Zhu, 2020), Turkey (Taranto & Saygin, 2018) and Mexico (WRI, 2019)
Economic/financial	<ul style="list-style-type: none"> • Higher upfront costs and longer payback time to invest in building efficiency measures, which is aggravated by split incentives (Cohn & Eram, 2022; Höfele & Thomas, 2011; IRENA et al., 2020; Ürgel-Vorsatz et al., 2020) • Potentially high operational costs for electrification (IRENA et al., 2020; Loves et al., 2022) • Lack of access to affordable finance by investors (e.g. Climate Action Tracker, 2022) to a large extent due to lacking technical knowledge among capital providers, perception of high lending and investment risk due to the lack of track records of lenders, low collateral asset value, long project lifetimes, high performance risks, small size of individual building projects and correspondingly high transaction costs (G20 EEFTG, 2017) • It is costly for suppliers of components and material to transition, which is aggravated by lack of or high uncertainty about market demand for energy efficiency options (Cohn & Eram, 2022; Cristino et al., 2021; Höfele & Thomas, 2011; Park et al., 2021)
Technical	<ul style="list-style-type: none"> • Incumbent heating infrastructure associated with significant sunk costs invested by gas utility companies (Loves et al., 2022; Nadel, 2019) • Limited suitability of renewable-based heating and cooling in certain buildings with limited roof space for solar thermal, historical/heritage buildings with planning limits, etc. (IRENA et al., 2020) • Maturity of specific technologies such as solar cooling (Sheldon et al., 2018); • Challenges to the power grid system due to the increasing electrification of heating and cooling (Love et al., 2017; Loves et al., 2020a, 2020b) • Lack of professionals specialised in developing building energy efficiency projects (Cristino et al., 2021); shortage of skilled workers for energy retrofits and heat pumps installation (IEA, 2022a)
Information/knowledge	<ul style="list-style-type: none"> • A lack of information and knowledge about building energy efficiency and low carbon heating/cooling options along the whole value chain (Höfele & Thomas, 2011; IEA, 2020; IRENA et al., 2020; Mata et al., 2021) • A lack of reliable data on energy performance and cost savings after the implementation of measures (Criado-Perez et al., 2020)
Social/cultural	<ul style="list-style-type: none"> • Building occupants' value and behaviour, e.g. demand for more living space (Bierwirth & Thomas, 2015) • Ingrained habits, lack of interest in energy savings, lack of time or other priorities (Bagaini et al., 2020; Blomqvist et al., 2022)
Structural	<ul style="list-style-type: none"> • Increasing population, rapid urbanisation and building stock growth (IEA, 2021b; Zhou et al., 2018)

respective national situation (M. Braune, personal communication, 4 August 2023; S. Kumar, personal communication, 1 August 2023).

In addition, governments and other actors could also adopt more specific commitments, such as the following:

- To address market uncertainty, technical barriers to trade, as well as design and compliance costs of manufacturers, governments could help to drive

demand by committing to accelerating efficiency improvements of their own, often substantial, building stock and coordinated procurement of efficient heating and cooling technologies (Victor et al., 2019) as well as coordinate on product efficiency standards and associated test methods for traded goods (Cabeza et al., 2022; IPEEC Building Energy Efficiency Taskgroup, 2014; S. I. Karlsson-Vinkhuyzen et al., 2012). Co-ordination on product standards and test methods would

avoid duplication of effort and allow for international interoperability of goods, thereby creating a larger, shared market and providing greater incentives to invest (S. I. Karlsson-Vinkhuyzen et al., 2012).

- To address lack of stringency of building energy codes, rating and certification systems and labels, governments could harmonise definitions and measurement methodologies to cover all emissions and apply to actual energy and emission performance (IPEEC Building Energy Efficiency Taskgroup, 2014; Victor et al., 2019). However, performance-based standards are difficult to operationalise. To support countries with limited capacity, countries could also coordinate on the stringency of component efficiency values in prescriptive building codes or on low-carbon, energy-efficient building design concepts.¹
- To address higher upfront costs and longer payback periods of climate-friendly options, governments could coordinate on emission pricing (e.g. Keohane et al., 2017; van den Bergh et al., 2020), removal of fossil fuel subsidies (S. I. Karlsson-Vinkhuyzen et al., 2012) and/or comprehensive climate budget reform (Green, 2017; Verbruggen, 2011; Verbruggen & Brauers, 2020).

In terms of transparency and accountability, to help overcome lacking political commitment and insufficient policies, governments could agree that countries need to internationally submit sectorally differentiated reports on national emissions, actions taken and their impacts. On this basis, international review could identify implementation shortcomings and suggest remedies, or potentially also impose penalties (A. Gupta & van Asselt, 2019). In addition to the effects of government-to-government scrutiny, international transparency provisions and review processes also provide non-party actors with information and political fora to appeal to public opinion and put pressure on governments to remedy insufficient policies (Dai, 2010; Hale, 2020). Activities of sub-national and non-state actors should also include robust transparency provisions to help ensure implementation.

¹ The authors thank one of the anonymous reviewers for pointing out that performance standards may be beyond the capacity of many countries to operationalise.

In terms of means of implementation, provision of financial, technological and capacity building support can help overcome a number of barriers. At its most basic, it can help bolster the political commitment to tackle building efficiency in poor countries where otherwise more immediate development needs would take precedence. Where political commitment already exists, international support can help overcome lack of resources and institutional capacity (Seto et al., 2014; WBCSD, 2010). Specific areas of application include the following:

- To address lack of resources and institutional capacity, donors can provide resources for policy development, planning, implementation, evaluation and enforcement capacity of national and local governments in developing countries (Cabeza et al., 2022; IPEEC Building Energy Efficiency Taskgroup, 2014; WBCSD, 2010).
- To help overcome problems of access to finance, high upfront costs, long payback periods and (perceived) investment risks, donors can also provide financial support to governments and private investors such as grants, low-interest loans and loan guarantees (Cabeza et al., 2022).
- To address lack of information and knowledge and shortage of skilled workers, donors can support international training, capacity building and awareness programmes (IPEEC Building Energy Efficiency Taskgroup, 2014; Oberthür et al., 2017).
- To address technological barriers, countries could coordinate on development and demonstration of, e.g. high efficiency and more cost-effective building designs and achievable performance standards, innovative highly efficient heating and cooling technologies, inter-seasonal storage, demand-side response and smart meters and grids (Victor et al., 2019).

Finally, global governance could help overcome a number of barriers related to knowledge and learning, e.g. by developing and sharing consistent metrics to assess building energy performance, metrics to assess the multiple benefits of energy efficiency, knowledge on technological innovations and options for enabling policy, financing, and market frameworks (IPEEC Building Energy Efficiency Taskgroup, 2014; S. I. Karlsson-Vinkhuyzen et al., 2012; Oberthür et al.,

Table 2 Synthesis of potential for international cooperation and governance to help overcome barriers

Governance function	Barriers	Potential of international cooperation to address barriers
Guidance and signal	<ul style="list-style-type: none"> • Lacking political commitment, insufficient policies and uncertainty about market demand 	<ul style="list-style-type: none"> • Provide reference point for policy and other actors by agreeing international targets/road-maps
Rules and standards	<ul style="list-style-type: none"> • Lacking political commitment, insufficient policies and uncertainty about market demand • Lack of stringency of building energy codes, rating systems and labels • Market uncertainty, technical barriers to trade, design and compliance costs of manufacturers • Higher upfront costs and longer payback periods of efficient/renewable options 	<ul style="list-style-type: none"> • Create pressure by international requirements to include sectoral targets and policies in NDCs and long-term climate strategies • Harmonise efficiency measurement methodologies • Coordinate on product efficiency standards and associated test methods for traded goods • Coordinate commitments to improve efficiency of own building stock and to procure only highly efficient/renewable heating and cooling equipment • Coordinate on emission pricing or comprehensive climate budget reform
Transparency and accountability	<ul style="list-style-type: none"> • Lacking political commitment and insufficient policies 	<ul style="list-style-type: none"> • To create pressure, require reporting on measures taken and their impacts and impose penalties for non-compliance
Means of implementation	<ul style="list-style-type: none"> • Lack of resources and institutional capacity • Lacking access to finance, higher upfront costs, longer payback periods and (perceived) investment risks • Lack of information and knowledge and shortage of skilled workers • Technological barriers 	<ul style="list-style-type: none"> • Provide resources for policy development, planning, implementation, evaluation and enforcement capacity • Provision of grants, low-interest loans and loan guarantees • International training, capacity building and awareness programmes • Coordinate technology development and demonstration
Knowledge and learning	<ul style="list-style-type: none"> • Information and awareness problems 	<ul style="list-style-type: none"> • Provide policy and technical knowledge platforms and exchange formats

2017; Victor et al., 2019). Provision of detailed model regulations (at regional level to account for regional differences) would be particularly useful to help strengthen national policies (N. Steurer, personal communication, 3 June 2022).

Table 2 summarises the above discussion to serve as reference point for the subsequent analysis of the current governance landscape.

Current status of global governance and international cooperation for efficiency in buildings

Overview of institutions

This section summarises the empirical results of our study to what extent the governance potential identified in the previous section has so far been mobilised. As described in the “[Methods and material](#)” section,

we surveyed the activities of international institutions that are active on energy efficiency in buildings based on existing databases, literature and internet research and interviews. In total, we identified about 40 institutions as undertaking relevant activities. Discussing them one by one would be rather long-winded and exceed the size limitation of a journal article. The following subsections therefore present a synthesis of major findings. More detailed overview tables of ongoing activities are provided in the annex.

One may debate whether further institutions should be included, but based on the responses we received during the interviews and based on a review by two external experts, we are confident that we captured the large majority of institutions that are relevant.

There is no formal international agreement dedicated to buildings (Patt et al., 2022). The International Renewable Energy Agency (IRENA) serves as central

institution for the renewable energy supply side of buildings decarbonisation. However, there is no comparable international institution for enhancing building energy performance or overall building decarbonisation. Indeed, in some respects, the international attention for energy efficiency in buildings has rather decreased instead of increased in recent years, and much activity is short-term stop-and-go rather than long-term strategic (B. Lebot, personal communication, 30 May 2022). The IEA is usually the main reference on energy efficiency in buildings and beyond. It provides comprehensive analysis, data, policy recommendations and solutions to governments and broader audiences and has worked to promote energy efficiency as “first fuel”, but it mostly acts as think tank and its membership is limited (Voïta, 2021).

The closest approximation to an international energy efficiency agency was the International Partnership for Energy Efficiency Cooperation (IPEEC), which was founded at the 2009 G8 summit in L'Aquila and subsequently came to include 17 of the G20 countries as members. However, the funding of IPEEC was always limited and it was ultimately disbanded in 2019. IPEEC was intended to be replaced by a new Energy Efficiency Hub under the IEA. However, the transition has been difficult. At the time of its establishment, the Hub had lost India, Italy, Mexico and South Africa as members (Voïta, 2021). Another example of discontinuation is the Major Economies Forum on Energy and Climate (MEF) which was originally established by the US Obama administration. Its activities included an action agenda on improving energy efficiency in buildings through sharing of best practices and policies (A. Hinge, personal communication, 8 June 2022; U.S. Department of State, 2013). The MEF was also discontinued under the Trump administration. It was revived under the Biden administration but buildings did not feature on the agenda of its recent meetings. At the same time, the most recent MEF meeting pledged to mobilise US \$90 billion in public investments in new technologies not yet commercially available under the “Clean Energy Technologies Demonstration Challenge” (The White House, 2022). So availability of resources or ambition does not seem to be a constraint, but it is focused on other sectors, in particular novel technologies (B. Lebot, personal communication, 30 May 2022).

Nonetheless, while there is no clear fulcrum of activity, a large number of international organisations are active in the area, such as the United Nations Human Settlements Programme (UN Habitat) and UN Environment, which is hosting the secretariat of the Global Alliance Buildings and Construction (GABC), a coalition of 280 members, including 39 countries, private companies, civil society, intergovernmental and international organisations (GlobalABC Website, 2023c). The World Bank and other multilateral development banks (MDBs) overall have a large portfolio of programmes relating to buildings. International standardisation bodies, most notably the International Organization for Standardization (ISO) the International Electrotechnical Commission (IEC), the international Code Council (ICC) and ASHRAE have developed energy efficiency definitions and measurement standards for building energy performance, building products and equipment.

Furthermore, several city networks are active on climate change, including in the buildings sector, such as C40 Cities, the Global Covenant of Mayors for Climate and Energy and ICLEI—Local Governments for Sustainability. Among businesses, for example the World Green Building Council is organising a network of national green building councils to support decarbonisation. The Efficient Cooling Initiative, the Cool Coalition and the Clean Cooling Collaborative aim to bring together governments, intergovernmental organisations and the private sector to build high-level political leadership for climate-friendly cooling and facilitate collaboration among stakeholders. The Net Zero Asset Managers Initiative, the Net-Zero Asset Owner Alliance and the Net-Zero Banking Alliance are UN-convened coalitions of private investors that have pledged to make their portfolios net-zero.

The UNFCCC has tried to orchestrate activities by non-state and sub-national actors by creating a registry and establishing the “Marrakech Partnership for Global Climate Action” (MPGCA). Two “High Level Climate Champions” coordinate this process. One outcome is the “Building to COP coalition”, a Joint initiative of C40, GlobalABC, WGBG and others in cooperation with the UN High Level Climate Champions and the COP26 Presidency (Building to COP Website, 2022).

Finally, the COP26 Presidency coordinated a number of frontrunner coalitions called “breakthroughs”

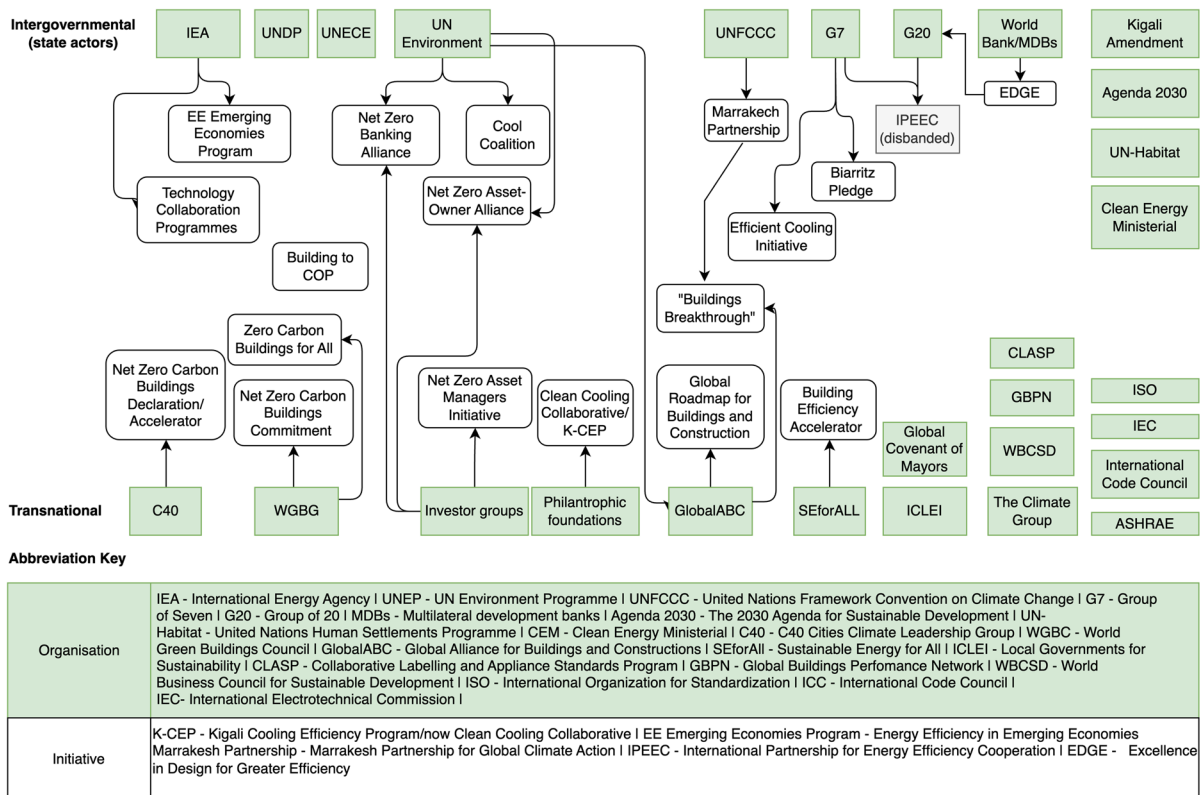


Fig. 1 Overview of the governance landscape. Source: authors

on various sectors. Buildings was not one of these sectors, but at COP27 in Sharm el-Sheik, a “break-through” on buildings was launched, led by France and Morocco, supported by 14 other countries and 13 initiatives and foundations. The GlobalABC Secretariat serves as secretariat of the “buildings break-through” (GlobalABC Website, 2023b).

Figure 1 illustrates the current governance landscape. It illustrates that while there is a high number of institutions and initiatives, there is no dedicated centre or fulcrum of activity.

Current governance landscape by governance function

This section discusses to what extent these institutions and their initiatives have so far activated the governance potential identified in the previous section. In order not to lose sight of the forest for the trees, this section provides a high-level overview. More detailed lists of the ongoing activities with detailed references are provided in the annex.

There currently is only limited guidance and signal to help overcome weak national policies. There are no internationally agreed global decarbonisation or building efficiency targets. Increasing numbers of non-state and sub-national actors are promoting targets to halve emissions by 2030, have all new buildings at net zero carbon by 2030 and achieve full decarbonisation by 2050, as in the C40 Net Zero Carbon Buildings Declaration (C40 Cities, 2022), the Net Zero Carbon Buildings Commitment organised by the World Green Building Council (WorldGBC Website, 2022b), or the “Race to Zero” campaign maintained by the UNFCCC High-Level Champions within the framework of the Marrakech Partnership (Owen-Burge, 2021). However, these targets have so far gained only very limited government support despite various attempts to organise frontrunner coalitions. The “Buildings as Critical Climate Solution (BCCS)” call, the “Zero Carbon Buildings for All Initiative”, and the “Global Call for Low Carbon, Energy Efficient, and Resilient Buildings” each gained only three

to six government signatories (GlobalABC, 2022). The largest such coalition is the “buildings breakthrough” launched at COP27 in Sharm el-Sheikh with the vision statement “near-zero emission and resilient buildings are the new normal by 2030”. However, this vision statement is less specific than the targets promoted by non-state actors as listed above. Moreover, while larger than previous intergovernmental initiatives, the “breakthrough” so far still has only 16 supporting countries and nearly all of them are from Europe and Africa, so the geographic reach is limited (GlobalABC Website, 2023b).

Similar to guidance and signal, there currently is only little firm rule-setting. There are currently no requirements that NDCs should have a sectoral breakdown. Nor is there intergovernmental coordination on specific policies and measures such as decarbonisation of public buildings or emission pricing, with one exception: the G20 in 2009 pledged to “phase out inefficient fossil fuel subsidies”. However, the pledge contains no definition or what constitutes an “inefficient fossil fuel subsidy” or “subsidies” in general, nor a clear timeline (G20, 2009). And in practice, G20 fossil fuel subsidies are currently at record levels, at more than USD 1 trillion in 2022 (Laan et al., 2023). There has been some movement towards coordinating building codes and energy efficiency standards for air conditioners (Park et al., 2021; UNEP, 2021). For example, UNECE developed Framework Guidelines for Energy Efficiency Standards in Buildings (ECOSOC, 2020), the Caribbean Community developed a Regional Energy Efficiency Building Code; the non-state International Code Council developed an International Energy Conservation Code (IECC) and an International Green Construction Code (IgCC) already in 2000 and 2010 respectively and is working to broaden their uptake (UNEP, 2021). In terms of coordinating purchasing power, efforts to organise buyers’ or sellers’ clubs for cooling technology were not successful (Clean Cooling Collaborative, 2022).

Finally, in terms of non-state and subnational actors, various institutions such as C40, the World GBC, the Net Zero Asset Managers Initiative, the Net-Zero Asset Owner Alliance and the Net-Zero Banking Alliance collect building decarbonisation commitments from relevant actors. However, these are not legally binding and do not cover national governments. In addition, the robustness of the financial

alliances has been questioned. A recent report found that these initiatives were still financing fossil fuel expansion on the order of hundreds of billions of USD annually (McCully, 2023). While not directly relevant to buildings, this questions their robustness. Another report focusing on the Net Zero Asset Managers Initiative found that their targets were both unambitious and gameable (Universal Owner, 2021).

Existing transparency and accountability provisions also show little potential to force state and non-state actors to enhance action. Parties to the UNFCCC and to the PA must regularly submit GHG emission inventories and reports on policies and measures implemented and their impact. However, per Article 4 of the PA, parties are required to maintain NDCs and to pursue domestic mitigation measures—but they are not required to actually achieve their NDCs. Moreover, existing literature questions the capacity of the PA’s transparency mechanisms to have an impact on parties’ actions: first, these mechanisms have neither the mandate to assess the adequacy of individual parties’ NDCs, nor the mandate to assess the adequacy of parties’ policies and actions to achieve their NDCs. Second, the wide variety of NDCs complicates assessment. Third, opportunities for non-party stakeholders to participate in the transparency mechanisms are restricted. Fourth, there are doubts as to whether Parties and the UNFCCC Secretariat have sufficient resources to adequately operate the Enhanced Transparency Framework (Pauw et al., 2018; Raiser et al., 2022; Weikmans et al., 2020).

Institutions that are addressing non-state and subnational actors (C40 Net Zero Carbon Buildings Declaration, WorldGBC Net Zero Carbon Buildings Commitment, Net Zero Asset Managers Initiative, Net-Zero Asset Owner Alliance and the Net-Zero Banking Alliance) are requiring regular progress reports. However, the actual robustness of these transparency mechanisms is unclear as no reporting on implementation seems to be publicly available. Positively, the UN system and the International Standards Organisation (ISO) are tackling the transparency and accountability of non-state action. UN Secretary-General Guterres convened a High-Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities which published recommendations for more credible climate pledges by non-state actors at COP27 (United Nations’ High-Level Expert

Group on the Net Zero Emissions Commitments of Non-State Entities, 2022). The ISO elaborated Net Zero Guidelines, a standard for credible targets and measures for climate neutrality at the corporate level (International Standards Organisation, 2023). However, to what extent these standards will gain traction remains to be seen.

A large number of institutions are providing means of implementation to help overcome lack of technical capacity and financial constraints, including the MDBs, UNEP, UNDEP, UNECE, private financial institutions, the IEA, the GlobalABC, C40, ICLEI, the WorldGBC, the GBPN and the Cool Coalition. The IEA is also organising a broad range of Technology Collaboration Programmes on energy efficiency, district heating and cooling to organise international collaborative RD&D as well as knowledge exchange and to develop market and policy recommendations (IEA, 2022b).

However, there is a lack of data on financial needs and actual flows, both in the UNFCCC and in the academic literature (Oberghassel et al., 2022; Patt et al., 2022). The latest IPCC assessment report cites IEA figures which estimate the incremental decarbonisation investment needs in the sector between 2026 and 2030 at USD 711 billion, including USD 509 billion for building energy efficiency and USD 202 billion for renewable heat for end-use and electrification in buildings. This would imply a growth of investments from their 2016–2020 levels by a factor of 3.6 and 4.5, respectively. The IPCC also notes that bottom-up literature reports significantly higher investment needs than the IEA; the actual investment gap is therefore likely to be even higher (Cabeza et al., 2022). Moreover, international funding is currently often not provided for the long term but on an annual basis, which impedes long-term strategic planning (B. Lebot, personal communication, 30 May 2022; N. Steurer, personal communication, 3 June 2022). There also is a lack of capacity building of regional and local authorities for implementation and enforcement (S. Kumar, personal communication, 1 August 2023). To be more effective, donors would need to provide more immersive input and remain engaged over longer periods of time with firm commitments and clear follow-up (M. Braune, personal communication, 4 August 2023).

Finally, very many institutions are working to overcome lack of knowledge and learning. For example, the UNFCCC Technical Examination Process (TEP)

has collated and synthesised good practice policies for a variety of sectors, including low-emission housing and buildings (UNFCCC Website, 2022). The GlobalABC tracks global progress on buildings decarbonisation in its annual Global Status Report for Buildings and Construction (Buildings-GSR) and its Building Climate Tracker. The Energy Efficiency Hub has 16 country members and promotes sharing of information and best practices among countries, international organisations and the private sector and also aims to generally provide greater international visibility for energy efficiency. Tasks groups are working, e.g. on buildings, digitalisation, deployment of super-efficient equipment and appliances or energy management systems (Energy Efficiency Hub Website, 2023). Further institutions that promote knowledge and learning include, among others, the UNEP Sustainable Buildings and Climate Initiative (SBCI), UNDP, UNECE, the Clean Energy Ministerial, the MDBs, C40 and the WBCSD. This governance function therefore seems to be relatively well-developed.

Table 3 below summarises the results of the above analysis, picking up on the list of governance options in Table 2 above. Overall, while the knowledge and learning functions seems to be relatively well developed, governance in four of the five functions discussed in this paper features substantial weaknesses. The next section will discuss options for overcoming these weaknesses.

Discussion: factors impeding and promoting governance and options for enhancement

Factors impeding and promoting global governance on buildings

The previous section identified weaknesses in the areas of guidance and signal, rules and standards, transparency and accountability and means of implementation. These findings match earlier work on the current status of global energy governance in general and efficiency governance in particular, which has described the governance landscape as “diffuse” (J. Gupta & Ivanova, 2009, p. 340), “a mixed bag of incidental outcomes” (Leal-Arcas & Filis, 2013, p. 2f) or “a hodgepodge of multiple actors” (Sovacool & Florini, 2012, p. 252). Scathingly, Sovacool and Florini conclude, “The sheer

Table 3 Summary of current status of global governance and international cooperation

Governance function	Current status of global governance and international cooperation
Guidance and signal	<ul style="list-style-type: none"> • No internationally agreed targets, various call for actions were supported only by handfuls of countries • Calls/commitments for halving emissions by 2030 and/or full decarbonisation by 2050 by some countries, C40 Cities, World GBC, GlobalABC, and Race to Zero campaign
Rules and standards	<ul style="list-style-type: none"> • No international requirements to include sectoral emission targets and concrete policies in NDCs and long-term climate strategies • Transnational decarbonisation commitments organised by C40 Cities, World GBC, and Race to Zero, but robustness of the financial alliances has been questioned • Model building codes, e.g. by the Caribbean community and non-state International Code Council • Some regional harmonisation of standards for cooling appliances • No international coordination on public and private procurement of low-emission heating and cooling • G20 pledge on fossil fuel subsidy reform but definition and implementation has been weak • No international coordination on emission pricing
Transparency and accountability	<ul style="list-style-type: none"> • Robust sectoral emission inventories under UNFCCC, National Communications report on measures taken and their impacts, but little attention to sector-specific developments, no assessment of adequacy, and no penalties for non-compliance • G20 process on fossil subsidy reform has weak transparency provisions • Robustness of transparency mechanisms of institutions addressing non-state and sub-national actors is not yet clear
Means of implementation	<ul style="list-style-type: none"> • Substantial provision of resources, but lack of data on actual needs and flows. IPCC and IEA consider that investment needs to grow 3–4 times • Support is often short-term rather than long-term and strategic • Coordinated research, development and demonstration are undertaken, e.g. by IEA Technology Collaboration Programmes
Knowledge and learning	<ul style="list-style-type: none"> • Seems to be well-developed

number of actors creates a global energy governance scene that appears frenetically busy... the current global energy governance model is full of sound and fury, yet signifies far too little substance” (Sovacool & Florini, 2012, p. 252). This matches the finding above that the potential for global governance has been exploited only to a limited extent. The application of governance functions has enabled us to identify that much of the “frenetic” activity relates to knowledge and learning, while the more difficult functions are being tackled to a much lesser extent.

There are probably several factors causing this state of affairs. Rational functionalism posits that countries follow a logic of consequences, engaging in international cooperation based on their perceptions of costs and benefits (R. O. Keohane, 1984). Constructivism argues that actors follow a logic of appropriateness, reflecting common beliefs and understandings of priorities, but the two logics are not mutually exclusive (Belyi, 2014; March & Olsen, 2011). Indeed, the perceived need for action in the

buildings sector appears to be low not only in terms of international action but indeed any kind of action. For instance, in 2020, about two-thirds of countries lacked mandatory building energy codes; more than two-thirds of the buildings that are expected to be constructed between now and 2050 are expected to be constructed in countries that currently do not have any building energy codes. Moreover, where codes exist, they are often not enforced properly (IEA, 2021a; UN Climate Change, 2021). The high degree of fragmentation of the sector is a key barrier in this regard, while in the Global South, this is compounded by a strong lack of capacity. The high fragmentation makes it more difficult for policy-makers to address the sector since there are no large key emitters that could be addressed by policy. For civil society organisations, it is also easier to address large emitters rather than dispersed emission sources as in the buildings sector (I. Geppert, personal communication, 25 July 2022; B. Lebot, personal communication, 30 May 2022). Moreover, formation of international

institutions has in the past often been driven by the formation of transnational alliances of interest groups (Young, 1989)—but the high fragmentation of the buildings sector has entailed a lack of strong interests pushing efficiency options internationally (J. Gupta & Ivanova, 2009). Finally, a key ingredient for successful formation of international institutions is effective leadership (Hale, 2020; Young, 1989). However, as discussed in the preceding section, efforts to enhance international cooperation on buildings have so far been dominated by short-term stop-and-go efforts, probably a result of the factors mentioned previously.

However, the sector also features characteristics that can facilitate international cooperation. Energy efficiency in buildings can yield multiple benefits, such as contribution to most SDGs and increasing returns, i.e. initial action leading to lower costs of future action. In sectors with these characteristics, the largest challenge may indeed be the emergence of first movers to lead on action. Once first movers have emerged and achieved a critical mass, they can capitalise on the multiple benefits and increasing returns of action to engender further cooperation (Hale, 2020).

And current developments may signify that first movers are now starting to emerge. In recent years, a number of multi-actor coalitions pushing for addressing the buildings sector more strongly have formed, such as the GlobalABC, the Building to COP Coalition, and most recently the “buildings breakthrough”. In particular, the formation of the “buildings breakthrough” may be a sign that at least some countries are now willing to increase their engagement on this sector. The following discusses institutional avenues which such frontrunners could pursue to work towards achieving critical mass.

General potential of existing institutions

As laid out in the “Options to enhance global governance” section, the following section discusses institutional options to overcome the identified governance weaknesses based on the criteria of membership, institutional strength and capacity, legitimacy and political feasibility. The discussion will focus on institutions that have the potential to influence national action. While the robustness and transparency of current actions by sub-national and non-state actors needs to be improved, the UN system has

started tackling this question. Moreover, as noted in the “Synthesis of main barriers to energy efficiency in buildings” section, given the high degree of fragmentation of the sector, policy is crucial to align all of these actors towards energy efficiency.

In terms of the criterion of membership, institutions to fill the identified gaps therefore either need to be intergovernmental or transnational with strong government membership. In terms of institutional strength, filling the gaps identified requires institutions that have the capacity to give clear guidance and signals, define rules and standards, provide transparency and accountability and mobilise means of implementation. Moreover, while institutions do not need to be exclusively focused on energy efficiency or decarbonisation of buildings, this should at least be a strong focus.

On this basis, several of the institutions discussed in the “Evidence base” section can arguably be excluded from the further discussion:

- Agenda 2030 is a fixed document.
- IRENA is focused on renewables.
- The Multilateral Development Banks by their mandates may address only means of implementation.
- UN-Habitat as a UN-Programme has near-universal membership and correspondingly high legitimacy. However, while its mission includes environmental sustainability, the focus of its mandate is quality of life (UN-Habitat, 2022).

In addition to these considerations, none of the interview partners highlighted these institutions as being promising avenues for strengthening the gaps identified. This leaves the UNFCCC/PA, the IEA, the G7/G20 and UNEP, in particular the GlobalABC that is hosted by UNEP, and the new “buildings breakthrough”. The following will discuss each of these institutions in turn.

The “buildings breakthrough” seems a promising starting place to enhance action on buildings because it was founded with exactly this objective. However, as noted above, its membership is currently limited. Moreover, no details about its planned activities are available. Finally, the secretariat of the GlobalABC serves as secretariat of the “breakthrough”, but its staff capacity is very limited. Currently, four people work on buildings in UNEP’s Cities Unit (this includes staff

and consultants), but only one of them works full-time for the GlobalABC (GlobalABC Website, 2023a; N. Steurer, personal communication, 3 June 2022).

The GlobalABC has 280 members including 39 countries from the Americas, Europe, Africa and Asia and many other relevant actors from the sector. Member countries include many major emitters such as the Brazil, Canada, France, Germany, Japan, Mexico, Russia, the UK and the USA. Furthermore, many large international organisations are members of the GlobalABC, including the IEA, IRENA, the IFC, UNECE, UN-Habitat and UNEP (GlobalABC Website, 2023c). So while membership is not universal, it arguably constitutes a “critical mass”. Expertise is strong as the institution is dedicated to buildings. However, the mandate is limited. Existing work areas relate in particular to the governance functions guidance and signal, means of implementation in terms of capacity building and knowledge and learning. The common statement which members must subscribe to does not include a requirement to reduce own emissions (GlobalABC Website, 2022a). Finally, in terms of practical feasibility, as noted above, staff capacity is very limited.

The IEA’s membership is limited to OECD countries but its association membership also includes 11 emerging economy countries, for example, Brazil, China, India, Indonesia and South Africa (IEA, 2022c). The key mission of the IEA is to provide analysis, data and policy recommendations. It is widely seen as authoritative on energy issues and has strongly tried to promote energy efficiency as “first fuel” and to highlight its multiple benefits (Voita, 2021), which provides indicative guidance and signal. Given its mission, it has no scope to facilitate target setting, to create rules and standards or to mobilise finance, but it could play a key role in enhancing transparency and accountability.

With 194 parties (UNFCCC Website, 2023b), the Paris Agreement has near-universal membership and in consequence high legitimacy. In terms of institutional strength and capacity, the Conference of the Parties to the UNFCCC serving as Meeting of the Parties to the Paris Agreement (CMA) has legal competence to act on all five governance functions and there is a large secretariat with around 450 staff in place (UNFCCC Website, 2023a). In terms of feasibility, promoting efficiency is a key lever for GHG reductions, so generally in line with the institution’s mandate. However, its large membership also entails

a broad variety of interests. Moreover, excepting some procedural matters, all decisions need to be taken by consensus (Yamin & Depledge, 2004).

G7/G20 have limited membership and hence limited legitimacy, but in particular, the G20 includes all large emitters. In terms of strength and capacity, the example of fossil fuel subsidy reform illustrates that they may in principle take action across all governance functions. However, in terms of practical feasibility, the example also shows that adopting stringent commitments and providing strict transparency has been difficult. Moreover, given the annually changing presidencies, continuity is a problem. For example, the Australian 2014 G20 presidency prioritised energy efficiency, but it did not stay a priority in the following years (A. Hinge, personal communication, 8 June 2022).

Options to enhance cooperation per governance function

Based on the above discussion of the general potential of existing institutions, the following section discusses which actions could be pursued by first movers within these institutions to close the identified governance gaps and engender catalytic cooperation.

In terms of guidance and signal, normative goals can provide a focal point around which potential first movers can converge, and they can enhance such actors’ leverage in political contestation (Dai, 2010; Hale, 2020). The “buildings breakthrough” adopted the vision statement, “near-zero emission and resilient buildings are the new normal by 2030”. However, this goal may be too unspecific to mobilise actors. To add value to the existing governance landscape, a more specific objective may be more helpful, such as targets to have all new buildings at net zero carbon by 2030 the latest, and achieve full decarbonisation by 2050, as advocated by several institutions. But at the same time, it would need to take into account the capacities of developing countries. As noted in the “Potential of global governance to address barriers and potentials” section, conduct-based rather than outcome-based targets might be more appropriate for countries with limited capacity, such as percentages of new building construction that should be code-compliant by a certain date. To accommodate different levels of capacity, targets could be differentiated by country groups, where countries with high capacity would adopt more ambitious targets.

Under the Paris Agreement, there are at least two near-term opportunities to strengthen guidance and signal. First, COP26 and COP27 established a work programme to scale up mitigation ambition and implementation. Interested governments could try to use this work programme to develop government-backed targets and roadmaps at sector level (Evans, 2022). The second opportunity is the first Global Stocktake (GST) which is concluding in December 2023. It could be used to collate and institutionalise existing knowledge and roadmaps on what achieving the Paris objectives would mean for each sector and what the current status is (Hermwille et al., 2019).

The G7 could potentially also send a signal on efficiency in buildings or buildings decarbonisation more generally. The 2022 G7 summit in Elmau adopted a number of sectoral targets, including commitment “to a highly decarbonised road sector by 2030” and a commitment to “achieving a fully or predominantly decarbonised power sector by 2035” (G7 Germany, 2022b). While the buildings sector was not even mentioned in the Elmau communiqué, G7 member France is one of the coordinators of the “buildings breakthrough” and G7 members Canada, Germany and the UK are also supporters of the “breakthrough”. They could therefore coordinate efforts to promote adoption of a target for the buildings sector by the G7.

In terms of rules and standards, a balance needs to be struck between keeping entry costs to actually start cooperation low on the one hand (Hale, 2020) and actually adding to the existing governance landscape on the other. To add value, the work programme of the “buildings breakthrough” would need to include adoption of more specific pledges by its individual members, for example to phase out fossil heating by a certain date or relating to the weaknesses identified in the previous section as regards harmonisation of building code methodologies, standards for appliances and coordination of procurement. To entice participation, flexibility could be given to countries on the form and content of their individual pledges, as in the Paris Agreement. To capture the results of increasing returns, such pledges should be updated regularly, also as in the Paris Agreement (Hale, 2020). To promote policy consistency, such pledges should then also be included in countries’ NDCs.

Under the Paris Agreement, the iterative nature of NDCs already allows for capturing increasing returns. To relate NDCs more directly to relevant

actors, frontrunner countries could push for making inclusion of more sectoral details in NDCs mandatory. However, the guidance on features of NDCs is up for further consideration only in 2025 (UNFCCC, 2019a). Since the next round of NDCs for the period 2030–2035 is also due in 2025 (UNFCCC, 2016), any changes to the NDC guidance would apply only far ahead in the future. To accelerate this process, given that current NDCs are clearly not aligned with the objectives of the Paris Agreement, frontrunner countries could try to utilise the GST. As part of the GST’s outcome, parties could decide that future NDCs need to include a sectoral breakdown (van Asselt et al., 2023). Parties could also decide that a thorough review and revision of the NDC guidance should take place in 2024 so that it would already apply to the NDCs that need to be submitted in 2025.

Transparency and accountability provisions can enhance the political leverage of pro-compliance actors by providing them with information they might otherwise not have and with a political forum to demand enhanced action (Dai, 2010; Hale, 2020). If countries did include building-related pledges in their NDCs, implementation of these pledges would be subject to the Paris Agreement’s transparency mechanisms. However, substantial strengthening of the PA’s transparency provisions is required to enable them to actually have an impact. However, the first review and potential update of modalities, procedures and guidelines for the Enhanced Transparency Framework is due only in 2028 (UNFCCC, 2019b, p. 2). As with the NDC guidance, frontrunner countries could try to achieve agreement on an acceleration of this timeline. In the meantime, interested countries and in particular COP presidencies could try to use the new mitigation work programme and the annual high-level ministerial meeting on pre-2030 targets and implementation as complementary means to strengthen accountability. The COP presidencies could make clear that parties will be expected to demonstrate each year how they are strengthening ambition and implementation of their climate policies. In addition to NDCs, this could include a focus on sectoral commitments such as those made in the context of the sectoral “breakthroughs” (Evans, 2022; Obergassel et al., 2022).

Another option is to leverage existing activities by the GlobalABC and the IEA, which are already tracking the development of the buildings sector at global level (IEA, 2023). Moreover, the IEA is leading

tracking of progress against the “Breakthroughs” (IEA et al., 2022). If the parties to the Paris Agreement or the G7/G20 did adopt a target on buildings, they could thus similarly call on the IEA to track progress.

In terms of means of implementation, we found that there is a lack of data on needs and actual flows at sector level. Donor countries should therefore invest resources to fill these data gaps in order to gain a more accurate picture. In addition, this gap could be addressed under the GST. Once financing needs and gaps have been identified more clearly, both the formal negotiations and individual funding initiatives could target identified gaps more clearly. Especially the “breakthrough” could also try to mobilise pledges to increase provision of resources to developing countries. Given its limited staff, developed country members should also provide more resources to the secretariat.

In summary, most institutions have specific strengths but also weaknesses that limit their potential. However, there are also some synergies that may be leveraged among them. Table 4 summarises the above discussion.

Conclusion: pathways towards enhanced governance

Buildings are one of the main GHG emitting sectors, and energy efficiency is a fundamental lever for emission reductions in buildings. However, political attention to this action area has been low. Most countries lack strong mitigation policies and/or enforcement or even still provide subsidies for fossil fuels and boilers. There is also a large number of economic, technical, information, social/cultural and structural barriers. This paper has sought to analyse how global governance and international cooperation could help overcome these barriers.

Countries have traditionally been reluctant to cooperate on energy issues because they are seen as central to national security. In addition, the buildings sector in particular is less amenable to international cooperation than other sectors because it is strongly characterised by local and national circumstances. However, overcoming the capacity constraints of developing countries clearly requires international cooperation. International institutions can also help

overcome political inertia and market uncertainty by providing guidance and signals on the need to act as well as by specific rules and standards and transparency and accountability provisions.

In practice, however, options for global governance and international cooperation in the sector have been used only to a limited extent, though with some variation. Very many institutions are active on the provision of knowledge and learning. There is also substantial dynamic among non-state and sub-national actors to commit to net-zero emission targets, that is, to develop rules and standards and corresponding transparency mechanisms. However, the robustness of the transparency mechanisms of these initiatives cannot yet be assessed and the robustness of the initiatives by financial actors has been questioned in general. Regarding nation states, there is no strong government-backed international signal on the need to decarbonise the sector, little rule-setting and little transparency and accountability of countries’ actions in the sector. Regarding means of implementation, while substantial resources seem to be provided, there is a lack of data on actual needs. IPCC and IEA consider that investments need to grow by a factor of 3–4 by 2030 to get onto a Paris-compatible trajectory.

Overall, political engagement has been low. The buildings sector was not even mentioned in recent outcomes of key institutions such as the G7 or the Major Economies Forum. The sector has therefore lacked a key precondition of effective international cooperation, namely effective leadership. Emergence of first movers has probably been hampered by the high fragmentation of the sector and the corresponding difficulties to address it by policy and the lack of large pro-efficiency interest groups. However, this may currently be changing, given recent initiatives such as the formation of the GlobalABC, the “Building to COP Coalition” and the “buildings breakthrough”.

If some countries do indeed intend to become more active, they could capitalise on the multiple benefits and increasing returns of action in the sector to engender further cooperation. They could work through like-minded coalitions such as the “breakthrough” and at the same try to engender stronger cooperation in broader institutions such as the climate regime.

Table 4 Summary of options to close governance gaps

Gaps		Institutions and their potential activities to close the gaps			
	“Breakthrough”	IEA	Paris Agreement	GlobalABC	G7/G20
Lack of a strong guidance and signal	Adopt a more specific objective for the “breakthrough”	Is already emphasising importance of efficiency as “first fuel”	Use new mitigation work programme and GST, building on existing roadmaps such as the GlobalABC roadmap	Already prepared roadmap, which may serve as basis for work under the UNFCCC	Adopt sectoral target similar to Elmau targets
Lack of rules and standards	Adoption of specific pledges by individual members	No mandate	Specify NDC guidance Coordinate specific rules and standards Call on countries to include “breakthrough” pledges in NDCs	No mandate	Adopt sectoral target similar to Elmau targets
Lack of transparency and accountability of countries’ actions	Track progress of individual countries	Track progress of individual countries	Strengthen transparency mechanisms generally and focus on sectors Annual ministerial roundtables as accountability checkpoint If pledges are included in NDCs, they will be subject to PA transparency mechanisms	Track progress of individual countries	If sectoral target was adopted by G7/G20, could request IEA to track progress
Lack of means of implementation	Include mobilisation of resources in work programme	Fill data gaps on needs and actual flows	Fill data gaps on needs and actual flows and call on countries and financial institutions to fill finance gaps	Scale up capacity building	Organise commitments to fill finance gaps

To add value to the existing institutional landscape, the “breakthrough” could take a number of steps, such as the following:

- To strengthen guidance and signal, adopt a more specific objective, such as targets to have all new buildings at net zero carbon by 2030 the latest, and achieve full decarbonisation by 2050, as advocated by several institutions. To account for limited capacities of developing countries, targets could be differentiated by type of country, with developing countries adopting less ambitious targets relating to, e.g. on percentages of code-compliant new builds to be achieved by a certain date, or to phase out all support for fossil heating and aim for a full phase-out of on-site fossil heating by a certain date.
- To strengthen rules and standards, adopt coordinated commitments by state and non-state actors, for example to phase out fossil heating by a certain date or relating to the weaknesses identified regarding harmonisation of building code methodologies, standards for appliances and coordination of procurement. To promote policy consistency, such commitments should then also be included in countries’ NDCs.
- To strengthen means of implementation, scale up technical and financial support for policy development, planning, implementation, evaluation and enforcement capacity of national and local governments in developing countries as well as for training, capacity building and awareness programmes of professionals such as architects and installers.

Developed country members should also provide more resources to the Secretariat of the GlobalABC, which serves as a “breakthrough” secretariat and currently has only minimal staff. Finally, the “breakthrough” should aim to increase its membership at least to the number of countries that are members of the GlobalABC (currently 39, as opposed to 16 “breakthrough” members).

In addition to fleshing out the “buildings breakthrough”, the members of the “breakthrough” and other interested countries could also pursue a number of actions under the Paris Agreement to engender more cooperation. The Conference of the

Parties serving as Meeting of the Parties to the Paris Agreement (CMA) could take the following:

- To strengthen guidance and signal, develop a sector-specific international decarbonisation roadmap, for example in the framework of the new work programme for urgently scaling up mitigation ambition and implementation, including indications of when the buildings sector should achieve zero or net-zero emissions and interim emission reduction milestones. To that end, actors could build on existing roadmaps to sectoral decarbonisation, such as the Climate Action Pathways developed under the Marrakesh Partnership or roadmaps formed by other institutions, such as the International Energy Agency (IEA) or the Global Alliance for Buildings and Construction.
- To strengthen rules and standards, request parties to include sectoral emission targets and concrete policies in their NDCs and long-term climate strategies.
- To strengthen transparency and accountability, develop additional reporting requirements that specifically focus on implementing and achieving NDCs in individual sectors under the Paris Agreement’s Enhanced Transparency Framework (ETF). In the meantime, the COP presidencies could also try to use the annual high-level ministerial roundtables on mitigation as accountability checkpoints to demand demonstration of clear progress.

In addition, four of the seven G7 countries are supporters of the “breakthrough”. They could therefore work towards the adoption of a sectoral target and follow-up action by the G7, similar to the targets the G7 already adopted for decarbonisation of the power and transport sectors.

The governance landscape is evolving dynamically; this article therefore provides only a snapshot of the current status. Further work should therefore continue to observe the development of the landscape. Future research could also analyse more deeply how the multiple benefits and increasing returns of energy efficiency could be harnessed more strongly to enhance cooperation. Identifying ways and means to mobilise political action will be critical if the objectives of the Paris Agreement are still to be achieved.

Annex 1. More details on semi-structured interviews.

Of the eleven persons interviewed, one is a private consultant, one a representative of an international business association, two representatives of a national non-profit organisations, one an official of an industrialised country government, one an official of an international organisation, two employees of industrialised country development cooperation agencies and three academics. Five interview partners are from Europe, one from North America, three from South Asia and two from South Africa.

All interview partners were asked the following common questions:

- What are the most important enablers and barriers for mitigation actions in the buildings sector?
- What could global governance and international cooperation do in theory to help leverage enablers and overcome barriers?
- What is happening in practice, where are global governance and international cooperation on the right track and where are gaps and why do they exist?
- How could gaps be filled, e.g. by enhancing existing institution or creating a new one?

Annex 2. Synthesis of activities by international institutions by governance function.

Governance function	Activities
Guidance and signal	<ul style="list-style-type: none"> • SDGs target 7.3 aims at “doubl(ing) the global rate of improvement in EE”, but there is no specific target for buildings • New Urban Agenda adopted at the United Nations Conference on Housing and Sustainable Urban Development (Habitat III) in 2016 as guideline for urban development in the next 20 years includes a commitment to climate action but no quantified target • Buildings as Critical Climate Solution (BCCS) call and the Zero Carbon Buildings for All Initiative aim for halving building emissions by 2030 and full decarbonisation by 2050, but each call gained only 3–4 government signatories. The Global Call for Low Carbon, Energy Efficient, and Resilient buildings calls on countries to develop national strategies for buildings and construction in line with the Paris Agreement Goals and was signed by six countries (GlobalABC, 2022) • May 2022 meeting of G7 energy and climate ministers recognised the need to reach net-zero GHG emission by 2050 and pledged to “promote reaching zero carbon-ready/zero emission new buildings, ideally by 2030 or sooner” (G7 Germany, 2022a). However, communiqué from the June 2022 G7 Leader’s summit did not include any mention of the buildings sector (G7 Germany, 2022b) • “Buildings Breakthrough” has objective that “near-zero emission and resilient buildings are the new normal by 2030”, supported by 16 countries and 13 initiatives and foundations (GlobalABC Website, 2023b) • C40 Net Zero Carbon Buildings Declaration has the objective that all new buildings operate at net zero carbon by 2030 and all buildings by 2050 and has been signed by 28 cities (C40 Cities, 2022) • Net Zero Carbon Buildings Commitment organised by the World Green Building Council requires that by 2030 signatories achieve net-zero operating emissions of their existing buildings and net-zero lifecycle emissions for all new developments and major renovations. Signatories include 138 businesses and organisations, 28 cities and 6 federal states and regions (WorldGBC Website, 2022b) • UNFCCC High-Level Champions are maintaining the “Race to Zero” campaign, aiming to halve global emissions by 2030 and achieve net-zero emissions by 2050 at the latest. “Race to Zero” is open to participants from all sectors; signatories include investors accounting for USD 1.2 trillion in real estate assets, construction companies, architects and engineers (Owen-Burge, 2021) • Several actors are setting objectives to improve energy efficiency of cooling in the context of the requirement of phasing down HFC refrigerants as per the Kigali Amendment to the Montreal Protocol, e.g. the G7 Biarritz Pledge for Fast Action on Efficient Cooling (G7, 2019), the Efficient Cooling Initiative, the Cool Coalition and the Clean Cooling Collaborative

Governance function	Activities
Rules and standards	<ul style="list-style-type: none"> • G20 in 2009 pledged to “phase out inefficient fossil fuel subsidies”. However, pledge contains no definition of “inefficient fossil fuel subsidy”, nor of “subsidies” in general, nor a clear timeline (G20, 2009). IEA found that G20 fossil fuel subsidies have remained unchanged in nominal terms, at USD 159.3 billion in 2020 compared to USD 161.8 billion in 2010 (OECD/IEA, 2021) • Under C40 Net Zero Carbon Buildings Declaration, members pledge to enact regulations and/or planning policy to ensure new buildings operate at net zero carbon by 2030 and all buildings by 2050 (C40 Cities, 2022) • Net Zero Carbon Buildings Commitment organised by the World GBC requires that by 2030, signatories achieve net-zero operating emissions of existing buildings and net-zero lifecycle emissions for all new developments and major renovations. Signatories include 138 businesses and organisations, 28 cities and 6 federal states and regions (WorldGBC Website, 2022b) • Under the Net Zero Asset Managers Initiative, Net-Zero Asset Owner Alliance and Net-Zero Banking Alliance, coalitions of private investors have pledged to make their portfolios net-zero but robustness has been questioned (McCully, 2023; Universal Owner, 2021) • Regarding pooling of purchasing power, during design, K-CEP funders initially envisaged that buyers’ and/or sellers’ clubs could be an effective means to expand the market share of highly efficient cooling technology, but there was not sufficient interest or uptake, so initiative was ultimately abandoned (Clean Cooling Collaborative, 2022) • Some efforts to harmonise building codes and develop model regulations: UNECE developed Framework Guidelines for Energy Efficiency Standards in Buildings which are regularly reviewed and updated (ECOSOC, 2020), Caribbean Community developed a Regional Energy Efficiency Building Code; the non-state International Code Council developed an International Energy Conservation Code (IECC) and an International Green Construction Code (IgCC) already in 2000 and 2010 respectively and is working to broaden their uptake (UNEP, 2021) • Regional air condition harmonisation efforts ongoing in Southeast Asia, Southern Africa, East Africa, West Africa, the Caribbean and other regions (Park et al., 2021) • International standardisation bodies, most notably ISO and International Electrotechnical Commission (IEC), have developed energy efficiency definitions and measurement standards for building energy performance, building products and equipment (International Electrotechnical Commission, 2023; ISO Website, 2023)

Governance function	Activities
Transparency and accountability	<ul style="list-style-type: none"> • Parties to UNFCCC and PA must regularly submit GHG emission inventories and reports on policies and measures implemented and their impact. However, parties are not required to actually achieve NDCs and UNFCCC mostly focuses on economy-wide emissions, and literature questions the capacity of the transparency mechanisms to have an impact on parties' actions: first, these mechanisms have neither the mandate to assess the adequacy of individual parties' NDCs nor the mandate to assess the adequacy of parties' policies and actions to achieve their NDCs; second, the wide variety of NDCs complicates assessment; third, opportunities for non-party stakeholders to participate in the transparency mechanisms are restricted; fourth, there are doubts as to whether Parties and the UNFCCC Secretariat have sufficient resources to adequately operate the Enhanced Transparency Framework (Pauw et al., 2018; Raiser et al., 2022; Weikmans et al., 2020) • G20 peer-review process pledge to phase out inefficient fossil fuel subsidies is voluntary and since there is no common definition, countries are free to come up with their own definitions. Process would therefore need to become mandatory and more stringent to be effective (Asmelash, 2017) • C40 Net Zero Carbon Buildings Declaration requires annual progress reports. C40 produced a summary progress report (C40 Cities, 2022), but the web page dedicated to the Net Zero Carbon Buildings Declaration seems to have been taken offline • WorldGBC Net Zero Carbon Buildings Commitment includes requirements of annual progress reports, including verification of performance at individual building and portfolio level (WorldGBC Website, 2022b). WorldGBC Website includes a detailed page on how to report on Net Zero Carbon Buildings Commitment (WorldGBC Website, 2022a), but displays no information on reporting having been done • Net Zero Asset Managers Initiative, Net-Zero Asset Owner Alliance and the Net-Zero Banking Alliance also require regular reporting on progress made. Respective guidelines were developed under the aegis of UN institutions, in the former case the UNFCCC Race to Zero campaign and in the latter two cases the UNEP Finance Initiative (Net Zero Asset Managers Initiative, 2021; Net-Zero Asset Owner Alliance, 2021; Net-Zero Banking Alliance, 2022). All three so far reported on which targets the individual members have set for themselves but not on implementation (Net Zero Asset Managers Initiative, 2022; UNEP FI Website, 2022, 2023) • UN Secretary-General convened a High-Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities which published recommendations for more credible climate pledges by non-state actors at COP27 (United Nations' High-Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities, 2022) • ISO elaborated Net Zero Guidelines, a standard for credible targets and measures for climate neutrality at the corporate level (International Standards Organisation, 2023)

Governance function	Activities
Means of implementation	<ul style="list-style-type: none"> • As part of the Zero Carbon Buildings for all initiative, multilateral development banks and private finance institutions committed to mobilising USD 1 trillion in “Paris-compliant” building investments by 2030. Under the Net-Zero Asset Owner Alliance, the world’s largest pensions funds and insurers, who are directing more than USD 2.4 trillion in investments, committed to achieving carbon-neutral investment portfolios by 2050 (UN Climate Change, 2021) • GlobalABC has supported development of more than 30 national and sub-national building decarbonisation roadmaps (GlobalABC Website, 2022b) • IEA’s Energy Efficiency in Emerging Economies programme works with Brazil, China, India, Indonesia, Mexico and South Africa as well as other countries in Asia and Latin America to quantify and communicate multiple benefits of energy efficiency, supports policy development in these countries and offers series of thematic workshops and policy training (IEA, 2022d) • IEA is also organising a broad range of Technology Collaboration Programmes (TCPs) on energy efficiency, district heating and cooling including combined heat and power, energy storage, heat pumps, and solar heating and cooling to organise international collaborative RD&D as well as knowledge exchange and to develop market and policy recommendations (IEA, 2022b) • Other institutions that undertake capacity building include, e.g. the MDBs, UNDP, UNECE, C40, ICLEI, the WorldGBC, the GBPN and the Cool Coalition • Regarding building ratings, IFC developed the EDGE (Excellence in Design for Greater Efficiencies) certification system, which assesses savings in energy, water and embodied energy in materials of specific building projects. Based on their performance, buildings can receive a certification from accredited certifiers with the intention to enable developers and banks to easily differentiate green buildings and thereby mobilise investment (EDGE Buildings, 2022). MDBs are also using the EDGE system for their own finance (e.g. Asian Development Bank, 2019) • Following up on Kigali Amendment to the Montreal Protocol, cooling equipment has received increased attention. In addition to MDB programmes and the Montreal Protocol’s own financial mechanism, the Kigali Cooling Efficiency Program (K-CEP) united 17 foundations and individual donors in September 2016 with a joint commitment of \$50 million to help developing countries transition to energy efficient, climate-friendly, affordable cooling solutions (Clean Cooling Collaborative, 2022). Moreover, in October 2021, the Green Climate Fund (GCF) approved a World Bank Cooling Facility with USD 157 million in direct GCF financing, which is intended to leverage USD 722 million in World Bank co-financing (Sustainable Energy for All, 2022)

Governance function	Activities
Knowledge and learning	<ul style="list-style-type: none"> • UNFCCC Technical Examination Process (TEP) has collated and synthesised good practice policies for a variety of sectors, including low-emission housing and buildings (UNFCCC Website, 2022) • The G20 and the Major Economies Forum on Energy and Climate undertook activities to develop knowledge and promote implementation on a range of issues such as energy performance metrics, building codes and rating schemes and best practice policies, for example in the framework of the G20's, 2014 Energy Efficiency Action Plan (G20, 2014) • The Energy Efficiency Hub has 16 country members (Argentina, Australia, Brazil, Canada, China, Denmark, European Commission, France, Germany, Japan, Korea, Luxembourg, Russia, Saudi Arabia, UK and USA) and promotes sharing of information and best practices among countries, international organisations and the private sector and also aims to generally provide greater international visibility for energy efficiency. Tasks groups are working, e.g. on buildings, digitilisation, deployment of super-efficient equipment and appliances or energy management systems (Energy Efficiency Hub Website, 2023) • The GlobalABC tracks global progress on buildings decarbonisation in its annual Global Status Report for Buildings and Construction (Buildings-GSR) and its Building Climate Tracker. The GlobalABC also provides policy guidance and global and regional buildings and construction roadmaps outlining aspirational targets, timelines and key actions for essential policies and technologies, including guidelines for countries to incorporate the buildings sector in their NDC. The GlobalABC has also supported the development of 33 national roadmaps in close collaboration with the respective national governments • United for Efficiency (U4E) is a public–private partnership led by UNEP, the Global Environment Facility (GEF), the United Nations Development Programme (UNDP), the International Copper Association (ICA), CLASP and the Natural Resources Defence Council (NRDC) with the support of other international partners. The U4E Global Map includes Country Savings Assessments showing the potential financial, environmental, energy and societal benefits that are possible with a transition to energy-efficient lighting, refrigerators, room air conditioners, electric motors and distribution transformers. U4E has also developed Model Regulation Guidelines for setting MEPs and testing methods • Further institutions that promote knowledge and learning include, among others, the UNEP Sustainable Buildings and Climate Initiative (SBCI), UNDP, UNECE, the Clean Energy Ministerial, the MDBs, C40 and the WBCSD

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Declarations

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References

- Asian Development Bank. (2019). ADB, IFC, and Ulaanbaatar City Partner to apply green building standards in design and construction of affordable homes. News Release, 16 October 2019. Asian Development Bank. Retrieved August 31, 2023, from <https://www.adb.org/news/adb-ifc-and-ulaanbaatar-city-partner-apply-green-building-standards-design-and-construction>
- Asmelash, H. K. (2017). *Phasing out fossil fuel subsidies in the G20: Progress, challenges, and ways forward*. International Centre for Trade and Sustainable Development (ICTSD). Retrieved August 31, 2023, from <https://www.greenpolicyplatform.org/research/phasing-out-fossil-fuel-subsidies-g20-progress-challenges-and-ways-forward>
- Bagaini, A., Colelli, F., Croci, E., & Molteni, T. (2020). Assessing the relevance of barriers to energy efficiency implementation in the building and transport sectors in eight European countries. *The Electricity Journal*, 33(8), 106820. <https://doi.org/10.1016/j.tej.2020.106820>
- Barrett, S. (2010). A portfolio system of climate treaties. In J. E. Aldy & R. N. Stavins (Eds.), *Post-Kyoto international climate policy: Implementing architectures for agreement* (pp. 240–270). Cambridge University Press.
- Belyi, A. (2014). International energy governance: Weaknesses of multilateralism. *International Studies Perspectives*, 15(3), 313–328. <https://doi.org/10.1111/insp.12024>
- Bierwirth, A., & Thomas, S. (2015). Almost best friends: Sufficiency and efficiency. In *Can sufficiency maximise efficiency gains in buildings?* ECEEE 2015 Summer Study Proceedings Retrieved August 31, 2023, from https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2015/1-foundations-of-future-energy-policy/almost-best-friends-sufficiency-and-efficiency-can-sufficiency-maximise-efficiency-gains-in-buildings/
- Blomqvist, S., Ödlund, L., & Rohdin, P. (2022). Understanding energy efficiency decisions in the building sector – a survey of barriers and drivers in Sweden. *Cleaner Engineering and Technology*, 9, 100527. <https://doi.org/10.1016/j.clet.2022.100527>
- Building to COP Website. (2022). *Building to COP*. Building to COP. Retrieved August 31, 2023, from <https://buildingtocop.org/>
- Bulkeley, H., Andonova, L. B., Betsill, M. M., Compagnon, D., Hale, T., Hoffmann, M. J., Newell, P., Paterson, M., Roger, C., & Vandever, S. D. (2014). *Transnational climate change governance*. Cambridge University Press.
- Bundesverfassungsgericht. (2021). *Verfassungsbeschwerden gegen das Klimaschutzgesetz teilweise erfolgreich. Pressemitteilung Nr. 31/2021 vom 29. April 2021*. Bundesverfassungsgericht. Retrieved August 31, 2023, from <https://www.bundesverfassungsgericht.de/SharedDocs/Pressemitteilungen/DE/2021/bvg21-031.html>
- C40 Cities. (2022). *C40 net-zero carbon buildings declaration: How cities are delivering low carbon and energy efficient buildings*. C40 Cities. Retrieved August 31, 2023, from https://www.c40.org/wp-content/uploads/2022/02/C40-Net-Zero-Carbon-Buildings-Declaration_Public-progress-report_Feb-2022.pdf
- Cabeza, L. F., Bai, Q., Bertoldi, P., Kihila, J. M., Lucena, A. F. P., Mata, É., Mirasgedis, S., Novikova, A., & Saheb, Y. (2022). Buildings. In P. R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, & J. Malley (Eds.), *IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. <https://doi.org/10.1017/9781009157926.011>
- Clean Cooling Collaborative. (2022). *Scaling up clean cooling for all. In Kigali cooling efficiency program impact report (2017–2021)*. Clean Cooling Collaborative. Retrieved August 31, 2023, from <https://www.cleancoolingcollaborative.org/wp-content/uploads/2021/08/K-CEP-Phase-I-Impact-Report.pdf>
- Climate Action Tracker. (2022). *Decarbonising buildings: Achieving zero carbon heating and cooling*. Climate Action Tracker. Retrieved August 31, 2023, from

- <https://climateactiontracker.org/publications/decarbonising-buildings-achieving-net-zero-carbon-heating-and-cooling>
- Cohn, C., & Esram, N. W. (2022). *Building electrification: Programs and best practices*. American Council for an Energy-Efficient Economy. Retrieved August 31, 2023, from aceee.org/researchreport/b2201
- Criado-Perez, C., Collins, C. G., Jackson, C. J., Oldfield, P., Pollard, B., & Sanders, K. (2020). Beyond an 'informed opinion': Evidence-based practice in the built environment. *Architectural Engineering and Design Management*, 16(1), 23–40. <https://doi.org/10.1080/17452007.2019.1617670>
- Cristino, T. M., Lotufo, F. A., Delinchant, B., Wurtz, F., & Faria Neto, A. (2021). A comprehensive review of obstacles and drivers to building energy-saving technologies and their association with research themes, types of buildings, and geographic regions. *Renewable and Sustainable Energy Reviews*, 135, 110191. <https://doi.org/10.1016/j.rser.2020.110191>
- Dai, X. (2010). Global regime and national change. *Climate Policy*, 10(6), 622–637. <https://doi.org/10.3763/cpol.2010.0146>
- De Búrca, G., Keohane, R. O., & Sabel, C. (2014). Global Experimentalist Governance. *British Journal of Political Science*, 44(3), 477–486. <https://doi.org/10.1017/S0007123414000076>
- ECOSOC. (2020). *Updated framework guidelines for energy efficiency standards in buildings, ECE/ENERGY/GE.6/2020/4, 13 July 2020*. United Nations Economic Commission for Europe Retrieved August 31, 2023, from https://unece.org/sites/default/files/2020-12/ECE_ENERGY_GE.6_2020_4e.pdf
- EDGE Buildings. (2022). *About EDGE*. EDGE Buildings. Retrieved August 31, 2023, from <https://edgebuildings.com/about/about-edge/>
- Energy Efficiency Hub Website. (2023). *Energy Efficiency Hub Homepage*. Energy Efficiency Hub. Retrieved August 31, 2023, from <https://energyefficiencyhub.org/>
- Evans, T. (2022). *COP27: Designing a work programme to scale up pre-2030 mitigation ambition and implementation for 1.5°C*. E3G. Retrieved August 31, 2023, from <https://www.e3g.org/publications/cop27-designing-a-work-programme-to-scale-up-pre-2030-mitigation-ambition-and-implementation-for-1-5c/>
- Florini, A., & Sovacool, B. K. (2009). Who governs energy? The challenges facing global energy governance. *Energy Policy*, 37(12), 5239–5248. <https://doi.org/10.1016/j.enpol.2009.07.039>
- Follesdal, A. (1998). Survey Article: Subsidiarity. *Journal of Political Philosophy*, 6(2), 190–218. <https://doi.org/10.1111/1467-9760.00052>
- Future of Climate Cooperation Website. (2023). *The future of climate cooperation*. Retrieved August 31, 2023, from <https://www.bsg.ox.ac.uk/research/research-projects/future-climate-cooperation>
- G20. (2009). *G20 leaders statement: The Pittsburgh summit. September 24-25, 2009*. Retrieved August 31, 2023, from <http://www.g20.utoronto.ca/2009/2009communiqu0925.html>
- G20. (2014). G20 energy efficiency action plan. In *Voluntary collaboration on energy efficiency*. 16 November 2014. Retrieved August 31, 2023, from <https://www.unepfi.org/fileadmin/energyefficiency/G20EEActionPlan.pdf>
- G20 EEFTG. (2017). *G20 energy efficiency investment toolkit*. G20 Energy Efficiency Finance Task Group. Retrieved August 31, 2023, from <https://www.unepfi.org/wordpress/wp-content/uploads/2017/05/G20-EE-Toolkit.pdf>
- G7. (2019). *Biarritz pledge for fast action on efficient cooling* (22 August 2019). Retrieved August 31, 2023, from <https://www.elysee.fr/admin/upload/default/0001/06/306cf93611abfad315fbc8ebce8e86dc27282363.pdf>
- G7 Germany. (2022a). *G7 climate, energy and environment ministers' communiqué*. Berlin 27 May 2022. Retrieved August 31, 2023, from https://www.bmwk.de/Redaktion/DE/Downloads/G/g7-konferenz-klima-energie-umweltminister-05-2022-abschlusskommuniquee.pdf?__blob=publicationFile&v=16&utm_source=SendGrid&utm_medium=Email&utm_campaign=IEA+newsletters
- G7 Germany. (2022b). *G7 leaders' communiqué*, Elmau, 28 June 2022. Retrieved August 31, 2023, from <https://www.g7germany.de/resource/blob/974430/2062292/9c213e6b4b36ed1bd687e82480040399/2022-07-14-leaders-communique-data.pdf?download=1>
- Gaur, A. S., Fitiwi, D. Z., & Curtis, J. (2021). Heat pumps and our low-carbon future: A comprehensive review. *Energy Research & Social Science*, 71, 101764. <https://doi.org/10.1016/j.erss.2020.101764>
- Gibbs, D., & O'Neill, K. (2015). Building a green economy? Sustainability transitions in the UK building sector. *Geoforum*, 59, 133–141. <https://doi.org/10.1016/j.geoforum.2014.12.004>
- Ghosh, A., Runge-Metzger, A., Victor, D. G., & Zou, J. (2022). The new way to fight climate change. In *Small-scale cooperation can succeed where global diplomacy has failed*. Foreign Affairs. Retrieved August 31, 2023, from <https://www.foreignaffairs.com/world/new-way-fight-climate-change>
- GlobalABC. (2022). *Building country commitments*. Retrieved August 31, 2023, from <https://sway.office.com/y4RKgAEVxavSd5WF?ref=Link>
- GlobalABC Website. (2022a). *Common statement*. GlobalABC. Retrieved August 31, 2023, from <https://globalabc.org/about/join-us/common-statement>
- GlobalABC Website. (2022b). *Roadmaps for buildings and construction*. GlobalABC. Retrieved August 31, 2023, from <https://globalabc.org/index.php/roadmaps-buildings-and-construction>
- GlobalABC Website. (2023a). *Meet the secretariat*. GlobalABC. Retrieved August 31, 2023, from <https://globalabc.org/about/meet-the-secretariat>
- GlobalABC Website. (2023b, January 20). *A call for a buildings breakthrough as a rallying point*. GlobalABC. Retrieved August 31, 2023, from <https://globalabc.org/news/call-buildings-breakthrough-rallying-point>
- GlobalABC Website. (2023c, January 30). *Our members*. GlobalABC. Retrieved August 31, 2023, from <https://globalabc.org/members/our-members>
- Green, J. F. (2017). Don't link carbon markets. *Nature*, 543(7646), 484–486. <https://doi.org/10.1038/543484a>
- Gupta, J., & Ivanova, A. (2009). Global energy efficiency governance in the context of climate politics. *Energy Efficiency*, 2(4), 339–352. <https://doi.org/10.1007/s12053-008-9036-4>

- Gupta, A., & van Asselt, H. (2019). Transparency in multi-lateral climate politics: Furthering (or distracting from) accountability?: Transparency in climate politics. *Regulation & Governance*, 13(1), 18–34. <https://doi.org/10.1111/rego.12159>
- Hale, T. (2020). Catalytic cooperation. *Global Environmental Politics*, 20(4), 73–98. https://doi.org/10.1162/glep_a_00561
- Hermwille, L. (2021). Hardwired towards transformation? Assessing global climate governance for power sector decarbonization. *Earth System Governance*, 8, 100054. <https://doi.org/10.1016/j.esg.2020.100054>
- Hermwille, L., Siemons, A., Förster, H., & Jeffery, L. (2019). Catalyzing mitigation ambition under the Paris Agreement: Elements for an effective Global Stocktake. *Climate Policy*, 19(8), 988–1001. <https://doi.org/10.1080/14693062.2019.1624494>
- Höfele, V., & Thomas, S. (2011). Combining theoretical and empirical evidence: Policy packages to make energy savings in buildings happen. In *Conference paper for the 2011 ECEEE summer study* (pp. 1321–1327). Retrieved August 31, 2023, from https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2011/5-saving-energy-in-buildings-the-time-to-act-is-now/combining-theoretical-and-empirical-evidence-policy-packages-to-make-energy-savings-in-buildings-happen/
- IEA. (2021a). *Building envelopes*. International Energy Agency. Retrieved August 31, 2023, from <https://www.iea.org/reports/heating>
- IEA. (2021b). *India Energy Outlook 2021*. OECD. Retrieved August 31, 2023, from <https://doi.org/10.1787/ec2fd78d-en>
- IEA. (2020). Tracking cooling 2020 – analysis. IEA. <https://www.iea.org/reports/tracking-cooling-2020>
- IEA. (2022a). *The future of heat pumps*. IEA. Retrieved August 31, 2023, from <https://www.iea.org/reports/the-future-of-heat-pumps>
- IEA. (2022b). *Buildings – topics*. IEA. Retrieved August 31, 2023, from <https://www.iea.org/energy-system/buildings>
- IEA. (2022c). *Countries & regions*. IEA. Retrieved August 31, 2023, from <https://www.iea.org/countries>
- IEA. (2022d). *Energy efficiency in emerging economies – Programmes*. IEA. Retrieved August 31, 2023, from <https://www.iea.org/programmes/energy-efficiency-in-emerging-economies>
- IEA. (2023). *Tracking clean energy progress 2023*. Retrieved August 31, 2023, from <https://www.iea.org/reports/tracking-clean-energy-progress-2023>
- IEA, IRENA, & UN Climate Change High-Level Champions. (2022). The breakthrough agenda report 2022. In *Accelerating sector transitions through stronger international collaboration*. IEA. International Energy Agency. Retrieved August 31, 2023, from <https://iea.blob.core.windows.net/assets/49ae4839-90a9-4d88-92bc-371e2b24546a/THEBREAKTHROUGHAGENDAREPORT2022.pdf>
- International Electrotechnical Commission. (2023). *IEC - SC 23K Dashboard > Scope*. Retrieved August 31, 2023, from https://www.iec.ch/dyn/www/f?p=103:7:::FSP_ORG_ID:10046
- International Standards Organisation. (2023). *ISO - net zero guidelines*. ISO. Retrieved August 31, 2023, from <https://www.iso.org/netzero>
- IPEEC Building Energy Efficiency Taskgroup. (2014). Building energy efficiency. In *Opportunities for international collaboration*. International Partnership for Energy Efficiency Cooperation. Retrieved August 31, 2023, from <https://www.energy.gov.au/sites/default/files/BEET%20%20Building%20Energy%20Efficiency%20-%20Opportunities%20for%20International%20Collaboration.pdf>
- IRENA, IEA, & REN21. (2020). *Renewable Energy policies in a time of transition: Heating and cooling*. IRENA, OECD/IEA and REN21. Retrieved August 31, 2023, from <https://www.irena.org/publications/2020/Nov/Renewable-energy-policies-in-a-time-of-transition-Heating-and-cooling>
- ISO Website. (2023). *ISO - Standards*. ISO. Retrieved August 31, 2023, from <https://www.iso.org/standards.html>
- Jordan, A., Huitema, D., van Asselt, H., & Forster, J. (Eds.). (2018). *Governing climate change: Polycentricity in action?* (1st ed.). Cambridge University Press. <https://doi.org/10.1017/9781108284646>
- Karlsson-Vinkhuyzen, S. (2015). The legitimation of global energy governance: A normative exploration. In F. Manabe & I. Sachs (Eds.), *Transitions to sustainability* (pp. 119–130). Springer Netherlands. <https://doi.org/10.1007/978-94-017-9532-6>
- Karlsson-Vinkhuyzen, S. I., Jollands, N., & Staudt, L. (2012). Global governance for sustainable energy: The contribution of a global public goods approach. *Ecological Economics*, 83, 11–18. <https://doi.org/10.1016/j.ecolecon.2012.08.009>
- Keohane, R. O. (1984). *After hegemony: Cooperation and discord in the world political economy*. Princeton University Press.
- Keohane, N., Petsonk, A., & Hanafi, A. (2017). Toward a club of carbon markets. *Climatic Change*, 144(1), 81–95. <https://doi.org/10.1007/s10584-015-1506-z>
- Kinley, R. (2017). Climate change after Paris: From turning point to transformation. *Climate Policy*, 17(1), 9–15. <https://doi.org/10.1080/14693062.2016.1191009>
- Kinley, R., Cutajar, M. Z., de Boer, Y., & Figueres, C. (2021). Beyond good intentions, to urgent action: Former UNFCCC leaders take stock of thirty years of international climate change negotiations. *Climate Policy*, 21(5), 593–603. <https://doi.org/10.1080/14693062.2020.1860567>
- Laan, T., Geddes, A., Bois van Kursk, O., Jones, N., Kuehne, K., Gerbase, L., O'Manique, C., Sharma, D., & Stockman, L. (2023). *Fanning the Flames: G20 provides record financial support for fossil fuels*. International Institute for Sustainable Development. Retrieved August 31, 2023, from <https://www.iisd.org/publications/report/fanning-flames-g20-support-of-fossil-fuels>
- Leal-Arcas, R., & Filis, A. (2013). The fragmented governance of the global energy economy: A legal-institutional analysis. *The Journal of World Energy Law & Business*, 6(4), 348–405. <https://doi.org/10.1093/jwelb/jwt011>
- Loorbach, D. A. (2010). Transition management for sustainable development: A prescriptive, complexity-based governance framework. *Governance*, 23(1), 161–183.
- Love, J., Smith, A. Z. P., Watson, S., Oikonomou, E., Summerfield, A., Gleeson, C., Biddulph, P., Chiu, L. F., Wingfield, J., Martin, C., Stone, A., & Lowe, R. (2017). The addition of heat pump electricity load profiles to GB electricity demand: Evidence from a heat pump field

- trial. *Applied Energy*, 204, 332–342. <https://doi.org/10.1016/j.apenergy.2017.07.026>
- Lowes, R., Rosenow, J., Qadrdan, M., & Wu, J. (2020a). Hot stuff: Research and policy principles for heat decarbonisation through smart electrification. *Energy Research & Social Science*, 70, 101735. Retrieved August 31, 2023. <https://doi.org/10.1016/j.erss.2020.101735>
- Lowes, R., Woodman, B., & Speirs, J. (2020b). Heating in Great Britain: An incumbent discourse coalition resists an electrifying future. *Environmental Innovation and Societal Transitions*, 37, 1–17. <https://doi.org/10.1016/j.eist.2020.07.007>
- Lowes, R., Rosenow, J., Scott, D., Sunderland, L., Thomas, S., Graf, A., Baton, M., Pantano, S., & Graham, P. (2022). The perfect fit: Shaping the fit for 55 package to drive a climate-compatible heat pump market. Regulatory Assistance Project, Agora Energiewende, CLASP, Global Buildings Performance Network.
- March, J. G., & Olsen, J. P. (2011). The logic of appropriateness. In R. E. Godin (Ed.), *The Oxford handbook of political science* (pp. 479–498). Oxford University Press. <https://doi.org/10.1093/oxfordhb/9780199604456.013.0024>
- Mata, É., Peñaloza, D., Sandkvist, F., & Nyberg, T. (2021). What is stopping low-carbon buildings? A global review of enablers and barriers. *Energy Research & Social Science*, 82, 102261. <https://doi.org/10.1016/j.erss.2021.102261>
- McCully, P. (2023). *Throwing fuel on the fire: GFANZ financing of fossil fuel expansion*. Reclaim Finance. Retrieved August 31, 2023, <https://reclaimfinance.org/site/wp-content/uploads/2023/01/Throwing-fuel-on-the-fire-GFANZ-financing-of-fossil-fuel-expansion.pdf>
- Meckling, J. O., & Chung, G. Y. (2009). Sectoral approaches for a post-2012 climate regime: A taxonomy. *Climate Policy*, 9(6), 652–668. <https://doi.org/10.3763/cpol.2009.0629>
- Morseletto, P., Biermann, F., & Pattberg, P. (2017). Governing by targets: Reductio ad unum and evolution of the two-degree climate target. *International Environmental Agreements: Politics, Law and Economics*, 17(5), 655–676. <https://doi.org/10.1007/s10784-016-9336-7>
- Nadel, S. (2019). Electrification in the transportation, buildings, and industrial sectors: A review of opportunities, barriers, and policies. *Current Sustainable/renewable Energy Reports*, 6(4), 158–168. <https://doi.org/10.1007/s40518-019-00138-z>
- Net Zero Asset Managers Initiative. (2021). *The net zero asset managers commitment*. Retrieved August 31, 2023, from <https://www.netzeroassetmanagers.org/media/2021/12/NZAM-Commitment.pdf>
- Net Zero Asset Managers Initiative. (2022). Initial target disclosure report. Retrieved August 31, 2023, from <https://www.netzeroassetmanagers.org/media/2022/07/NZAM-Initial-Target-Disclosure-Report-May-2022.pdf>
- Net-Zero Asset Owner Alliance. (2021). *Inaugural 2025 target setting protocol*. UNEP Finance Initiative. Retrieved August 31, 2023, from <https://www.unepfi.org/wordpress/wp-content/uploads/2021/01/Alliance-Target-Setting-Protocol-2021.pdf>
- Net-Zero Banking Alliance. (2022). NZBA intermediate target disclosure checklist. Retrieved August 31, 2023, from <https://www.unepfi.org/wordpress/wp-content/uploads/2022/08/NZBA-intermediate-target-disclosure-checklist.pdf>
- Obergassel, W., Lah, O., & Rudolph, F. (2021). Driving towards transformation? To what extent does global climate governance promote decarbonisation of land transport? *Earth System Governance*, 8, 100098. <https://doi.org/10.1016/j.esg.2021.100098>
- Obergassel, W., Bauer, S., Hermwille, L., Aykut, S. C., Boran, I., Chan, S., Fraude, C., Klein, R. J. T., Mar, K. A., Schroeder, H., & Simeonova, K. (2022). From regimebuilding to implementation: Harnessing the UN climate conferences to drive climate action. *Wires Climate Change*. <https://doi.org/10.1002/wcc.797>
- Oberthür, S., Hermwille, L., Khandekar, G., Obergassel, W., Rayner, T., Wyns, T., Mersmann, F., Jones, D., Kretschmer, B., & Melkie, M. (2017). *Key concepts, core challenges and governance functions of international climate governance*. Retrieved August 31, 2023, from <https://cop21ripples.climatestrategies.org/resources/deliverable-4-1/>
- Oberthür, S., Khandekar, G., & Wyns, T. (2021). Global governance for the decarbonization of energy-intensive industries: Great potential underexploited. *Earth System Governance*, 8, 100072. <https://doi.org/10.1016/j.esg.2020.100072>
- OECD/IEA. (2021). *Update on recent progress in reform of inefficient fossil-fuel subsidies that encourage wasteful consumption*. Organisation for Economic Co-operation and Development (OECD) and International Energy Agency (IEA). Retrieved August 31, 2023, from <https://www.oecd.org/fossil-fuels/publicationsandfurtherreading/OECD-IEA-G20-Fossil-Fuel-Subsidies-Reform-Update-2021.pdf>
- Otto, S., & Oberthür, S. (2022). *Global governance for the decarbonisation of energy-intensive industries*. Retrieved August 31, 2023, from <https://ndc-aspects.eu/news-events/assessing-sectoral-climate-governance-gaps-and-policy-options>
- Owen-Burge, C. (2021, October 26). *Race to Zero hits breakthrough built environment targets*. Climate Champions. Retrieved August 31, 2023, from <https://climatechampions.unfccc.int/race-to-zero-hits-breakthrough-targets-in-the-built-environment/>
- Park, W. Y., Shah, N., Vine, E., Blake, P., Holuj, B., Kim, J. H., & Kim, D. H. (2021). Ensuring the climate benefits of the Montreal Protocol: Global governance architecture for cooling efficiency and alternative refrigerants. *Energy Research & Social Science*, 76, 102068. <https://doi.org/10.1016/j.erss.2021.102068>
- Pathak, M., Slade, R., Shukla, P. R., Skea, J., Pichs-Madruga, R., & Ürge-Vorsatz, D. (2022). Technical summary. In P. R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, & J. Malley (Eds.), *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press. <https://doi.org/10.1017/9781009157926.002>
- Patt, A., Rajamani, L., Bhandari, P., Boncheva, A. I., Caparrós, A., Djemouai, K., Kubota, I., Peel, J., Sari, A. P., Sprinz,

- D. F., & Wettestad, J. (2022). International cooperation. In P. R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, M. Pathak, S. Some, P. Vyas, R. Fradera, M. Belkacemi, A. Hasija, G. Lisboa, S. Luz, & J. Malley (Eds.), Cambridge and New York, NY: Cambridge University Press, *IPCC, 2022: Climate Change 2022: Mitigation of climate change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. <https://doi.org/10.1017/9781009157926.016>
- Pauw, W. P., Klein, R. J. T., Mbeva, K., Dzebo, A., Cassanmagnago, D., & Rudloff, A. (2018). Beyond headline mitigation numbers: We need more transparent and comparable NDCs to achieve the Paris Agreement on climate change. *Climatic Change*, 147(1–2), 23–29. <https://doi.org/10.1007/s10584-017-2122-x>
- Raiser, K., Çalı, B., & Flachsland, C. (2022). Understanding pledge and review: Learning from analogies to the Paris Agreement review mechanisms. *Climate Policy*, 22(6), 711–727. <https://doi.org/10.1080/14693062.2022.2059436>
- Rayner, T. (2021a). Keeping it in the ground? Assessing global governance for fossil-fuel supply reduction. *Earth System Governance*, 8, 100061. <https://doi.org/10.1016/j.egs.2020.100061>
- Rayner, T. (2021b). Taking the slow route to decarbonisation? Developing climate governance for international transport. *Earth System Governance*, 8, 100100. <https://doi.org/10.1016/j.egs.2021.100100>
- Rayner, T., Oberthür, S., & Hermwille, L. (2021). A sectoral perspective on international climate governance: Key findings and research priorities. *Earth System Governance*, 8, 100105. <https://doi.org/10.1016/j.egs.2021.100105>
- Reda, I. A. (2023). Global energy governance. In R. Leal-Arcas (Ed.), *Climate and energy governance for a sustainable future* (pp. 241–254). Springer Nature. <https://doi.org/10.1007/978-981-19-8346-7>
- Reda, F., Ruggiero, S., Auvinen, K., & Temmes, A. (2021). Towards low-carbon district heating: Investigating the socio-technical challenges of the urban energy transition. *Smart Energy*, 4, 100054. <https://doi.org/10.1016/j.segy.2021.100054>
- Saurer, J., & Purnhagen, K. (2016). Klimawandel vor Gericht – Der Rechtsstreit der Nichtregierungsorganisation “Urgenda” gegen die Niederlande und seine Bedeutung für Deutschland. *Zeitschrift Für Umweltrecht*, 27(1), 16–23. Retrieved August 31, 2023, from https://www.zur.nomos.de/fileadmin/zur/doc/Aufsatz_ZUR_16_01.pdf
- Sawa, A. (2010). Sectoral approaches to a post-Kyoto international climate policy framework. In Aldy, J.E., Stavins, R.N. (Eds.): *Post-Kyoto International Climate Policy: Implementing Architectures for Agreement* (pp. 201–239). Cambridge University Press.
- Schmidt, J., Helme, N., Lee, J., & Houdashelt, M. (2008). Sector-based approach to the post-2012 climate change policy architecture. *Climate Policy*, 8(5), 494–515. <https://doi.org/10.3763/cpol.2007.0321>
- Seto, K. C., Dhakal, S., Bigio, A., Blanco, H., Delgado, G. C., Dewar, D., Huang, L., Inaba, A., Kansal, A., Lwasa, S., McMahon, J. E., Müller, D. B., Murakami, J., Nagendra, H., & Ramaswami, A. (2014). Human settlements, infrastructure and spatial planning. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge, and New York, NY: Cambridge University Press.
- Sheldon, M., Sethuvenkatraman, S., & Goldsworthy, M. (2018). Promoting the use of solar cooling and heating in Australia buildings (PUSCH): An industry roadmap. Australian Renewable Energy Agency.
- Simmons, B. A., & Martin, L. L. (2002). International organizations and institutions. In W. Carlsnaes et al. (Eds.), *The handbook of international relations* (2nd ed., pp. 195–196). Sage Publications.
- Smith, A. (2007). Translating sustainabilities between green niches and socio-technical regimes. *Technology Analysis & Strategic Management*, 19(4), 427–450. <https://doi.org/10.1080/09537320701403334>
- Sovacool, B. K., & Florini, A. (2012). Examining the complications of global energy governance. *Journal of Energy & Natural Resources Law*, 30(3), 235–263. <https://doi.org/10.1080/02646811.2012.11435295>
- Stavins, R., Zou, J., Brewer, T., Grand, M. C., den Elzen, M., Finus, M., Gupta, J., Höhne, N., Lee, M.-K., Michaelowa, A., Paterson, M., Ramakrishna, K., Wen, G., Wiener, J., & Winkler, H. (2014). International cooperation: Agreements and instruments. In O. Edenhofer, R. Pichs-Madruga, Y. Sokona, E. Farahani, S. Kadner, K. Seyboth, A. Adler, I. Baum, S. Brunner, P. Eickemeier, B. Kriemann, J. Savolainen, S. Schlömer, C. von Stechow, T. Zwickel, & J. C. Minx (Eds.), *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York, NY: Cambridge University Press.
- Stokke, O. S. (2012). *Disaggregating international regimes*. MIT Press.
- Sustainable Energy for All. (2022). *Sustainable cooling financial flows*. Sustainable energy for all | SEforALL. Retrieved August 31, 2023, from <https://www.seforall.org/chilling-prospects-2022/sustainable-cooling-financial-flows>
- Taranto, Y., & Saygın, D. (2018). *Energy pricing and non-market flows in Turkey's energy sector*. Sabanci University. Retrieved August 31, 2023, from <https://shura.org.tr/wp-content/uploads/2019/05/SHURA-2019-05-Energy-Pricing-and-Non-Market-Flows-in-Turkeys-Energy-Sector.pdf>
- The White House. (2022, June 17). *FACT SHEET: President Biden to galvanize global action to strengthen energy security and tackle the climate crisis through the Major Economies Forum on Energy and Climate*. The White House. Retrieved August 31, 2023, from <https://www.whitehouse.gov/briefing-room/statements-releases/2022/06/17/fact-sheet-president-biden-to-galvanize-global-action-to-strengthen-energy-security-and-tackle-the-climate-crisis-through-the-major-economies-forum-on-energy-and-climate/>

- Thema, J., Suerkemper, F., Couder, J., Mzavanadze, N., Chatterjee, S., Teubler, J., Thomas, S., Ürgе-Vorsatz, D., Hansen, M. B., Bouzarovski, S., Rasch, J., & Wilke, S. (2019). The multiple benefits of the 2030 EU energy efficiency potential. *Energies*, 12(14), 2798. <https://doi.org/10.3390/en12142798>
- U.S. Department of State. (2013). *Seventeenth leaders' representatives meeting of the major economies forum on energy and climate*. U.S. Department of State Retrieved August 31, 2023, from <https://2009-2017.state.gov/e/oes/rls/other/2013/215422.htm>
- UN Climate Change. (2021). Climate action pathway human settlements 2021. *Vision and Summary*. Retrieved August 31, 2023, from <https://unfccc.int/climate-action/marrakech-partnership/reporting-tracking/pathways/human-settlements-climate-action-pathway#eq-1>
- UN Climate Change. (2023). *GCAP UNFCCC - Home page*. Retrieved August 31, 2023, from <https://climateaction.unfccc.int/>
- UNEP. (2020). *Adopting decarbonization policies in the buildings & construction sector: Costs and benefits*. United Nations Environment Programme Retrieved August 31, 2023, from <https://globalabc.org/resources/publications/adopting-decarbonization-policies-buildings-and-construction-sector>
- UNEP. (2021). *2021 Global Status Report for Buildings and Construction: Towards a Zero-emission, Efficient and Resilient Buildings and Construction Sector*. United Nations Environment Programme. Retrieved August 31, 2023, from <https://www.unep.org/resources/report/2021-global-status-report-buildings-and-construction>
- UNEP FI Website. (2022). *Net-Zero Asset Owner Alliance progress report demonstrates advance on decarbonisation targets - United Nations Environment - Finance Initiative*. Retrieved August 31, 2023, from <https://www.unepfi.org/industries/investment/net-zero-asset-owner-alliance-progress-report-demonstrates-advance-on-decarbonisation-targets/>
- UNEP FI Website. (2023, January 30). *Net-Zero Banking Alliance first progress report: Significant achievement with over 50% setting intermediate decarbonisation targets - United Nations Environment - Finance Initiative*. Retrieved August 31, 2023, from <https://www.unepfi.org/industries/banking/nzba-progress-report-published/>
- UNFCCC. (2016). *Decision 1/CP.21, adoption of the Paris Agreement, FCCC/CP/2015/10/Add.1, 29 January 2016*. Retrieved August 31, 2023, from <https://unfccc.int/resource/docs/2015/cop21/eng/10a01.pdf>
- UNFCCC. (2019a). *Decision 4/CMA.1, Further guidance in relation to the mitigation section of decision 1/CP.21, FCCC/PA/CMA/2018/3/Add.1, 19 March 2019*. Retrieved August 31, 2023, from https://unfccc.int/sites/default/files/resource/4-CMA.1_English.pdf
- UNFCCC. (2019b). *Decision 18/CMA.1, Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, FCCC/PA/CMA/2018/3/Add.2, 19 March 2019*. Retrieved August 31, 2023, from https://unfccc.int/sites/default/files/resource/cma2018_3_add2_new_advance.pdf
- UNFCCC Website. (2023a). *About the secretariat*. UNFCCC. Retrieved August 31, 2023, from <https://unfccc.int/about-us/about-the-secretariat>
- UNFCCC Website. (2023b). *Paris agreement—status of ratification*. UNFCCC. Retrieved August 31, 2023, from <https://unfccc.int/process/the-paris-agreement/status-of-ratification>
- UN-Habitat. (2022). *About us*. UN-Habitat. Retrieved August 31, 2023, from <https://unhabitat.org/about-us>
- United Nations. (2023). *The sustainable development goals report 2023: Special edition. Towards a rescue plan for people and planet*. Retrieved August 31, 2023, from <https://unstats.un.org/sdgs/report/2023/>
- United Nations' High-Level Expert Group on the Net Zero Emissions Commitments of Non-State Entities. (2022). *Integrity matters: Net zero commitments by businesses, financial institutions, cities and regions*. Retrieved August 31, 2023, from https://www.un.org/sites/un2.un.org/files/high-level_expert_group_n7b.pdf
- Universal Owner. (2021). *Missing the target. Why asset managers have not committed to net zero*. Universal Owner. Retrieved August 31, 2023, from <https://www.universaloowner.org/missingthetarget>
- Ürgе-Vorsatz, D., Khosla, R., Bernhardt, R., Chan, Y. C., Vérez, D., Hu, S., & Cabeza, L. F. (2020). Advances toward a net-zero global building sector. *Annual Review of Environment and Resources*, 45(1), 227–269. <https://doi.org/10.1146/annurev-environ-012420-045843>
- van den Bergh, J. C. J. M., Angelsen, A., Baranzini, A., Botzen, W. J. W., Carattini, S., Drews, S., Dunlop, T., Galbraith, E., Gsottbauer, E., Howarth, R. B., Padilla, E., Roca, J., & Schmidt, R. C. (2020). A dual-track transition to global carbon pricing. *Climate Policy*, 20(9), 1057–1069. <https://doi.org/10.1080/14693062.2020.1797618>
- van Asselt, H., Obergassel, W., Hall, C., Hermwille, L., Oberthür, S., Otto, S., Sanz, M. J., & Xia-Bauer, C. (2023). Leveraging the global stocktake for effective sectoral climate governance. *PLOS Climate*, 2(6), e0000229. <https://doi.org/10.1371/journal.pclm.0000229>
- Verbruggen, A. (2011). A turbo drive for the global reduction of energy-related CO2 emissions. *Sustainability*, 3(12), 632–648. <https://doi.org/10.3390/su3040632>
- Verbruggen, A., & Brauers, H. (2020). Diversity disqualifies global uniform carbon pricing for effective climate policy. *Environmental Science & Policy*, 112, 282–292. <https://doi.org/10.1016/j.envsci.2020.04.014>
- Victor, D. G., Geels, F. W., & Sharpe, S. (2019). *Accelerating the low carbon transition: The case for stronger, more targeted and coordinated international action*. Retrieved August 31, 2023, from <http://www.energy-transitions.org/content/accelerating-low-carbon-transition>
- Vikkelsø, A., & Boye Olesen, G. (2021). *Analysis of the affordability of switching to renewable heating for a standardised middle-income family in the EU*. European Environmental Bureau. Retrieved August 31, 2023, from <https://www.coolproducts.eu/wp-content/uploads/2021/10/coolproducts-heating-subsidies-report-web-october21.pdf>
- Voita, T. (2021). The missing guest. In *Energy efficiency in the multilateral energy arena* (Briefings de l'Ifri). ifri - French Institute of International Relations. Retrieved August 31, 2023, from <https://www.ifri.org/en/publications/briefings-de-lifri/missing-guest-energy-efficiency-multilateral-energy-arena>
- WBCSD. (2010). *The new agenda for business*. WBCSD. Retrieved August 31, 2023, from <https://www.wbcsd.org>

- [org/Overview/About-us/Vision_2050/Resources/Vision-2050-The-new-agenda-for-business](https://www.wri.org/Overview/About-us/Vision_2050/Resources/Vision-2050-The-new-agenda-for-business)
- Weikmans, R., van Asselt, H., & Roberts, J. T. (2020). Transparency requirements under the Paris Agreement and their (un)likely impact on strengthening the ambition of nationally determined contributions (NDCs). *Climate Policy*, 20(4), 511–526. <https://doi.org/10.1080/14693062.2019.1695571>
- WorldGBC Website. (2022a). *Reporting*. World Green Building Council. Retrieved August 31, 2023, from <https://www.worldgbc.org/reporting>
- WorldGBC Website. (2022b). *The net zero carbon buildings commitment*. World Green Building Council. Retrieved August 31, 2023, from <https://www.worldgbc.org/the-commitment>
- WRI. (2019). *Accelerating building decarbonization: Eight attainable policy pathways to net zero carbon buildings for all*. Retrieved August 31, 2023, from <https://www.wri.org/research/accelerating-building-decarbonization-eight-attainable-policy-pathways-net-zero-carbon>
- Yamin, F., & Depledge, J. (2004). *The international climate change regime: A guide to rules, institutions and procedures* (1st ed.). Cambridge University Press. <https://doi.org/10.1017/CBO9780511494659>
- Young, O. R. (1989). The politics of international regime formation: Managing natural resources and the environment. *International Organization*, 43(3), 349–375.
- Young, O. R. (Ed.). (1999). *The effectiveness of international environmental regimes: Causal connections and behavioral mechanisms*. MIT Press.
- UNFCCC Website. (2022). *Technical examination process on mitigation*. UNFCCC. Retrieved August 31, 2023, from <https://unfccc.int/topics/mitigation/workstreams/technical-examination-process-on-mitigation#Technical-Expert-Meetings-2020-%E2%80%9CHuman-settlements>
- Zhou, N., Khanna, N., Feng, W., Ke, J., & Levine, M. (2018). Scenarios of energy efficiency and CO2 emissions reduction potential in the buildings sector in China to year 2050. *Nature Energy*, 3(11), 11. <https://doi.org/10.1038/s41560-018-0253-6>
- Zhu, X. (2020). China's remarkable success in developing ESCOs: Current status, policy drivers, and prospects. In *Incorporating energy service companies in nationally determined contributions—The potential of ESCOs for meeting the climate goals in the Paris Agreement* (pp. 119–133). Retrieved August 31, 2023, from <https://orbit.dtu.dk/en/publications/chinas-remarkable-success-in-developing-escos-current-status-poli>

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