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Hardwired towards transformation? Assessing global climate governance for power sector decarbonization

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ABSTRACT

Fully decarbonising global power supply is essential to meet the objectives of the Paris Agreement. A wide range of inter- and transnational governance institutions exist that work towards the transformation of the power sector. But are these governance efforts sufficient to address the challenges? To address this question the article first identifies governance needs on the basis of systemic sector-specific transformation challenges and discusses the potential for international governance to address them. Second, the paper surveys existing inter- and transnational institutions and assess to what extent they exploit the potential of international governance. The analysis shows that many of the governance needs are already being satisfied to some extent, particularly with respect to the deployment of renewable energy. It also shows that a significant blind spot remains: the phase-out of fossil fuels for electricity generation. The detailed analysis enables us to identify options for enhancing the governance landscape.

1. Introduction

Meeting the goals of the Paris Agreement requires a fundamental transformation of our economies and societies. In this regard, global power supply is a key sector for two reasons: (1) with maturing renewable energy (RE) technologies, solutions for zero-emissions electricity are already technically available and cost competitive, and (2) for many other sectors electrification of processes is the most promising mitigation strategy (Lechtenböhmer et al., 2016). But despite this, global CO_2 emissions from electricity generation have been rising continuously (IEA, 2018).

This article analyses the promise and potential for international governance to address the transformation challenges in this key sectoral system. The magnitude and urgency of the task is outlined in the recent IPCC Special Report on the 1.5°C target (IPCC, 2018). International governance can make significant contributions through coordinating cooperation for collective action (Barrett, 1990; Hasenclever et al., 1997), alignment of expectations (Kanie and Biermann, 2017; Young, 2017), as well as "soft" modes of governance including provision of means of implementation and creation and diffusion of knowledge. Yet, we know that international governance is suboptimal on aggregate and certainly not adequate to address the global climate emergency. The analysis provided in this article and the other contributions of this special issues allow us to develop a much more detailed and systematic diagnosis of what aspects are underperforming and how they are underperforming by linking it to sector-specific transformation challenges.

To do so, two dimensions of complexity need to be taken into account. Firstly, the global climate regime is not only *complicated* but can be considered a *complex* system (Orsini et al., 2013, see also the introductory paper of this special issue by Oberthür et al.). Over the last decade, a plethora of inter- and transnational institutions have emerged alongside the United Nations Framework Convention on Climate Change (UNFCCC), interacting in various ways. The result of these interactions may well be more than the sum of the parts. There have been many attempts to assess the effectiveness of individual institutions (Bulkeley et al., 2014; Young, 2011). And several studies map, describe and assess the global climate change regime complex (e.g. Abbott, 2012; Bulkeley et al., 2012; Sanderink et al., 2018; Widerberg et al., 2016). Some studies specifically focus on transnational climate governance and their collective mitigation potential (Chan et al., 2019; Hale, 2020; Hsu et al., 2018; Roelfsema et al., 2018; UNEP, 2018; van der Ven et al., 2017). Yet, efforts to systematically assess the effectiveness of the climate change

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Table 1
Summary of the five governance functions considered. *Source: author.*

Function	Description
Guidance & Signal	This function derives from the principles and objectives on which intergovernmental and transnational institutions are based. Institutions can signal the resolve of members to pursue a certain course of action (decarbonization). This can provide direction beyond the respective international institution.
Rules & Standards	Collective action may be enabled by establishing common/reciprocal obligations of result and standards of behaviour (obligations of conduct). This may include prohibition or prescription of certain behaviour, harmonisation of (technical) standards or provision of incentives.
Transparency & Accountability	Collecting and analysing relevant data and identifying and addressing problems in implementation of agreed rules/standards.
Means of Implementation	The provision of capacity building, technology (transfer), and financial resources including coordination efforts for effective allocation.
Knowledge & Learning	Creation and diffusion of scientific, economic, technical and policy-related knowledge on the understanding of and/or possible solutions to the problem at hand.

regime complex as a whole including both inter- and transnational institutions and taking into account complex interactions has received scant attention to date.

The second dimension of complexity relates to the fact that climate change is essentially a transformation challenge (Hermwille, 2016; Kinley, 2017). It will fundamentally alter global societies and economies – either by way of catastrophe or a transformation towards sustainability. Achieving the latter is complicated because our economies and societies build on a patchwork of currently unsustainable sectoral socio-technical systems. Each of these systems, including the power sector, is a complex system on its own with existing path dependencies and often entrenched actor structures that actively resist transformative change (see also Victor et al., 2019).

This issue has only partially been addressed in the current literature on global energy governance. The existing literature has rather focused on different energy carriers instead of assuming a system-perspective (Dubash and Florini, 2011; Müller, 2015; Van de Graaf, 2013, 2017; Van de Graaf and Colgan, 2016). To some extent this can be explained by the historical focus of the existing international organisations such OPEC, the IEA or IRENA each of which has been tied to specific energy carriers, at least historically. A systematic analysis of global governance of the power sector taking into the sector-specific transformation challenges on the route to decarbonization is still lacking.

To close this research gap, the article first introduces key concepts and explain the methodology (section 2). It then briefly outlines seven main challenges and barriers towards decarbonization in the power sector (section 3.1). From this a set of governance needs is derived, i.e. areas in which global governance can accelerate the transformation (section 3.2). Section 4 analyses the governance landscape. It provides an overview of the more than 30 relevant intergovernmental and transnational institutions and their respective governance contribution. Subsequently, section 5 synthesises the analysis of the individual institutions and assesses to what extent they collectively meet the identified governance needs. Section 6 concludes by discussing options to close the identified gaps and to improve the adequacy of the global governance response to support the decarbonization of the power sector.

2. Key concepts and method

The paper applies a theory-based and systematic research framework developed and justified in detail in the introductory article of this special issue (Oberthür et al.). The framework combines two theoretical perspectives. The first is a focus on sectoral systems: Our societies and economies are supported by a patchwork of interdependent socio-technical systems each providing specific identifiable societal functions (in this case electricity) and each has its own distinct set of related actors, technologies, infrastructures, institutions and ideas (Geels and Schot, 2010; Schot and Kanger, 2018). When speaking of "sectoral systems" and their respective governance/transformation challenges, we are referring to complex systems as ensembles of actors (corporations, administrative bodies, political groups/parties, international organisations), technologies and infrastructures, economic structures, and the change resistance and path dependencies they collectively produce (Page, 2010). Transforming these sectoral systems means to fundamentally re-configure them with co-evolutionary changes in several of the elements mentioned above (see also Victor et al., 2019).

The second foundation of the research framework is a set of diverse theoretical perspectives on global environmental governance. We understand governance as the steering of behaviour towards a common and shared goal through the setting of rules, standards or guidelines, or through targeted support. Five distinct governance functions guide the analysis (see Table 1 below). A more detailed discussion of the theoretical foundations of the framework as well as a justification of the analytical choices made is included in the introductory article to this special issue (Oberthür et al., this issue).

To identify relevant institutions,[1] I screened existing databases (Mitchell and IEA Database Project, 2019; UNEP DTU 2020; UNFCCC, 2020). Those institutions that are intergovernmental or transnational, display intentionality to steer the behaviour of its members, have identifiable governance functions, and explicitly mention a common governance goal related to climate change mitigation were considered for further analysis (cf. Widerberg et al., 2016). The latter criterion was applied flexibly, to allow inclusion of initiatives with significance for decarbonization. A subset of 34 of more than 150 intergovernmental and transnational institutions were identified as possessing particular relevance for the decarbonization of the power sector. Each of these 34 institutions was individually evaluated to appraise their contribution to the five governance functions. The assessment was based on a review of each institution's official documentation and available third-party literature. The assessment was carried out by the author with support of a research assistant. The results were reviewed by two project-internal reviewers and validated with two external reviewers. An overview of the assessment is provided in the supplementary material.

[1] We understand institutions as negotiated, dynamic, normative systems consisting of rules and practices, including decision-making procedures, that prescribe behavioural roles, constrain activity and shape actor expectations.

3. Transformation challenges and governance needs

3.1. Main challenges and barriers towards decarbonization

The transformation of the global power sector is already well underway. Sustainable alternatives are technically and economically mature and competitive. Still, seven major remaining challenges and barriers have been identified that stand in the way of achieving a complete decarbonization of the power sector.

Technologically, there are two main pillars for climate change mitigation in electricity systems: (1) eliminating greenhouse gas emissions from energy supply and (2) limiting power demand through energy efficiency. The implementation of energy efficiency measures, however, happens in related but separate sectoral systems. The key actors of the power system have relatively limited direct influence on this. We therefore chose not to consider energy efficiency measures in detail in this sectoral analysis.

To eliminate emissions from energy supply, there are essentially three options: renewable energy, other low-carbon technologies particularly nuclear, and capturing and storing CO2 from fossil fuelled thermal plants (CCS). Massive advancements have been made on the first option, but very little has been achieved on the latter two options. For CCS only two commercial scale demonstration plants exist to date and there are no other projects in advanced development stages (Global CCS Institute, 2018; also see Gaede and Meadowcroft, 2016). There is no indication that the technology will play a significant role in the power sector (IPCC, 2018).

Similarly, the outlook for nuclear energy is bleak. After the nuclear meltdown in the Fukushima plant, environmental concerns have led policy makers to reconsider their positions on nuclear energy in many countries. Moreover, nuclear energy is also facing economic headwinds. China, hitherto the largest investor in nuclear power, has not started construction of any new reactor in the last three years and is set to miss its own targets by a wide margin. And new renewable energy is now cost competitive even with existing nuclear power in many countries (Schneider and Froggatt, 2019; also see IPCC, 2018).

Despite tremendous advances in renewable energy (IPCC, 2018), some technological transformation challenges also remain in this area. First, the integration of increasing shares of renewable energy remains a barrier. Significant energy storage will be necessary to ensure the stability of power systems with high shares of intermittent renewable energy. Short-term storage can help with buffering variability in frequency and voltage in a matter of split seconds up to a couple of minutes.[2] Long-term storage will be required to balance out seasonal variability in the availability of RE. However, the challenge varies across geographies. Countries with a high share of hydropower, for example, have the associated advantage of flexible dispatch. Other countries will need to develop different technical solutions to balance out intermittent RE. Research spending as well as investments in battery storage have been skyrocketing. As a consequence, battery costs have plummeted at rates similar to those seen in the cost reductions of solar PV (IEA, 2016; IPCC, 2018).

A second remaining challenge is the need to update and re-build existing grid infrastructures. In countries that historically relied on fossil fuelled generation, power plants typically were built at locations that are close to the centres of electricity demand (i.e. major industrial centres). By contrast, renewable energy generation units ideally should be located wherever the potential of renewable resources are highest. In a prototypical fossil fuelled power systems transmission grids connected industrial hubs, whereas in a prototypical RE-based power system it connects connecting centres of supply to the centres of demand. This may require fundamentally different grid layouts and enormous investments over the coming decades (IEA, 2016b). The issue becomes an international one where power systems are physically interconnected. As a decarbonization of the power sector will also reshape the grid infrastructure, the transformation in one country will have ripple effects on the power system in neighbouring, interconnected countries. Coordinating and interconnecting power systems may also have benefits e.g. for balancing weather-related fluctuations in renewable energy supply.

The third challenge is economic. Decarbonizing the power sector entails a monumental investment challenge. Investments in renewable energy in 2017 amounted to nearly USD 280 billion (REN21, 2018), but investments in the order of USD 20 trillion need to be shifted from fossil fuel infrastructure to renewables and energy efficiency between 2015 and 2050, and an additional USD 27 trillion needs to be attracted compared to current levels of investment to meet the Paris objectives (IRENA, 2018a). The challenge is not so much an issue of costs anymore, as technology costs have plummeted. In particular, cost decreases for solar PV and wind are likely to continue (IRENA, 2016). Despite low cost for the hardware, renewable energy can still become excessively expensive if high prime lending rates and currency-related risks drive up capital costs. The issue of excessive capital cost is pertinent for any highly capital-intensive component of the energy system, including storage and grid infrastructure. The situation is aggravated by the fact that the consumption and production of fossil fuels is still heavily subsidised (see also Rayner and Kretschmer et al. in this special issue).

Another economic challenge concerns international competition. Given that the majority of national power sectors are dominated by nationally operating utilities there is hardly any direct competition among generators, but there is still an important indirect effect. Since electricity is an essential input to almost all industries, there may be competition among countries: if a country experiences (temporary) electricity price increases during the transformation, energy intensive industries may migrate to another country with lower prices (Görlach and Zelljadt, 2019). A power sector transformation can thus become an issue of international industrial competitiveness.

The fifth challenge is a matter of limited capacities particularly with respect to human capital. Implementing global transformation towards renewable energy requires a skilled workforce. In many developing countries technical capabilities and skilled workers are still a bottleneck (Hirsch, 2015).

Sixth, energy deprivation of large parts of the developing world remains an important issue. In 2016 still some 1.1 billion people lacked access to electricity, mostly in Africa and South Asia (IEA, 2017a). This issue is also closely linked to economic and capacity-related transformation challenges described above. Connecting remote and often very poor communities to grid infrastructure is often not economically viable. More decentralized renewable energy solutions might be an alternative but often capacity and/or financial means of implementation are missing. Providing access to modern and clean energy to this significant share of the global population remains a moral obligation of global scale.

Finally, social barriers remain an issue. Changes in the provision of electricity may result in shifting costs and payments. The transformation may have significant distributional effects. These

[2] Another option for integration of volatile renewable energy is the demand side management (DSM), i.e. improving the responsiveness of power demand. Since DSM would have to be implemented in adjacent sectoral systems, we have not considered it for in depth analysis in this article.

Table 2
Synthesis of international governance needs in the power sector. *Source: author.*

Guidance & Signal	Rules & Standards	Transparency & Accountability	Means of Implementation	Knowledge & Learning
• Signal for low-carbon investments in energy infrastructure	• coordinated target setting to address competitiveness concerns • coordination at the regional level (especially grid development)	• required to support collective action function	• risk sharing for capital intensive investments in sustainable power systems, especially in developing countries • administrative and technological capacity building	• sharing of good practice policies with respect to inter alia distributive effects of transformation

issues have been highlighted under the notions of 'just transition' and 'energy poverty' from an intranational perspective (Global Commission on the Gepolitics of Energy Transformation & IRENA, 2019). In managing distributional effects particular attention needs to be paid to avoid negative effects on marginalized communities (Cherian, 2015). Addressing those issues is not only a moral obligation and required to legitimate the processes of change, it is also required to avoid pushback and resistance.

3.2. The promise and potential of international cooperation

The **signalling function** of international governance can help address the investment challenge outlined above as well as contribute to solve the technological challenges of storage and grid reconfiguration. A robust signal is particular important, because investments in the sector are extremely long-lived. On the one hand, this means that investments in fossil fuel infrastructure today may literally cement a carbon-intensive pathway. On the other hand, this long-term perspective requires investors to make decisions on the basis of long-term expectations of the sector and the economy in general (for a more detailed analysis of the role of the financial sector see Kretschmer, this issue). If countries credibly agree on long-term visions and goals, this may take away some of the political uncertainty hampering investments and alter investors' expectations about the viability of prospective projects and hence change their investment decisions of today (also see Morseletto et al., 2016; Kanie and Biermann, 2017).

Rule setting to facilitate collective action may address two of the above-mentioned challenges. The first relates to industrial competitiveness concerns. Coordinated target setting could address such concerns at least partially (Hasenclever et al., 1997). This could take the form of harmonized RE targets or even collective cap-and-trade systems for carbon emissions. Second, where power grids are interconnected, regional governance approaches may be conducive to the transformation. For instance, coordinated investments in the grid infrastructure could minimize the need for storage capacities as variability in renewable energy supply to some extent balances itself out over large distances (Fürsch et al., 2013).

Transparent reporting and monitoring can support and help reinforce rules, targets and/or standards collectively agreed as outlined above (Mitchell, 1998; also see Gupta and van Asselt, 2019). What needs monitoring and by whom, of course, depends on the specific rules, targets or standards agreed. Also a basic level of transparency is required as a basis for rule-setting in the first place.

Another leverage point for international governance is mobilizing the **means of implementation** for sector transformation (Chayes and Chayes, 1993). In particular, international cooperation relating to means of implementation could help address the investment challenge as well as the energy access challenge described above. Highly capital-intensive investments may not be feasible wherever high prime lending rates and other currency related risks are major barriers. Enhancing the attractiveness of investments in sustainable power systems could expedite the transformation of power sectors across the globe (IPCC, 2012). International governance may especially contribute through arrangements for sharing the increased financial risks for investments in developing countries. More specifically, international institutions could facilitate the provision of some form of guarantee or security, which in turn could help bring down lending rates in developing countries (Schwerhoff and Sy, 2017; Sweerts et al., 2019). With respect to technology transfer, possible approaches to international cooperation include joint research programmes, patent pooling and removing trade barriers. International institutions can also make a difference in organizing capacity building on both administrative and technical levels. Providing dedicated training and creating educational programmes can help to overcome the human capital bottlenecks outlined above.

Knowledge creation and diffusion can positively affect power sector decarbonization. Particularly with regard to distributive effects, there is a case for institutionalized and systematic governance learning: which policies work and which political processes are promising in order to forge alliances and align interests so as to minimize social hardship in the course of transformations. Demonstrating the feasibility and social viability of successful sector transformation in one country may also indirectly contribute to the investment challenge, again by doing away with some of the political, technical and social uncertainties. Creating fora in which experimentation and good practice sharing with respect to policies and political processes can be facilitated would be one way to address the governance need for knowledge and learning (also see Quitzow et al., 2019).

Table 2, above synthesizes the potential of global governance to advance the transformation of the power sector.

4. Governance supply

The identified institutions can be grouped into seven thematic clusters. The first group of *overarching international institutions* includes the UNFCCC with its Paris Agreement, the Sustainable Development Goals (SDGs), the G7, G20 and the World Trade Organisation (WTO). Next is a group of *energy-specific international organisations* comprising the International Energy Agency (IEA), the International Renewable Energy Agency (IRENA), the Sustainable Energy for All (SE4All) initiative and the Renewable Energy Policy Network for the 21st Century (REN21). The next group entails various *international financial institutions*, the World Bank, various multilateral development banks (MDBs) as well as Climate Investment Funds (CIF). Beyond these rather formalized institutions a group of more *informal energy alliances* exists including the International Solar Alliance, the Powering Past Coal Alliance, the Clean Energy Ministerial, REEEP – Renewable Energy and Energy Efficiency Partnership, Mission Innovation and the Breakthrough Energy Coalition. Moreover, a few *institutions with region-specific focus* have been identified such as the African Renewable Energy Initiative (AREI), various regional power pools (Eastern African Power

Pool, Southern African Power Pool, West African Power Pool and the EU's Energy Union) and the Western Climate Initiative. There are also various *institutions catering to cities and municipalities* across the globe: the Covenant of Mayors for Climate & Energy, ICLEI – Local Governments for Sustainability with its 100% Renewable Energy Cities & Regions Network, and the Carbon Neutral Cities Alliance. Finally, we included two *initiatives geared toward the private sector* – RE100 and Global 100% RE. Note that the Organization of Oil Exporting Countries (OPEC), the International Energy Charter Treaty, or the International Atomic Energy Agency were not included in the survey for a lack of explicit engagement with climate policy and/or decarbonization of the sector.

Of all these institutions, only the UNFCCC contributes to all governance functions, but on a very abstract overarching level. Particularly important are its contribution to the guidance and signal function and its contribution, albeit limited, to rule setting. It provides guidance and signal through its long-term goal of holding global temperature increase to well below 2°C and pursuing efforts to limit warming to 1.5°C (Art. 2.1(a)) and the accompanying goals of peaking of greenhouse gas emissions as soon as possible, rapid reductions thereafter and achieving net zero emissions in the second half of the century (Art. 4.1). The implications of these goals provide a relatively clear signal for the power sector. Essentially it requires a complete phase out fossil fuelled electricity (Kuramochi et al., 2018). The Nationally Determined Contributions (NDCs) under the Paris Agreement responds to the rule-setting function, with the power sector at the core of nearly all NDCs and RE explicitly considered by a vast majority (IRENA, 2018b). Yet, since NDCs are developed by countries independently of each other and there is no 'obligation of result' to actually achieve them (Oberthür and Bodle, 2016), it is rather a form of coincidental than coordinated target setting.

Beyond the UNFCCC, guidance and signal is directly provided only by a relatively small number of institutions. These include the SDGs, particularly SDG 7 "to ensure access to affordable, reliable, sustainable and modern energy for all". Other examples include the Powering Past Coal Alliance with its commitment to phase-out coal-fired power plants and the AREI with its goal to achieve installation of at least 300 GW of RE generation capacity on the African continent by 2030. The IEA contributes indirectly with its annual World Energy Outlook (WEO) and Energy Technology Perspectives reports, which provide energy-market analysis and projections that are so influential that they effectively function as a benchmark for decision making in all sorts of organisations – from public administrations to private enterprises.

The subset of institutions engaging in rule-setting for collective action is also fairly small. It includes the various power pools that engage in coordinated standard setting for their respective grid operations. Mission Innovation is also notable. Its member countries committed to double public spending for energy R&D with a view to cumulatively reaching over USD 32 billion by 2020 (Sanchez and Sivaram, 2017). Noteworthy are also the RE100 and Global 100% RE initiatives with their members' commitments to use 100% renewable electricity and to invest exclusively in 100% renewable energy systems respectively.

In terms of transparency and accountability, it is again just a few institutions that make significant contributions. Most notable is the IEA with its regular energy statistics and databases. Particularly pertinent is also SE4All with its global tracking framework for SDG 7 (SE4All, 2019).

Somewhat larger is the subset of institutions serving the means of implementation function. For the financial aspects of this function the World Bank and the other MDBs play an obvious role. Less obvious are AREI and REEEP which also provide financial means of implementation. The International Solar Alliance contributes by cooperating with various MDBs on risk sharing arrangements and implementing financial mechanisms to support solar energy in developing countries (International Solar Alliance, 2016). Capacity building is on the agenda of a various of institutions ranging from IRENA to the Clean Energy Ministerial. The WTO is relevant with respect to transfer of technology, particularly through promoting trade of renewable energy and other low carbon technologies.

Nearly all institutions contribute to the knowledge and learning function in one way or another. Particularly IRENA has attained a leading role by building a global knowledge base on renewable energy that it consequently employs as a means "to exert power over knowledge" (Müller, 2015, p. 252). Key contributions in this regard are the 'Global Atlas for Solar and Wind' as well as IRENA's regular and comprehensive renewable energy statistics and regional and/or technology specific roadmaps. Worth mentioning also is REN21 with its series annual Global Status Reports Renewable Energy (REN21, 2018). Peer-learning is at the core of the Clean Energy Ministerial, the Covenant of Mayors for Climate & Energy and ICLEI.

Due to the large number of institutions the above account is not only cursory but also not exhaustive. An overview of the 34 surveyed institutions and their corresponding engagement with the five governance functions is provided in Fig. 1 below and in the annex.

5. Assessing the governance complex

5.1. Guidance and signal

Strong signals are especially important to influence investment decisions. The guidance and signal from existing inter- and transnational governance institutions is already relatively elaborated. Overarching institutions collectively provide relatively clear 'terms of reference' for the global energy transformation as per their respective goals and targets. While the 1.5°C goal of the Paris Agreement still falls short of an explicit call for the phase-out of fossil fuel consumption in the power sector, its implications are straightforward but some ambiguity remains with regard gas fuelled power. Natural gas can contribute to short-term emission reductions by substituting coal (Mohlin et al., 2018; Tanaka et al., 2019; an opposing view is held by e.g. Howarth, 2014). Yet, in the long-run gas use is clearly incompatible with decarbonization. To date, the only institution which has sent a strong signal to this effect is the World Bank with its commitment to no longer finance upstream oil and gas investments (World Bank, 2017).

These overarching signals are being echoed and amplified by a range of other institutions. For example, SE4All supports the required shift, aiding actual implementation. The Covenant of Mayors for Climate & Energy and the Carbon Neutral Cities Alliance are actively developing the signal from the UNFCCC and SDG7 and translating it into action at the local level. And in the realm of private sector institutions Global 100% RE, for example, explicitly demands from its members to invest according to the name of the initiative: 100% renewable energy.

While the signal to the power sector to ramp up renewable energy is loud and clear, the signal to phase out fossil fuel consumption is weaker. The Powering Past Coal Alliance is the only institution providing a corresponding signal directly and explicitly. Among the founding members, though, are only countries that have limited coal generation capacity already and the overall mitigation effect of the collective pledges is limited (Jewell et al., 2019). Other institutions like the World Bank are also supporting the signal indirectly by turning away from new investments in fossil fuel related activities. Yet, the pipeline of coal power plants is still extensive. Were all these plants to be built, global average

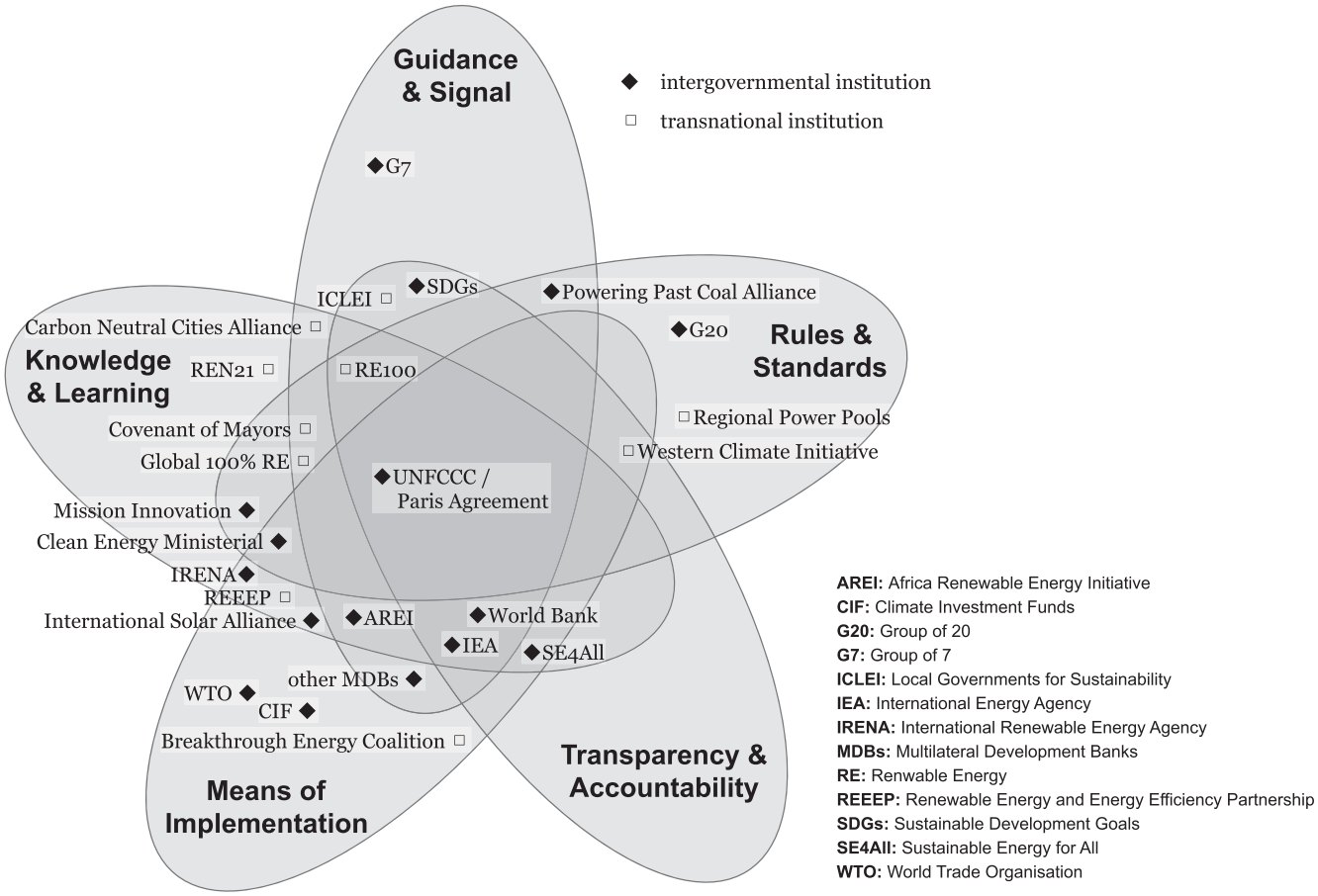

Fig. 1. Overview of the climate change regime sub-complex for the power sector and the corresponding inter- and transnational institutions constituting it. *Source:author. Each institution has been placed to represent its main contribution to the five governance functions.*

temperature rise would exceed the 2°C limit (Tong et al., 2019).

5.2. Setting rules

Rule setting in the form of coordinated target setting, has not been achieved at a larger scale. The Paris Agreement with its NDCs has been criticised for its lack of legal 'bindingness' (e.g. Depledge, 2016). Its procedural obligations include the obligation to prepare and communicate NDCs and to implement policies and measures towards achieving them (Bodansky, 2016). The first round of NDCs has demonstrated the relevance for the power sector, with the vast majority mentioning renewable energy as a key mitigation option (IRENA, 2018b). Still, due to the lack of a common standardized format, NDCs' comparability is low and hence concerns over coordination of targets remains unresolved.

Apart from the UNFCCC, no other international institution has the authority or mandate to serve as a forum for the kind of coordinated target setting that would resolve the competitiveness concerns outlined above. For a long time, a harmonized global carbon price that affects all GHG emissions including those from the power sector has been considered the gold standard to address competitiveness concerns. While this ideal seems currently out of reach, the number of countries that implement corresponding policies at the national level is ever increasing (World Bank, 2018). This trend already to some degree addresses competitiveness concerns. Article 6 of the Paris Agreement provides potential avenues for countries to engage in "cooperative approaches" which may further facilitate the proliferation and harmonisation of such instruments. Beyond that, we see a few mostly voluntary institutions with limited scope that try to orchestrate target setting, whether for cities (Covenant of Mayors and Carbon Neutral Cities Alliance) or businesses (RE100).

The rule-setting function could also be important with respect to a global phase-out of coal use. To the extent that coal is an international commodity, potential spill-overs from national phase-outs (e.g. price effects) could be addressed by common rules (Wehnert et al., 2019). However, we do not see any international institutions that establish common rules with the exception of the Powering Past Coal Alliance. The PPCA has set itself ambitious targets, but whether these will be translated into formal rules that actually get implemented remains to be seen. Also, as noted above, membership is relatively limited.

We do observe some progress with respect to a very different yet also necessary dimension of rule setting: international technical standards. This includes for example the efforts of regional power pools in Africa and the EU that aim to further integrate and harmonize the interconnected power grids of their respective member countries.

5.3. Transparency and accountability

A basic level of transparency is necessary to establish a shared understanding of the transformation challenge and consequently to enable the determination of collective goals and individual targets.

This need for transparency seems to be met in the power sector. Major institutions like the IEA, IRENA, World Bank and REN21 collectively provide a high degree of transparency. The legitimacy of two of the most informative sources – IEA and REN21 – is somewhat limited. The IEA is an organisation under the OECD and hence has a strong focus on OECD countries. While it also provides information on non-member countries, this data is less frequent and less accurate. Also, non-members may consider the IEA information not authoritative enough. The REN21 Global Status Reports ensure a high degree of rigor through a well-organized scientific process involving a large number of contributors and reviewers. Yet, it lacks the kind of political vetting that, for instance, makes the IPCC a highly authoritative source of information.

Transparency and accountability are also required to track progress on the implementation of agreed targets and build trust. As stated above, such agreed goals are lacking. Hence there is no need for further transparency on that matter. Those institutions that engage in coordinated target setting at the transnational level (e.g. the Western Climate Initiative, RE100 and the Covenant of Mayors) have their own transparency arrangements that meet their respective needs.

5.4. Means of implementation

Financial means of implementation are provided first and foremost by the Multilateral Development Banks, especially in developing countries. However, their role is not unambiguous. MDBs have also been accused of impeding the process towards sustainable energy systems by continuing to fund fossil fuel projects (Kim and Urpelainen, 2013; Wright et al., 2017). But this has started to change, as evidenced by the World Bank's 2017 commitment to stop funding upstream fossil fuel investments (World Bank, 2017).

Alongside the MDBs numerous other institutions provide financial means for more targeted purposes. These include, for example, the Green Climate Fund serving the financial mechanism of the UNFCCC, the Africa Renewable Energy Initiative as well as Mission Innovation and the Breakthrough Energy Coalition, the latter two of which focus on research and innovation. But are the available means sufficient to meet the enormous investment needs? While the current growth rate of renewables is in line with the required pace to embark on a 1.5°C compatible pathway (see Kuramochi et al., 2018), it is unclear whether this high level of growth (25–30% annually over the last decade) and the corresponding investments can be sustained and for how long.

The specific challenge to de-risk investments in renewable energy and energy infrastructure in countries with unfavourable investment climates remains a salient one. The International Solar Alliance is championing risk-sharing arrangements in collaboration with several MDBs in its "Affordable Finance at Scale" programme (International Solar Alliance, 2016). But given the enormous need for investments, other institutions should engage in similar activities.

Assessing the actual demand for financial means is extremely difficult in detail and beyond the scope of this article. Whether the current level of finance is sufficient to sustain current growth in renewable energy is therefore uncertain. Also, many international institutions are still funnelling money into unsustainable fossil fuel infrastructure. Yet, there is no lack of governance institutions per se and most of them seem to be turning in the right direction.

For transfer of renewable energy and other low carbon technologies, preferential trade agreements could play a strong facilitative role. Yet, their potential is currently not being exploited according to some analysts (Lewis, 2014; Morin and Jinnah, 2018). In 2014 a group of countries started to negotiate a so-called "Environmental Goods Agreement" under the WTO to reduce tariffs and trade barriers on low-carbon technologies (Van de Graaf and Colgan, 2016). Yet the negotiations are slow and seem to have lost some of the initial momentum (Meyer, 2016).

The number of institutions providing capacity building is even higher than with respect to financial means of implementation. These include the IEA, IRENA with its various regional initiatives, SE4All, and the Clean Energy Ministerial among others. Overall, there is ample governance supply. The plethora of capacity building institutions may suggest that there is a high degree of specialisation among the institutions and hence a broad range of aspects are covered. But it also bears the question whether the resources are spent in an efficient manner. Assessing this question in detail is beyond the scope of this study.

5.5. Knowledge and learning

There is a plethora of inter- and transnational institutions that serve the knowledge and learning governance function, key among them the IEA with its World Energy Outlook, Energy Technology Perspectives reports and the various Technology Collaboration Programmes. IRENA as an information hub for authoritative information, analyses and data on renewable energy is central as well. Noteworthy in this regard are also IRENA's collaborative stakeholder partnerships for energy transformation. In terms of policy learning, the Clean Energy Ministerial with its various initiatives to support decision makers with information is highly pertinent. The Covenant of Mayors, the Carbon Neutral Cities, RE100 and Global 100% RE initiative provide similar opportunities for municipalities and private businesses respectively.

The challenge of addressing the distributive effects of the energy transformation and the socio-economic implications thereof, seems to be not as high on the agendas of the institutions engaged in the area. This is perhaps due to the fact that the most dramatic distributive effects have yet to come. But a general observation is that knowledge production focuses on rather technical issues. Social science knowledge inter alia about socio-economic and cultural implications of energy transformations seems underrepresented (Overland and Sovacool, 2020).

6. Conclusion and options for enhancing global governance

The climate governance complex for the power sector is populated with many diverse institutions. Collectively, they respond to most identified governance needs, particularly for the transparency & accountability, means of implementation and knowledge & learning functions. But significant shortcomings remain: while the signal is strong and clear for the phase-in of renewable energy, it could still be strengthened, for instance, by adopting an explicit global decarbonization roadmap for the power sector. Moreover, without such a roadmap the signal remains somewhat vague as to the phase-out of coal and virtually absent for oil and particularly gas. The issue of phase-out of fossil fuel infrastructures will become increasingly central as renewable energy technologies begin to challenge the very existence of incumbent fossil-fuel based systems. Under the increasingly prominent notion of "just transition" (Obergassel et al., 2018, see also Rayner on extractive industries in this issue) the socio-economi side effects of the discontinuation of fossil fuel use are increasingly anticipated. Arguably, these kinds of issues will become even more salient as the 'rear-guard battle' of the fossil fuel industry unfolds. Another significant shortcoming is the lack of a mechanism for coordinated target setting. While the Paris Agreement enhances coordination somewhat, competitiveness concerns are not sufficiently addressed as NDCs are not coordinated internationally and binding obligations of result are

Table 3
Summary of findings and overall assessment of governance supply for the power sector per governance function. *Source: author.*

Guidance & Signal	Rules & Standards	Transparency & Accountability	Means of Implementation	Knowledge & Learning
+ strong signal for phase-in of RE - signal remains ambiguous for natural gas – weak signal for pro-active phase-out of fossil fuels – clear Decarbonization Roadmap is missing	+ procedural rules through NDCs – no coordinated target setting on phase in/out + some regional cooperation on technical standards	◯ lack of coordinated targets limits demand for transparency and accountability + high degree of transparency provided by IEA, IRENA, REN21 + some target setting and corresponding transparency at transnational level	+ financial means are being provided by MDBs (but is it enough?) – finance is still going into fossil fuels + many institutions provide capacity building (potential for efficiency gains through coordination)	+ technological knowledge is being provided by a plethora of institutions – limited knowledge on social science e.g. on social and cultural dimensions of energy transformations
Extent to which governance needs are met:				
MEDIUM	LOW_MEDIUM	HIGH	MEDIUM_HIGH	MEDIUM_HIGH

lacking. The key findings of the analysis are summarized in Table 3.

There are at least two salient institutions which could expand their scope to address some of the identified gaps. Firstly, the IEA already "is the closest we currently have to a World Energy Organization" (Van de Graaf, 2013, p. 107). It could take on an even more important role by orchestrating knowledge and learning and capacity building, by refining guidance and signal through developing authoritative decarbonization roadmaps and by becoming an implementing agency for a global pact to phase-out fossil fuels (also see Newell and Simms, 2019).

The annual World Energy Outlook is already an authoritative sectoral roadmap and indirectly serves the guidance and signal function. It is not authoritative in the sense that it has any coercive influence on national governments, but in the way it shapes expectations of all kinds of stakeholders. However, to fully comply with the goals of the Paris Agreement, the IEA's scenarios would have to reflect more ambitious climate action. In the past, the IEAs scenarios have been criticized for repeated skewed predictions and dramatically underestimating the uptake of renewable energy, in particular solar PV (Creutzig et al., 2017). Muttitt (2018) even accuses the IEA of distorting its projections in ways that systematically support investments in fossil fuels and high carbon infrastructures. But in this, the IEA was "hardly the only organization that got it wrong" (Heubaum and Biermann, 2015, p. 232).

With its substantial analytical capacity and its strong convening power the IEA could foster international coordination towards managing the decline and ultimately phase-out of fossil fuel consumption in the power sector. This, however, would mean a dramatic identity shift for the organisation. Originally, the IEA was founded as a 'buyers club' to counter the Organisation of Petroleum Exporting Countries (OPEC) and to help secure oil supplies (Dubash and Florini, 2011). While the IEA has widened its portfolio to include all energy sources (Heubaum and Biermann, 2015) and has recently launched an extensive "Clean Energy Transition Programme" (IEA, 2017b) the IEA remains an institution that propagates the expansion of (efficient) energy production and consumption. Even today a membership requirement is that members need to hold oil reserves for up to 90 days. At present, organizing the decline of the fossil fuel industry is clearly not in its purview.

A second legacy that hampers the IEA's capacity to contribute more effectively to the governance functions is its affiliation with the OECD. Full membership (and hence full voting rights in the IEA's governing bodies) is restricted to OECD members. With its "opening the doors strategy", the IEA has made serious efforts to overcome this limitation, with some success: Brazil, China, India, Indonesia, Morocco, Singapore, and Thailand are now associated countries (Elkind, 2017; Heubaum and Biermann, 2015). Still, being part of the OECD system may discourage many developing countries and emerging economies from joining the IEA and providing it with a more global mandate. Former IEA Deputy Director Ambassador Jones described the situation of the IEA as an autonomous agency of the OECD as follows: "It's like being 35 years old and still living with your parents" (quoted in Lesage et al., 2010, p. 52). Maybe it is time to move out?

A second salient starting point is the UNFCCC. The guidance and signal function of international governance could be significantly strengthened by developing and negotiating a global vision and/or roadmap for the power sector. Yet, given its strong focus on GHG emissions in general and the historically minor role that sector-specific perspectives played in the negotiations, this would require a paradigm shift for the UNFCCC. Nevertheless, the UNFCCC could still take up visions developed at other international fora and, for example, "endorse" them by way of a COP decision. This would help to raise the profile of such sectoral visions and further institutionalize them thus amplifying the signal and guidance provided. One way to strengthen its role particularly in view of the rule setting function, would be to engage in 'supply side climate policy', i.e. policies that restrict the production/extraction of fossil fuels (Asselt and Kulovesi, 2017, also see Rayner on extractive industries in this issue).

It is fairly obvious that global governance is underperforming. This article provides a systematic and detailed diagnosis of why it is failing and what is missing in view of the specific challenges of the power sector. But how can this be remedied? While some entry points for improved governance are fairly obvious, the applied research framework does not provide the tools for a more systematic assessment of different options to close the identified gaps, which remains a task for future research.

Declaration of competing interest

I do not have any conflicts of interest.

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Appendix A. Supplementary data

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