AN ACTIONABLE RESEARCH AGENDA FOR INCLUSIVE LOW-CARBON TRANSITIONS FOR SUSTAINABLE DEVELOPMENT IN THE GLOBAL SOUTH

Enabling Policy Environment

Environment for Development

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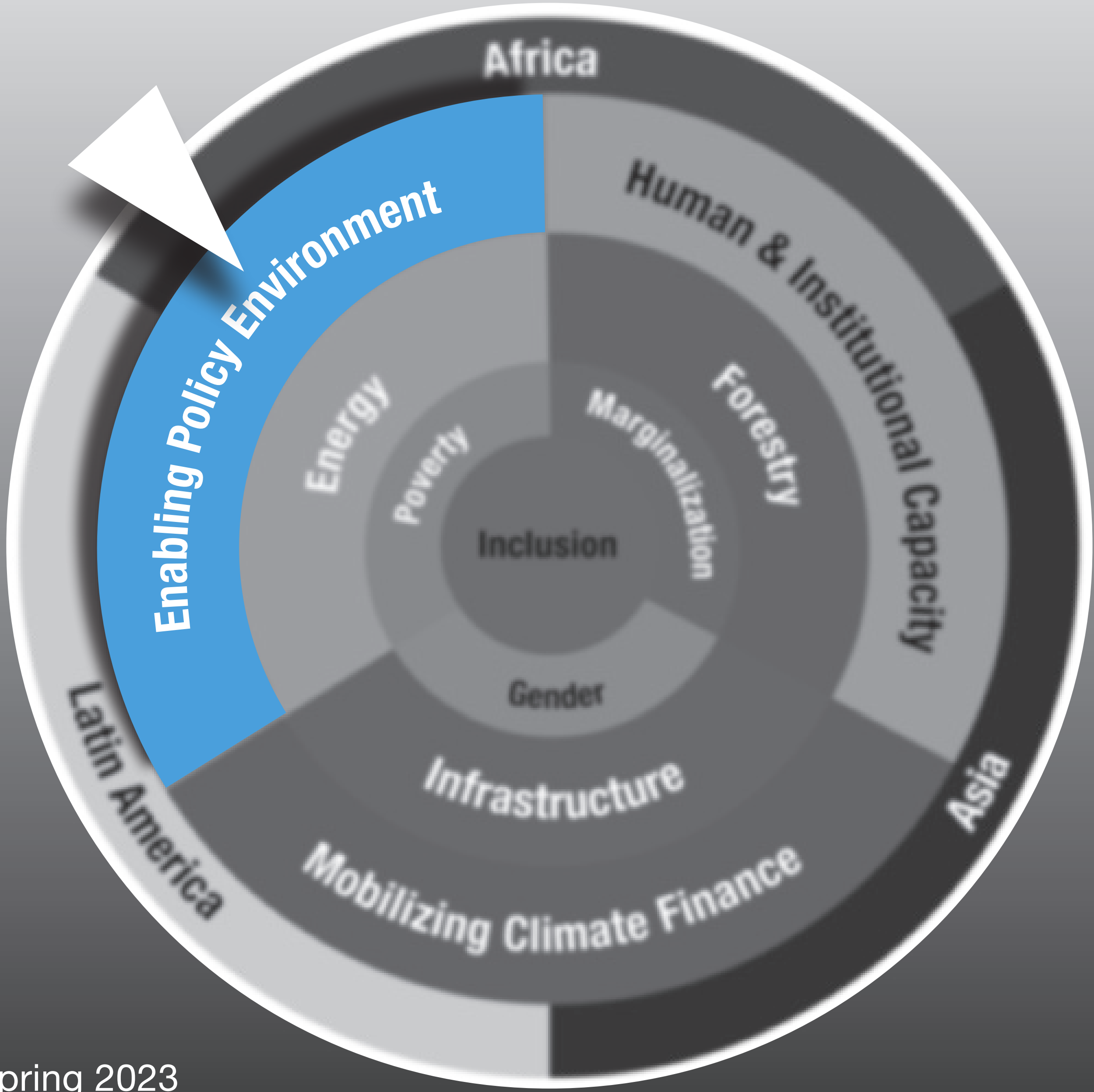

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Contents

Preface

All countries now face enormous challenges posed by climate change. The consequences of continued greenhouse gas emissions are dire, particularly for countries in the Global South that are both more affected and more vulnerable to climate change at the same time as they have less capacity to adapt (AfDB, 2022). The realization that a low-carbon transition needs to be implemented in countries in the Global South is well established and is also reflected in most countries' ratification of the Paris Agreement and in their Nationally Determined Contributions. In effect, most countries in the Global South are now confronted with the fastest and most dramatic transformation of their economies that they have ever experienced – or at least they would need to be.

The low-carbon transition in the Global South needs to be guided by research since such a transition is inherently a very knowledge-intensive process. This is why the Sustainable Inclusive Economies (SIE) Division of the International Development Research Centre (IDRC) has identified this area as particularly interesting to support. This report was commissioned by SIE as part of a bigger initiative to develop an actionable research agenda that IDRC can support to achieve a low-carbon transition with gender equity in the Global South.

Enabling Policy Environment is part of the Research Agenda for Low Carbon Transition and Gender Equity in the Global South series of papers. The consortium that is working on this series of papers is global and consists of 60 researchers from a multitude of universities and institutions. This particular paper has been written by Anjali Ramakrishnan from EfD Global Hub, Gothenburg, and Jan Steckel and Farah Mohammadzadeh Valencia from Mercator Research Institute for Global Commons and Climate Change.

Enabling Policy Environment aims at identifying the actors, processes and methods that enable the creation of a policy environment to put climate and low-carbon energy transition policies in motion. The paper highlights the need for a comprehensive understanding of the socio-economic processes and the political dynamics between the various actors involved in decarbonization. We hope to receive constructive comments on this draft paper from IDRC, our networks and external scholars and practitioners. We will then revise the paper for validation by policy makers and senior civil servants in the Global South. Based on the reviews and validations we plan to prepare final versions of both the paper and the accompanying High-Level Research Agenda by March 2023. The ambition is that these papers will be useful both for donors and research institutions in supporting an even greater research contribution to a much-needed low-carbon transition with gender equity in the Global South in this crucial Decade of Action.

Gunnar Köhlin
Director, Environment for Development

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Enabling Policy Environment

1. 1 Motivation

Decarbonising the energy system is a massive task, and particularly challenging with regard to countries in the global south. At the same time, it can be seen as an opportunity for industries and utilities to innovate, develop, and grow in up-and-coming markets. The transition to a low-carbon economy requires transformation in infrastructure, energy systems and the technologies adopted, amongst other changes. This demands a policy portfolio that facilitates the process. Policies, specifically in the global south, are implemented with the focus of simultaneously addressing multiple priorities such as affordability, security, and sustainability. This means that policies aimed at addressing climate change impacts by reducing sectoral greenhouse gas emissions have to be intrinsically aligned with socio-conomic developmental priorities such as equitable access to sustainable development, poverty eradication and access to a decent standard of living (Alfarargi, 2021).

Efforts to mitigate climate change impacts in terms of increasing the share of renewables, lowering emission intensity levels, and shifts in production and consumption practices to more energy efficient options, have been underway for over a decade. Yet, these actions fall short of what is needed for the world to reach recent pledges of carbon neutral or net-zero levels by mid-century (2050) so as to limit temperature rise above 2 degrees (from pre-industrial levels). The existing barriers in mobilising financing, availability of technical and institutional capacity, strong political will, weak approaches to assist in implementation of behavioural changes, and the current low development levels in low and middle-income countries (LMICs) to afford such a transformation have prevented the timely execution of the policies and associated actions to maintain the transition pathways. Some of these barriers may be related to specific technologies, for example, and other may be specific to a country or regional context (IPCC, 2022).

The need for low-carbon transition calls for policy and systematic innovation. In essence, the needed innovation will entail policies that facilitate the application of existing or potentially new technologies and practices. This calls for innovation in information technology, policy frameworks, market design, business models, engagement of new actors, financing instruments, and enabling infrastructure and sector coupling (IRENA, 2017). Innovation will be key to accelerating the pace of integration of low-carbon solutions and technology options into the society, thus becoming high priority for policymakers worldwide.

To ensure smooth planning, robust designing, and effective implementation of climate policies there needs to be an enabling environment that fosters these changes. These enablers include state and non-state actors that perform functions of planning, coordination, and implementation by influencing the policy process. In addition, they comprise institutional and regulatory frameworks that facilitate a network and collaborative governance across actors and institutions of policymaking, and finally market mechanisms that create the necessary incentives for overcoming barriers to policy adoption. This section thus aims at identifying the actors, processes and methods that enable the creation of an environment to put climate and energy transition policies in motion. More importantly, we will look to answer the following research questions:

What are the dimensions and dynamics between various actors of decarbonisation that can act as enablers to faster low-carbon transition?

What is the landscape of policy instruments that can facilitate a low-carbon transition?

What methods have been used to assess the impacts of low-carbon transition policies (ex-ante and ex-post analysis)?

The review undertaken in the following sections highlight the need for a comprehensive understanding of the socio-economic enablers and the political dynamics. These include the existing networks and vested interests between the various actors involved in the process of societal decarbonisation.

The section is organised as follows: section 1.2 discusses the actors and associated objectives that will support or hinder the energy transition process. Section 1.3 will review the existing policies in the global south countries and their respective impacts. This section will also have a focus section on emission pricing, specifically the market experiences and the political realities in their implementation. Section 1.5 will compile various methods adopted to assess different policy implications across sectors and identify best practices for future policy plans. This section will then highlight the research and knowledge gaps that have emerged from the review and conclude by identifying opportunities for high-impact research that will feed into future low-carbon research agendas.

1.2 The political economy of descarbonisation and actor analysis

To decarbonise energy systems and move towards low-carbon technologies is a not linear endeavour and depends on various influences, from multi-actor processes, to overcoming uncertainty, moving through the changes and, ideally, finding a stable political context for climate policies. Implementing decarbonisation policies requires taking into account the existing political economy of each country, such as understanding wealth and income distribution, access to resources, political institutions, and vested interests of different private and public actors. For example, the policies needed to decarbonise economies – or slow down carbonisation – might interefere with the interests of powerful groups or other economic interests of a country. To better understand the feasibility of implementing decarbonisation policies, various actors, their specific objectives, and their influencing power need to be understood systematically. To do so, a proper actor analysis can be carried out by applying a framework that can account for multiple objectives, e.g. how certain ministries might prioritize employment or economic growth over sustainability targets, or how specific societal actors, e.g., NGOs, might lobby for specific environmental targets that may not be relevant in the actual policy making process.

When trying to understand the costs and incentives of actors by analysing from a political economy lens, it may be challenging to disentangle whether certain policies are implemented with the intention to promote the overall welfare goals of a society or to serve special interest groups at the cost of society as a whole. For example, are policies that condone existing (fossil) industries in place because they are first and foremost considered important sources for state revenue, or are they in place because they are providing regional employment opportunities? It is crucial to understand which political and societal actors are key for promoting specific policy goals and related instruments, and how and why those could block or support policy packages promoting decarbonisation. Generally, those who bear the greatest loss (also known as "losers") from policies that promote energy transitions are well known to potentially block such policies and instead influence political processes in their own interests (Trebilcock, 2014). Therefore, the costs and incentives of environmental regulations and how they affect the behaviour of certain actors should be understood to identify strategies to overcome potential challenges and to create stable conditions for climate policies (Fritz et al., 2014; Inchauste & Victor, 2017).

This section is organized as follows: the first part reviews the role of various actors in decarbonisation by focusing on the literature of the political economy of energy transitions. The literature identifies the important role of phasing out coal that – if current investment plans are not stopped and plants are phased out prematurely, i.e. before they reach the end of their economic lifetimes – would make achieving the 1.5°C target unachievable (Tong et al., 2019). Therefore, the second part provides a deep dive into the role of vested interests by focusing on challenges and opportunities to transition away from coal and the role of various actors in this process.

1.2.1 The role of actors in decarbonisation

The literature on the political economy of energy transitions offers various ways to analyse the role of actors in decarbonisation strategies. Empirical research and case studies assess why and under which conditions climate policies can be implemented and remain stable. They find that effectiveness and stability depends on which political and societal groups benefit or lose out from a new regulation (Inchauste & Victor, 2017). To understand these conditions for environmental regulation in particular, two settings can be distinguisged and understood through the following theories: (i) whether few regulated actors benefit from a regulation while the costs are dispersed over many actors, known as a Stiglerian setting; or (ii) whether the regulatory benefits are broadly diffused across many different actors while the costs are concentrated on few actors, known as a Olsonian setting (Oye & Maxwell, 1994). When benefits are concentrated (as in a Stiglerian setting) the beneficiary actors can easily organise into special interest groups while the risk of lower public welfare and inequitable market access increases. Whereas if the benefits are diffused (as in an Olsonian setting) it is more difficult to galvanise these beneficiaries into political interest groups while those who bear the costs are concentrated, and thus can be compensated to overcome potential resistance. Ultimately, to create an effective and stable scenario, those who are regulated should reap benefits, either as a natural consequence of the policy or via compensation.

Several narratives in the political economy literature of climate policy seek to explain the role of actors in resisting the transition towards low-carbon energy systems and instead end up locking-in fossil fuel generation instead. Unruh (2000) argues that a carbon lock-in happens due to a simultaneous evolution of technology and institutions, which leads to a co-dependency and creates a techno-institutional complex. To understand how technologies contribute to political influence and institution building, more recent studies examine how the distribution of ownership in relation to the techno-economic characteristics (i.e. economic situation, dependence on fossil fuel imports and exports, global market developments for different energy technologies, renewable potential, and existing grid infrastructure) affect political power relations (Balmaceda, 2018; M. J. Burke & Stephens, 2018; Malm, 2013). In addition, understanding the historic evolution of institutions also allows contextualizing why certain societal or political actors gained influence and how they in turn affect policy processes (Lockwood et al., 2017).

Moe (2010) builds on the link between energy generation and economic development and posits the theory that governments should thwart vested interest groups from hampering structural changes. Building on these previous political economy perspectives, Geels (2014) developed the multi-level perspective framework, which analyses transitions from multiple dimensions and levels. Since fossil fuel technologies are especially favored in systems where infrastructure is built around large-scale coal and gas production, powerful rent-seeking interest groups influence regulatory regimes that perpetuate the existing system. These interest groups represent established socio-technical regimes that have the potential to enable but also constrain policies in relation to the existing system (Geels, 2014). To counteract the incumbent interest groups and disrupt fossil-fuel heavy systems, potential political mechanisms include the development of niche renewable technologies (Geels et al., 2017), governmental decentralization to usher in sustainability transition regionally (Ostrom, 2010; Urpelainen, 2013), and deliberately cultivating 'green' constituencies (Aklin & Urpelainen, 2018).

In a similar vein, another strand of literature argues that introducing policy instruments needs to follow a sequence that respects existing political economy barriers. The idea of sequencing is that barriers will eventually be eased and and a sequence of instruments will pave the way towards effective policy instruments (Pahle et al., 2018).

The political economy of energy transitions can also be analysed from the perspective of public opinion and special interest groups as main drivers – or barriers – for policy implementation (Hughes & Urpelainen, 2015). Beyond the techno-economic factors, understanding social preferences of actors allows the assessment of which objectives matter to which actor and why. Studies have shown that individuals have the tendency to make decisions based on "motivated reasoning", which refers to the tendency of individuals to assess a situation around some goal which is not necessarily based on facts or accuracy (Kahan, 2015a). For example, an individual's position on climate change policy is highly related to their political orientation and that of their peers within their social groups, rather than knowledge of scientific facts (Kahan, 2015a, 2015b). Thus, the goal of individuals might be to continue belonging to a social group, rather than making decisions based on facts. Distributional effects also play an important role in public perception, particularly when looking at fiscal energy transition policies such as taxes, credits, or direct subsidies, whereby the costs are incurred by the public. Evidence suggests that an individual's observed biases in decision making arises from "loss aversion" as put forward in behavioural economics (Kahneman & Tversky, 1979). Since the public will pay for increasing costs of such market-based instruments, analysing different options to offset costs could help address resistance to fiscal policies.

Analysing voting behaviour of the public, particularly special interest groups, can also shed light on what matters to different actor groups. Public choice theory is one method to assess voting behaviours and voter objectives, especially in presidential or parliamentary democracies. When looking at organized groups of actors, such as lobbies, the literature also shows how powerful vested interests can influence politics (Aidt, 2010; Moe, 2010). This is because lobbyists may provide financial support to political actors in direct relation to how much their demands may be fulfilled, or they may provide information that compels policy makers to adopt certain regulations beneficial to those firms that lobbyists represent. Along similar lines, assessing influencing behaviour, whether legal or illicit, by applying theories of corruption can also help uncover what motivates politically influential actors (Fredriksson & Svensson, 2003; Rafaty, 2018).

Another approach to understanding why climate policies may lag is through analysing investment decisions and how they may be influenced by a lack of credible policy commitment (Kalkuhl et al., 2020). A large body of literature highlights a vicious circle, whereby regulators have an incentive to modify previously announced climate targets as a result of firms underinvesting in clean energy technologies, and firms under-invest in cleaner technologies because the regulatory commitments are not credible and they do not want to lose out on profits (Brunner et al., 2012; Kalkuhl et al., 2020). To reduce resistance from potential losers and to build 'green' coalitions who could benefit from certain policies and thus support them, policy sequencing has been suggested as a means to apply certain policy instruments within given conditions (Pahle et al., 2018; Urpelainen, 2013). As an example, without a proper renewable support scheme it might be unreasonable to shut down all coal-fired power plants at one time.

Most studies that look into the political economy of energy transitions (see also (e.g. (Biber et al., 2017a; Karapin, 2012) for extended reviews) fall short in two aspects. First, they seldom identify the political economy of energy transitions in the global South; second, they assess political economy factors in a systematic way across countries in a limited capacity. One notable exception is the actors, objectives, context (AOC) framework developed by Jakob et al., (2020), which allows assessment of how different actors and special interest groups influence each other, assuming that political decisions are implemented that best serve the objectives of political actors and the societal groups that are most relevant for them. Importantly, the AOC framework acknowledges that decision makers can have multiple objectives whose importance may be weighted differently. It has been used in multiple case studies (including countries of the global South) to analyse the role of actors in the transformation of the energy sector, particularly with a focus on phasing out coal (Jakob & Steckel, 2022).

Applying the AOC framework to the case of coal

Coal is in multiple ways an interesting case to analyse in LMICs, considering the socio-economic and climate challenges that governments need to tackle simultaneously. LMICs have become major contributors to the increasing global coal fleet in recent decades, notably India and China, as well as several other Asian and - to a lesser extent- African countries (Steckel et al., 2015, 2020). Yet, we know that if the existing coal-fired power plants are not phased out, they have the potential to make climate targets unachievable if they are operated until the end of their lifetimes (Tong et al., 2019). Nevertheless, building coal fired power plants is often tightly interwoven with multiple policy objectives that go beyond energy policy, including geopolitical and social ones (Ohlendorf et al., 2022). Achieving those (or failing on them) can be decisive for policy makers to stay in power. Coal is hence a major factor when it comes to climate change mitigation policies in low- and middle income countries.

The literature has identified multiple economic reasons why countries continue to invest in coal. First, despite the costs of renewables having come down significantly, investments into fossil fuels, including coal, can be more attractive in market environments where capital costs of other energy sources remain high. Given differing cost structures (most of the life cycle costs of electricity for renewable energy are embedded in the upfront costs), high capital costs affect clean alternatives more than fossil fuels (Schmidt, 2014), which is also true for off grid applications or mini grids (Agutu et al., 2022). Second, coal holds spillover effects on regional economic growth and structural change. Regions where new coal fired power plants were opened have experienced a significantly higher growth rate (and structural change from agriculture to industry and service-based activities) than others, which has in particular proven true for green field power plants (Montrone et al., 2022). Yet, from an environmental point of view, investing in coal holds severe negative effects, not only regarding climate change, but also in terms of environmental pollution (Rauner et al., 2020).

Ohlendorf et al. (2022) investigate eight coal investing countries, mostly in Asia, and use the AOC framework to show that environmental objectives compared to others usually rank lower in terms of importance regarding policy making in the energy sector. From this study of eight countries in Asia, when looking into the role of specific ministries within governments, ministries of environmental issues tend to be less important and thus less influential for policy outcomes. By contrast, ministries of energy, the head of state, and the ruling parties of the eight countries studied are consistently the most important political actors for energy policy. In many countries, local regional actors (e.g. governments in coal mining regions within countries) are very important to consider. In addition, small elite groups as well as industry associations are the most important actors when looking at societal players across countries. Meanwhile other societal actors such as unions, international organizations, or environmental NGOs only play a low to medium role in policy making. Yet, how important specific actors are and what their connections are to the policy making process varies starkly between countries.

However, some have raised the concern that coal assets could become stranded as they are not in line with climate targets (Caldecott, 2017). Indeed, according to the IPCC (2022), between 30-70% of coal fired generation needs to be phased out by 2030 (compared to 2020) if ambitious climate targets are to be met. In this case, coal (and gas) fired power plants that are built today will need to be retired 20-30 years before their expected lifetime (IPCC 2022), at least when building expectations on historical observations. This does not necessarily lead to asset stranding in an economic sense, as today's coal investors likely anticipate at least some form of climate policy. If they didn't, climate policy might indeed be one of three ways how assets could become stranded, as highlighted by (Edenhofer et al., 2020). Authors also identify two additional channels: policy makers are time-inconsistent, and capital depreciation rates are too low in light of increasing carbon prices. Interest groups that are affected by asset stranding will oppose the respective policies, which might indeed render climate policies ineffective - at least when regulators cannot guarantee time consistent policies (Kalkuhl et al., 2020). Good institutions could prevent those outcomes, e.g. by delegating climate policy to an independent institution. What exactly this delegation would look like (nationally and also internationally) could be an interesting area of future research, particularly in low- and middle income countries.

Political actors usually relate to the objectives of specific societal or economic actors, which is why understanding the dynamics and interconnections is highly specific for each country. In the case of countries that invest in coal, the utilities, mining companies and heavy industry have the most influence on the policy making process (Ohlendorf et al., 2022). Their underlying objectives are, however, often different. While companies in heavy industry are primarily interested in affordable electricity prices to support their production, the business models of mining companies depend specifically on the continued use of coal. Political strategies to counterbalance the resistance of specific actors to climate and energy policies hence differ.

To provide a more concrete example, Figure 1 illustrates for Indonesia how actors and their specific objectives (e.g. to keep electricity tariffs low or to deliver public infrastructure) align with a specific policy outcome, in this case to build more coal fired capacity (Ordonez et al., 2021). Thinking of policy packages that foster an energy transition towards more renewable energy in Indonesia would need to take specific objectives into account.

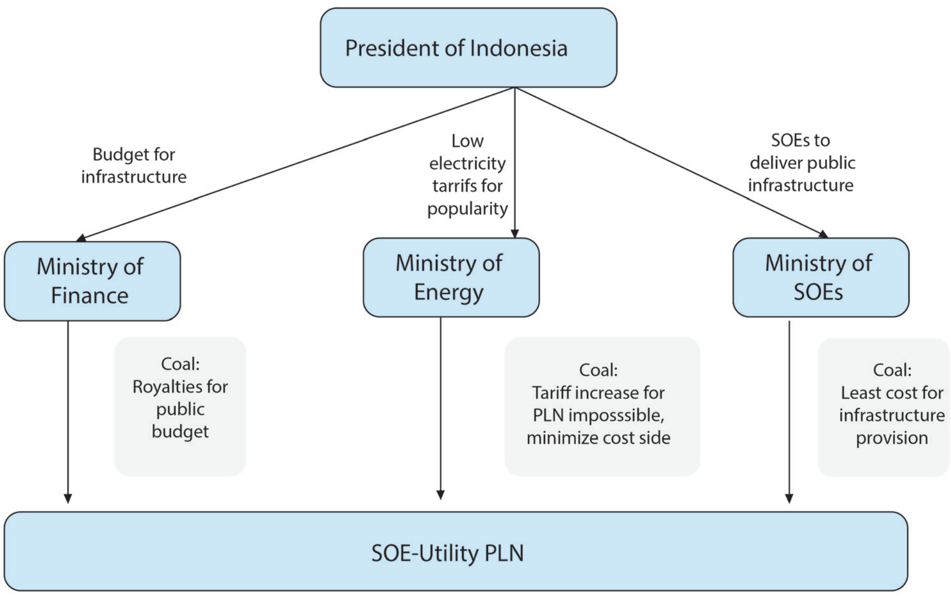

Figure 1 Schematic overview of actors and their incentives (in this case: to build more coal) for the example of Indonesia (Ordonez et al. 2021).

Notes: SOE stands for “State owned enterprises”; PLN is the Indonesian electricity utility.

To phase out coal, Jakob & Steckel (2022a) propose diferent strategies on how to account for actor constellations and the related political economy by categorizing countries into four distinct country groups – (1) phase-out; (2) phase-in; (3) established users; and (4) exporters – and applying these to 15 case studies. Countries that have already started to phase out coal (mostly OECD countries) usually have liberalised energy markets in place, which would allow for pricing instruments to effectively accelerate the transition. Indeed, ex-post studies find that price instruments have been very effective in phasing out coal (e.g. Leroutier, 2022). For countries that currently think of phasing in coal, such as Bangladesh or Pakistan, it is important to help build clean alternatives. That, however, often requires additional capital, with technological and institutional capacities that are economically competitive and politically acceptable. In established coal using countries, such as India or China, structural reforms of the electricity markets might be necessary before pricing instruments can become effective in reducing emissions. Coal exporting countries (such as Indonesia, South Africa or Colombia) will need to find ways to deal with potential losers of a phase out policy, both regarding coal workers as well as other incumbents.

1.3 Review of policy instruments for decarbonisation

The current incremental change in the energy sector is too slow to cope with the urgency of the climate change challenge. A more radical energy transition is needed[1]. Shifts in policy design and structures that will prompt drastic changes in daily routines and societal narratives, by penalizing some technologies and behaviours such as private car use or coal powered electricity, while supporting active travel and efficient thermal insulation, are becoming imperative (Lamb et al., 2020). Globally, demand-pull measures such as transport fuel taxes, carbon prices, peak power pricing, and renewable energy subsidies are being put in motion to shift the needle on decarbonization. Yet a crucial aspect to be considered for the longevity of such policies is avoiding any negative social impacts. In other words, the social perception or level of acceptability of policies in terms of their fairness and equity for all populations must be considered when drafting and rolling out policies. This issue is gaining higher relevance in developing country contexts that already struggle with issues around political trust, structural inequality, and limited institutional capacities, but also hold the higher potential to implement such policies to avoid future long-term carbon lock-ins. The onset of social acceptability studies that carry out the ex-ante and, in some cases, ex-post policy assessment on the public perception of energy taxation, emissions pricing, and other decarbonization policies, provide new knowledge on the political and social viability of such policies.

Even in 2022, energy access remains an unachieved goal in the majority of low- and middle-income economies. Moreover, the strong correlation between consumption and development and the urgency for economies to grow forces these countries to expand their fossil-fuel based electricity and transport infrastructure to meet at least decent living standards for its citizens. While the push toward increasing the share of renewable energy in the electricity mix may have achieved technological and economic viability in most developed countries and some emerging economies (e.g. China and India), its ultimate implementation, integration, and complete acceptance as the primary source of electricity is beset with many challenges. Relying on renewables to progress from consumptive use of energy to productive use, especially in rural areas where renewable solutions are available mostly as off-grid systems, is not conducive to economic growth due to the extremely low levels of consumption (Jeuland et al., 2020). Nevertheless, this path of enquiry on the different electrification policies and how they connect with climate and development outcomes merits examination.

Climate policies are often packaged into bundles of legislation, embedded in a milieu of other social, financial and non-climate policies (Lamb et al., 2020). Given the complexities of design and implementation in policymaking, examining and reviewing the outcomes and impacts of policies in their real implementation context will provide the groundwork for improvements in design and governance characteristics of climate policies.

1.3.1 An overview of systematic reviews of low-carbon policy instruments

Numerous systematic review studies have been published over the years on policies for low-carbon transition within the

1 Johnstone, P., Rogge, K.S., Kivimaa, P., Fratini, C.F., Primmer, E., Stirling, A., 2020. Waves of disruption in clean energy transitions: sociotechnical dimensions of system disruption in Germany and the United Kingdom. Energy Res. Soc. Sci. 59. https://doi.org/10.1016/j.erss.2019.101287.

energy and environment field. We find that the majority of the studies in the literature tend to be focussed on developed or high-income nations. This trend is more likely due to higher investments being made in research and knowledge growth on low-carbon economy in these economies, alongside the financial and frontier technological support that is provided to facilitate low-carbon solutions. This leaves few selected studies that systematically review the low-carbon policy landscape for the developing countries. Nevertheless, this section provides an overview of the trends and impacts of the policies reviewed in them with a focus on global south countries, but also includes studies comprising a combination with developed countries. We review 20 systematic review studies that in turn review policies and their subsequent outcomes and impacts, and include policies on renewable energy development, energy efficiency programs, taxation on energy, carbon and transport, regulatory and market-based interventions, and environmental management.

The focus of the review will be on extracting knowledge on specific policies and their impacts on outcomes such as emission levels and environmental sustainability, gender equity, economic growth and income distribution, and other social and technical outcomes that will be contextualised, to the extent possible, to regions and countries.

The assessment of policy impacts, for instance identified by Penasco et al. (2021), is based on the policy instrument evaluation criteria and narrative adopted by several international organisations including the EU Commission's decarbonisation pathways. Selected decarbonisation policies were assessed on a wide set of environmental, technological, and socio-economic outcomes. Lamb et al. (2020) review impacts of climate policy interventions on social outcomes such as access (to electricity and other services), energy affordability, employment, equality, livelihoods and poverty, procedural justice, subjective well-being and drudgery. Impact of climate policies ex-post on employment is also assessed by Godinho (2022). Several reviews have also looked at the impact of sector specific policies on different outcome categories. For instance, the impact of renewable energy policies on economic dimensions, emissions levels, electricity prices, and fuel imports is examined by Kabel and Bassim (2019). The impact of various electrification policies in LMICs on climate and development is reviewed by Jeuland et al. (2020). In another systematic review, Jeuland et al. (2021) assessed policies on access to traditional and modern energy sources and their impact on development and environmental outcomes. A meta-analysis of the monetary and non-monetary interventions on energy consumption emission levels was conducted by Khanna et al. (2021), while Ohlendorf et al. (2021) carried out a meta-analysis of the distributional effects of carbon pricing. Table 1 summarizes the policies, their associate impact or outcome categories, and their implications.

Table 1 Impact categories and associated implications of reviewed policy instruments

Sector or Policy	Outcome or Impact categories	Policy implications and findings	References
Climate and Energy policies (reviewing multiple low-carbon policies)	Employment	Impacts are modest and net positive or neutral, but distributional outcomes can be uneven	Godinho (2022)
	Access (electricity and other services), Affordability (electricity/fuel) Community Cohesion, Employment, Equality (gender/geographic/ income), Livelihoods & poverty, Procedural justice, Subjective wellbeing, Time/labour/ drudgery	Most policies fall short of delivering positive social outcomes. Carbon and energy taxes find mixed effects, subsidies have positive, mixed, and negative effects, FiTs mostly find negative effects, direct procurements have positive and mixed effects, RE policies have negative impacts	Lamb et al. (2020)
	Competitiveness, Distributional outcome, Environmental effectiveness, Tech. effectiveness, Cost-related outcomes, Innovation outcomes.	Policy impacts were positive on environmental, technological and innovation outcomes, short-term negative impacts on distributional and competitiveness outcomes	Penasco et al. (2021)
Renewable Energy policies	Economic growth	RE does not hinder economic growth in developing and developing countries, while a threshold level of RE has insignificant impact on growth for developed countries	Bhuiyan et al. (2022)
	Economic growth, Job creation, Welfare, CO_2 emissions, Electricity prices, Fuel imports	Shift to RE reduced CO_2 emissions, with positive correlation with economic growth, job creation and welfare	Kabel and Bassim (2019)
Energy Access and Electricity policies	Climate and Development	Off-grid electricity (renewable), and low-service level access have negligible climate effects while on-grid electrification and high-service level electricity access is carbon intensive.	Jeuland et al. (2020)
	Development (households, firm, public service, national economy) and Environmental	No strong evidence that access to modern energy services improve environmental and development outcomes, mixed effects	Jeuland et al. (2021)
	Education, Socioeconomic welfare, Health, Environmental	Positive but small effect on education, marginal increase in household welfare and income, positive time allocated to paid work and leisure, insignificant effect on business outcomes, marginal improvement in female empowerment at the household decision-making, positive (but weak) health outcomes, small positive effect on lower pollution levels and use of traditional fuels.	Moore et al. (2020)
	Economic, Education, Gender Empowerment	Positive and significant effect on income and consumption expenditure, employment, and education indicators, negative and insignificant effect on fertility levels but positive on female labour market participation and decision making	UNESCAP (2021)
Coal (phase-out)	Environmental, Social, Economic	Negative economic outcomes – job losses, negative impacts on GDP and public finances, negative social outcomes – decline in quality of life, high poverty, and decrease of municipal and social services, positive environmental outcomes – reduced CO_2 and SO_2 emissions and black smoke, improvement in air quality	Diluiso et al. (2021)
Carbon Pricing policies	Distributional impacts	Progressive impacts within lower-income countries and transport policies; subsidy reforms are not inherently more progressive than carbon pricing instruments	Ohlendorf et al. (2021)
Market-based instruments	Environmental impacts – air quality, water, and waste management	Targeted taxes and subsidy shifts (from fossil to clean energy) can lower air pollution levels; water pricing, effluent taxes and information provision can reduce water pollution; data and water level monitoring, integrating informal sector to existing frameworks and deposit-refund schemes are improved waste management processes	ADB (2021)
Behavioural Interventions	Energy consumption /Emission reduction	Medium average effect of all behavioural interventions; though monetary has greater effect than motivation and social comparison, the effect of a combination of interventions is higher than individual intervention.	Khanna et al (2021)

Source: Author's compilation

The following sections provide an overview of sectoral policies that were systematically reviewed in the selected studies.

1.3.2 Renewable Energy Transitions Policies

In a majority of the studies reviewed by Penasco et al (2021), policies that supported the deployment of renewable energy, such as renewable energy obligations (REO), feed-in-tariffs (FiTs), auctions or tradable green certificates (TGCs) were found to have negative short- to medium-term distributional impacts. In the case of negative distributional effects from REOs, they were due to fewer opportunities or lower commercial prospects for small producers and developers when compared to large ones. The reviewed literature is still inconclusive or neutral on the impact of FiTs on emissions reduction or national target achievements. As a key outcome of concern for policy makers that supports low-carbon transition with regards to cost-effectiveness of renewable energy development policies, energy auctions were assessed as the least cost-effective alternative, with literature on FiTs, REOs and TCGs suggesting a mixed effect on cost outcomes. These differences in assessments for FiTs could be attributed to country-specific design elements or technology specific aspects (Jenner et al., 2013; Menanteau et al., 2003; Schallenberg-Rodriguez, 2017). In terms of social impact of RE policies, TGCs, REOs and energy auctions impact negatively on the NIMBY[2] syndrome, as well as on market risks and transaction costs. However, these policies have a positive impact on perceived health benefits and transparency of the schemes. Evaluation of FiTs is seen to positively impact small generators, ease of implementation, and mitigate the NIMBY syndrome.

1.3.3.1 RE consumption and economic growth

Countries with highly significant opportunities for investments in renewable energy include the United States, China, and India (RECAI, 2020). As a strong alternative to curb carbon emissions and reduce environmental degradation, renewable energy gains significance in most large-scale decarbonisation plans of transition countries.

Yet, the development of renewable energy can coincide with other development objectives such as economic growth and affordable energy access. The persistent high capital cost of setting up renewable energy capacities can impact energy consumption, which is a key contributor to economic growth, as well as increase the cost of electricity, making it unaffordable for the majority of the low-income consumers. Several studies have looked at this relationship impact across sectors and various forms of renewable energy. Renewable energy is seen to aid growth in the services sector in high-income economies, and the manufacturing sector in middle-income economies (Doytch & Narayan, 2021). A bidirectional causal relationship has been found between economic growth and renewable energy (Acheampong et al., 2021), with renewable energy supporting economic development (based on the development level of the country) while income growth and institutional quality have positive impacts, and urbanisation has negative impacts on the growth of renewable energy (Islam et al., 2022). Chinese investments in RE projects in sub-Saharan Africa is found to have economic co-benefits in terms of new job opportunities, production and training activities, linkages with actors in the local systems among others, even though limited in their extent (Lema et al., 2021). Further, hybrid renewable energy systems were found to perform better in Asian countries than in African nations on account of mini-grid maintenance and productivity.

A systematic review of how renewable energy systems affect economic growth levels and plans for Next-11 countries (Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey, and Vietnam) reveals varying effects of renewable energy development on economic and environmental indicators. Table 2 compiles the positive and negative impacts on various factors as a result of the set-up and use of renewable energy in the Next-11 countries.

2 NIMBY – Not In My Back Yard

Table 2 Impact of renewable energy systems on economic and environmental factors for Next-11 countries

Country	Factors affected by renewable energy systems					
	Positive effect = ↑, Negative effect = ↓					
Bangladesh	Economic Growth ↑	CO2 Emissions ↓	Foreign Direct Investment ↑	Domestic Investment ↑	Urbanisation	
Egypt	Economic Growth ↑			Electricity Sustainability ↑		
Iran	Economic Growth ↑		Attraction of Foreign Capital ↑		Policy Stabilisation ↑	
Mexico	Economic Growth ↑			Shared Ownership Models ↑		
Nigeria	Economic Growth ↑	Physical market-places ↑	Energy Management ↑	Environ-mental Quality ↑	Sustainable Development ↑	Suboptimal quality of life ↑
Pakistan	Economic Growth ↑		Human Development ↑		Terrorism Reduction ↑	
Philippines	Economic Growth ↑		Environmental Quality ↑		Services Growth ↑	
South Korea	Economic Growth ↑	Research and Development Sector ↑	Environmental Quality ↑		Electricity Sustainability ↓	
Turkey	Economic Growth ↑		Electricity Sustainability ↓		Environmental Quality ↑	
Vietnam	Economic Growth ↑		Green Jobs ↑		Tariff Price ↓	
Indonesia	Economic Growth ↑	Green Jobs ↑	Environmental Sustainability ↑	Energy Management ↑	Research and Development Sector ↑	

Source: Bhuiyan et al., 2022

1.3.3 Carbon Pricing/Taxation policies

Environment effectiveness in terms of emissions reduction or energy savings was found to be high for policies such as environmental taxes and GHG emission allowance trading schemes. On the other hand, the distributional impact of levying energy taxes was found to have negative distributional impacts in over 60% of the policy evaluation reviews, with rural areas suffering higher welfare losses from energy taxes than urban areas. Some studies in fact showed lesser distribution impacts from fuel taxes and local air pollution as compared to carbon taxes, especially when revenue recycling schemes were not in place (Peñasco et al., 2021). Based on ex-post policy evalutaions of carbon pricing policies, an upcoming meta-analysis of emission reduction effects on the global and policy level reveal that the combined average reduction effect of all carbon pricing schemes is estimated between 6.8% and 10.4%. The effect varies substantially across schemes, due to country specific policy design and context (Döbbeling et al. 2023, submitted)

1.3.4 Energy Efficiency Policies

Amongst review policy instruments by Peñasco et al. (2021), building sector decarbonisation policies such as building codes and energy efficiency standards were associated with positive distributional impacts , with energy efficiency standards standing out as fair instruments as the cost of energy savings did not disproportionately burden low-income users. These instruments have also led to positive impacts in terms of their environmental and cost-effectiveness as low-carbon policies.

1.3.5 Energy Access policies

Electrification marks the initial access to sufficient electricity for a household to power a basic bundle of energy services. A review of the climate and development implication of electrification projects in the global south reveals a concentration of studies from India[3] and a small set of literature from Sub-Saharan Africa, Latin America, and East and Southeast Asia (Jeuland et al., 2020). Using the multi-tier framework for energy access from the World Bank (Bhatia & Angelou, 2015), the lower-tier access is supplied by off-grid or solar technologies and provides basic energy services such as lighting, phone charging and basic entertainment, and so entail lower emissions, unless they are diesel generator based-off-grids. Whereas, high-tier access creates provisions for heating, cooling and cooking services that are predominantly provided by grid-based electricity, and are emission intensive (Jeuland et al., 2020). The effect of electricity interventions on socio-economic factors was most studied in South Asia (India, Bangladesh) and Sub-Saharan Africa (Kenya and Ghana) (Moore et al., 2020). Effects were positive (but moderate) for education, household welfare, health, work-leisure time allocation, environment, and female decision-making. Given energy access as a key Sustainable Development Goal (SDGs), a review of the impacts of modern and traditional energy uses finds that shifts towards modern energy services may not always improve environmental and development outcomes. Policies around cooking as an energy service most reviewed in literature showed its impacts on household health and climate effects being examined more than impacts on gender equity, household income, or local environmental quality. In terms of the impact of energy interventions on SDGs, evidence is consistently positive on poverty alleviation goals, while largely negative on health and climate outcomes and ecosystems and forest health (Jeuland et al., 2021). The negative evidence is populated by studies

3 as a leading location for the adoption and experimentation of off-grid technologies and supporting business models (Singh, 2016).

that mainly look at the impact of traditional cooking.

1.3.6 Policy mixes reduce emissions

Policy mixes have been successful in the past in emission reduction, and have lessons to extend for future planning of climate policy packages. The effectiveness of different policy mixes on reduction in road-based CO_2 emissions was reviewed by Koch et. al (2022). Using emission breaks (significant reduction on CO_2 emissions) to assess different policies, the review identifies an efficient set (10) of policies that cause the reduction. Successful policy mixes are seen to combine carbon or fuel taxes with green incentives. A combination of policies that simultaneously address a common target, such as energy efficiency gap and rebound effects, are more effective than a single policy.

1.4 In focus: Emission markets and pricing – experiences

Economic research has argued for carbon pricing as one of the most efficient and cost-effective methods to addressing climate change effects through the reduction of GHG emissions. Further, it is increasingly being considered and implemented in developed countries – and also being piloted in developing countries. With its increasing coverage globally, reviewing the evidence base for emission pricing and markets merits a special section.

1.4.1 Theoretical foundations of Emissions Pricing

An increase in the level of emissions that contributes to environmental pollution is a negative externality. Since this externality is not reflected in the price of goods and services (which in turn also generate emissions), the outcome is considered a market failure. The economic response to such a problem of externality has been by way of taxation of the source of emissions, which also brings in the role of public policy to combat environmental problems. Discussing the positive and negative externalities, Pigou's (1929) contributions on their impacts on production and in turn finding ways of correcting or internalizing the externality, has laid the groundwork for modern research on optimal environmental taxation (Edenhofer et al., 2021). Pigou's tax is aimed at setting a cost on externalities that maximized economic welfare. Similarly, the tax set to the marginal environmental damages, in the form of environmental or carbon tax, has often been equated to the Pigouvian tax (Cremer et al., 1998).

Another strand of evidence on environmental pollution points to the problem of global commons, in other words, the problem of incomplete property rights. In line with the thinking of Coase (1960), Crocker (1966) and Dales (1968), this refers to the trading of property rights between private actors in a cost-effective manner. This was extended to the concept to addressing environmental externalities by providing a theoretical basis for the implementation of markets for emission licenses (Montgomery, 1972). The collective work that is seen as testing the efficiency of individual emission control options also provides the basis for the modern cap-and-trade or more generally emission trading systems (ETS). The system allocates the responsibility for curbing emissions in line with the cap to individual players, such as companies and industries (Ball, 2018). The emission reduction targets set by the system authorities allows for a limited number of authorized certificates (one certificate equates to a ton of carbon emission) to be traded within the system. The price of the certificate is induced by the supply and demand for certificates between players.

Economically, both systems – carbon taxes/pricing and cap-and-trade – operate similarly but with different outcomes. Carbon taxes fix the price for emissions and the outcome in terms of level of emissions generated is determined by market forces. The cap-and-trade system, on the other hand, set a ceiling for emission levels (within a jurisdiction or regulated sector), predicting the emission reductions, and the price for staying within the limit is determined by market forces. Pricing greenhouse gas (GHG) emissions holds the potential to 'internalise' the cost of climate change, thereby also enabling the decarbonization of economic growth (Duggal, 2021). Alongside promoting cost-effective abatement of emission, emission pricing can incentivize energy efficient and sustainable innovation as well as help improve government fiscal conditions. However, as abatement costs are often hard to quantify, it is challenging to set the right price on carbon or determine a market balancing price of a certificate.

1.4.2 Sectoral implementation with emission pricing mechanism

Implementing emission pricing is most efficient in sectors where alternative low-carbon technologies exist for easy switching or transition, and where polluters cannot easily relocate. Power/electricity is one such sector (Rosenbloom et al., 2020). The point of emissions generation being a large and static entity makes it difficult for power utilities to move locations to where energy would be cheaper. Moreover, with a higher share of energy sourced from fossil fuels and the carbon prices changing the relative price of different electricity generation technologies, cost-effective decarbonizing can be achieved by switching to more efficient equipment, shifting to lower-carbon fuels (eg. coal to natural gas), increasing the share of renewable energy in the electricity mix, or by adopting negative emission technologies such as carbon capture and sequestration (CCS). Utilities can also tap into demand-side solutions such as social norms to encourage electricity savings or providing incentives to reduce energy wastage behaviour (Ball, 2018). It is the economical and straightforward process of reducing emissions in the power sector, that makes it the most responsive sector compared to others to any carbon price signals (Hayes & Hafstead, 2020).

GHG reduction through emission pricing mechanisms have proven to be less effective in sectors with high structural heterogeneity and multi-actor involvement, such as agriculture, transport, and buildings. In the agricultural sector, the estimation of emission is challenging due to the heterogeneity of subsectors and the diversity and complexity of processes that emit GHG. Since the agriculture sector is significantly less consolidated than other sectors, reducing emission requires action by every person employed in agriculture. The adherence to traditional local practices (exacerbated among small landholdings) further limits the estimation of emission given insufficient infrastructure for the same (Ahmed et al., 2020). Moreover, the estimation of GHG emissions is further complicated by large data gaps and inconsistencies in GHG estimation and linked agricultural processes. The potential social and economic impact on farmers, loss of international competitiveness in the absence of global coordination, and the risk of emissions leakage of carbon policies are other concerns that pose as challenges to addressing agricultural emissions via price-based policies (Leahy et al., 2020)

Similar to the electricity sector, the transport sector also has a high degree of dependence on fossil fuels, but high carbon prices do not significantly affect the reduction of transportation emissions (Ball, 2018). Firstly, the evidence suggests that drivers/consumers show a low responsiveness to increases in petroleum or diesel taxes, as they seldom alter or reduce their daily commuting routines. Standalone high fuel costs do not shift the needle on passenger transport emission unless accompanying efforts such as vehicle efficiency standards, fuel standards and non-price policies are also put in place (Pryor et al., 2021). Secondly, unlike the electricity/power sector, fuel switching in the transportation sector is not easy. An internal combustion engine that operates on petrol/diesel, cannot use natural gas or electricity, without changing or altering the engine system of the vehicle, or plane or ship for that matter. Without incurring the additional cost of changing the entire engine mechanism to suit the fuel, in addition to the high carbon taxes, the transportation sector does not offer easy opportunities for emission reduction.

Emissions from the building sector are generated directly in homes from fuel combustion, for example in furnaces, and indirectly from the electricity in homes. Since the builders do not occupy their buildings themselves, they don't bear energy bills. This provides less incentive for the builders to undertake any additional capital costs to make the buildings efficient (Ball, 2018). Any changes in the indirect emission in buildings will mostly result from decarbonization in the electricity sector.

1.4.3 Approaches to carbon pricing – emission-based carbon tax, fuel tax and subsidy reforms

Traditionally, carbon pricing programs take two forms: carbon taxes and cap-and-trade programs such as emission trading systems (ETS). ETS sets a limit or a 'ceiling' on the emissions that can be generated by means of tradable permits. Each permit can be seen as a voucher that allows the holder to emit one ton of GHG emission, which can then be traded for the corresponding emission price that is set in the trading market. Carbon taxes are market-based instruments wherein a fixed price per ton of emission is set which then gives flexibility to the taxpayers to manage their emission levels. Further, carbon taxation is deployed through two approaches in countries: fuel-based carbon taxation and tax on direct carbon emissions. Fuel-based carbon taxation is the most widely adopted (such as in Sweden, Canada, EU and Mexico), and often uses the existing tax monitoring systems or customs administration (when fuel is imported) already in place in countries, such as for excise taxes on fossil fuels. For this reason, any technical processes in implementing and administering such taxes is easier and less costly. On the other hand, taxing direct carbon emissions (as implemented in Chile), where the tax is levied on the amount of emissions generated requires the setup of a Monitoring, Reporting and Verification (MRV) system. This MRV system calls for additional capacities and coordinated effort between the tax authorities (for collection) and the environmental departments/ministries that set the emission criteria, verifying and controlling the emission data. This results in additional administrative costs and could be complex to implement.

Table 3 Characteristics of fuel-based and emissions-based carbon tax approaches

	Fuel Approach	Direct Emissions approach
Tax Base	On fuels	On Emissions
Adoption	Predominant	Less frequent
Taxable event/ point of regulation	Varied as per production, importation point or most commonly sales of fuels by distributors	At the entity (usually sector companies including fossil fuel producers/importers, industrial producers, foresters etc.)
Structure of tax rate	Same for carbon content, but varies by fuels per weight or volume unit depending on their carbon content	Same across similar type of emissions
Rate calculation	In proportion to the carbon content	Directly on emissions
Coverage	Fuels	Potentially all emission sources, but reporting requires large facilities
Administrative Burden	Simple	Complex
MRV System	Simple	Complex
Institutions involved	Taxing Authorities	Tax and Environmental Authorities

Source: UN subcommittee on Environmental Taxation Issues, United Nations Workshop 2020

Another form of fuel taxation is carried out as a budgetary instrument to place charges on the provision of the fuel. They can be as excise duties charged in addition to the generally applied value added taxes (VAT)/goods and services tax (GST). They are primarily levied on fuels used in transportation ie. petrol, diesel, and gas. Lower taxes may be levied on fuels for agricultural vehicles, for home or industrial lighting and heating, or electricity generation. In many developing countries, these fuels and energy services are also subsidized. The objective or use of these taxes is explained by the need to achieve or increase revenue targets and mobilise fiscal resources towards public infrastructure and services.

However, without explicitly stating the primary intent of imposing a fuel tax on consumption of fossil fuels to account for the cost of GHG emissions in the final fuel cost, a fuel tax can be studied as a carbon tax. While the two objectives of emission reduction (or pricing negative externalities such as pollution) and revenue maximization can be justified when taxing fuels, one often takes precedence over the other (UNDP, 2016). In developing countries, it has been the case that revenue increases. On the other hand, subsidizing fossil fuels has been a common practice in developing and energy-poor countries with the primary objective of ensuring increased and easier access to energy and targeted support to the low-income sections of society. While this is in conflict with the consumption, and hence emission reduction targets, many countries have attempted reforming (phasing out or eliminating) some of the fossil fuel subsidies., particularly developing countries where subsidies are particularly large. Such subsidy reductions can be understood as a policy instrument that facilitates carbon pricing, and hence emission reduction. However, while carbon pricing is a way to price externalities to correct for market failure, eliminating fossil fuel subsidies addresses the removal of policy interventions that represent government failures (Aldy & Stavins, 2012). A large critique of subsidy reforms is the negative impact it will have on low-income households. Yet, in developing countries much of the fossil fuel subsidy disproportionately benefits the relatively wealthy (P. D. Coady et al., 2010). Like emission pricing schemes, fossil fuel subsidy reforms are also made palatable to the public through compensation and revenue recycling schemes.

1.4.4 Emission Market experiences

1.4.4.1 Political and institutional realities of emission market functioning

Carbon pricing or taxation can be considered amongst the largely unpopular and tricky climate policies to implement, as compared to for instance clean energy standards, or renewable energy capacities. Several factors of a technical, institutional, economic, and political nature come into play when looking at setting up a uniform and comprehensive system for implementing a carbon pricing mechanism. Moreover, the magnitude of these factors affecting the designing and structuring of the carbon pricing policy will vary across countries depending upon their historical and political contexts. So far, emission pricing mechanisms have been implemented or are currently operational mostly in developed countries. Only a few select countries in the Global South fall in this category, namely, China, South Korea, Japan, Mexico (on a pilot basis) and Kazakhstan with an emission trading mechanism, and Chile, Colombia, Mexico, Argentina, South Africa, Japan, Indonesia (scheduled to implement in July 2022) and Singapore with carbon tax policies. Yet, several more developing countries have ERS or carbon tax policies under consideration to be implemented in the upcoming years. The experiences of emission markets from a political and institutional perspective thus tends to be more skewed towards industrialised or developed countries in the literature.

A recent systematic review of factors affecting the adoption, implementation, and design of carbon pricing systems across countries identifies five factors, including political systems and institutional factors, business influence, public opposition, external influence, and policy diffusion (Khan & Johansson, 2022). In terms of the political systems in countries where carbon pricing currently exists (mostly the global north), early adopters of carbon pricing (or taxes) are where left-wing governments dominate, often in conjunction with green parties (Skovgaard et al., 2019). At the same time, political systems with proportional representation of different parties are also more likely to adopt carbon taxes (Andersen, 2019; Criqui et al., 2019; Harrison, 2010). Institutionally, the implementation of ETS or carbon taxes hinges not only on the power balance between ministries, but also on the presence of adequate financial markets and structured auction mechanisms (Oh et al., 2017). The review also found that good governance structures and control of corruption were other institutional requirements for a positive correlation with implementing carbon pricing policies (Best & Zhang, 2020; Levi et al., 2020).

Public support based on the public perception towards climate policies including environmental taxing, carbon pricing or fuel taxation is seen to influence the acceptance or opposition to the introduction of carbon pricing policies (Carattini et al., 2019; Klenert et al., 2018; Maestre-Andrés et al., 2019). Yet, political struggles and institutional (and administrative) incapacities have been found to play a more significant role in stopping the policy implementation or the rolling back of carbon pricing policies. For this reason, one of the key lessons when planning to introduce and implement carbon pricing is to facilitate a political dialogue to secure the buy-in of all stakeholders at the national level which is needed for the necessary political leadership and institutional readiness (de Gouvello et al., 2020).

The considerable diversity that exists across emission trading or carbon pricing systems across countries adds to the emission market experiences. The uniqueness in design and implementation processes provides insights into the benefits and challenges faced in executing the respective mechanisms. Countries and regions face their political and institutional realities when planning and implementing emission trading or pricing policies; that determines which emission pricing policy they choose to implement.

Asia

Indonesia

The introduction of a carbon tax in Indonesia faced political challenges in the form of institutional resistance, influence of the business players, and conflicts of interest (Dyarto & Setyawan, 2021). Despite multiple governmental agencies (Ministry of Planning (Bappenas), the Ministry of Finance, the Reducing Emissions from Deforestation and Forest Degradation (REDD+) agency, and the National Climate Change Council (DNPI)) involved in formulating climate policies and strategies, there was often a lack of policy coordination between them. Plausible reasons for the resistance from these institutions included:

- lack of commitment towards considering carbon tax as a policy solution, and
- low political will, specifically by the Ministry of Finance as a powerful institution, to recognise and make climate policies a national priority,

In addition, many members of the parliament originate from a business background. The historical and the ongoing engagement of business players in the political arena, through positions of power in political parties and government institutions, have also hindered the smooth passing of carbon tax policies in the country. Given their large contributions to the economy, the influence of businesses and companies on the policymaking process to favour self-interests has seen cost-inducing, but necessary policies such as a carbon price or tax on their operations and goods being lobbied to be stalled or opposed. The revolving door situation between business and political positions taken by the officials fosters a conflict of interest in actions of priority. In the choice between the national urgency to prioritise climate policies such as carbon pricing /taxing to reduce emissions levels from polluting industries and avoiding any additional charges on their production processes, the political-cum-business representation tends to fall unfavourably for the climate.

China

Lessons from the pilot ETS programs active at the provincial levels highlighted shortcomings on an institutional scale that are necessary to address for successful execution at a national level. Aside from the universal challenges to emission trading programs globally – emissions accounting, allowance allocation and market volatility (Schmalensee & Stavins, 2017), the experiences from the pilot programs have revealed additional challenges that can jeopardise the development of the national level ETS (P. Wang et al., 2019):

- Institutional incapacities and lack of legal support:

The data foundation was weak due to inconsistencies in emission inventories (between national and provincial levels), undefined market rules, and lack of strict enforcement of compliance mechanisms (such as the MRV[4] framework). The management of the program by lower-ranked government agencies with insufficient authority and understaffing contributed to this challenge (Deng et al., 2018; Yu & Lo, 2015).

- Excessive government intervention and incomplete regulatory mechanism: The monopolistic control of the state-owned enterprises (eg. in the power sector), and their strong influence on national policymaking can undermine any market mechanisms that are necessary for efficiency of the program (Lo, 2016).

These challenges are deeply entrenched in the political system and governing practices, and the success of the ETS at the national scale will depend on the transformation from the current state and market interconnectedness.

Kazakhstan

Piloted in 2013 and operated in phases, the Kazakhstan ETS has undergone several adjustments since. Over the duration it has also faced numerous challenges. Politically, the KazETS is comprised of an oligopolistic allowance market with few dominant firms, which brought into question the fairness of the allocation process where some firms received additional free allowances, while others did not (Kazenergy, 2017). Institutionally, there exists no independent body overseeing the allocations and assessment methods. The ETS data being publicly unavailable further limits its accountability. Additionally, in one of the early phases (2), the brokers controlled the emission trades (by being buyers and sellers), which resulted in a non-transparent pricing of the allowances. The lack of an institution or mechanism to ensure an adaptive management of the KazETS can limit the efficacy of the program and system in the future.

Latin America

Domestic elements such as the institutional design and the political economy dynamics can influence the design of emission pricing chosen by the governments (Stevens, 2021). For this reason, countries such as Mexico, Chile, Argentina, and Colombia opted to start with carbon tax over cap-and-trade, which were implemented through their fiscal reforms. The case study analysis of Mexico, which then extended applicability to other Latin American countries (Stevens, 2021), revealed that it was the nature of the political system: presidential, and the centralisation of the budgetary process that promoted the implementation of carbon taxes. By combining them with other fiscal policies under the revenue acts that also warranted timely budgetary approval, the countries were able to utilise the existing fiscal structures and processes to pass the carbon tax policy. As compared to introducing an ETS, passing carbon taxes as part fiscal reforms resulted in lower administrative and capacity building costs. The political will and use of institutional power of the governments to strategize energy as a national interest transformation further facilitated the speedy approval. However, the policy specifics were determined in collaboration with industry stakeholders (emission-intensive, trade-exposed sectors) that have a stake in the distributive implications of the carbon taxation. This could potentially indicate a business influence, as seen in the case of Indonesia, that was seen necessary to foster trust and ensure compliance with the policy.

1.4.5 Potential trade-offs and synergies to Emissions Pricing

1.4.5.1 Distributional effects of carbon pricing

There is growing literature on assessing the effects of carbon pricing across economies and population groups on employment, income and the health outcomes (Beck et al., 2015; Ganapati et al., 2020; Goulder et al., 2019; Hille & Möbius, 2019; Rausch et al., 2011). Introducing carbon pricing mechanisms, particularly in low and middle income countries (LMICs), have triggered concerns regarding the distributional justice of climate policy, which connects it to the political feasibility of these schemes (Steckel et al., 2021). Further, since emission pricing can increase energy prices, aspects of social equity enter public debates and can result in strikes and protests. Previous instances include mass protests during the Nigerian fuel and petroleum subsidy reform in 2012, the “gilets jaunes” protests in France in late 2018 (after an increase of carbon taxes on fuels), in Ecuador in late 2019 (following proposals by the government to cut fossil fuel subsidies). These concerns have also led to an increased research in the public perception and social acceptance of carbon pricing (Fairbrother, 2022; Jagers et al., 2021; Maestre-Andrés et al., 2019; Mildenberger et al., 2022).

Carbon pricing can have progressive or regressive impacts

4 MRV: Measuring, reporting and verification

on the consumers. That is, at a set carbon price or tax a progressive impact implies that a higher share of expenditure is allocated to buy the same basket of goods and service for higher expenditure categories, than lower, while a regressive impact would mean a lower share of expenditure is spent on the same basket of goods and service by households from higher expenditure categories than for those from lower expenditure categories. Evidence has found a tendency of regressive impacts for developed countries, while the impacts are proportional or progressive for developing countries although with some inconsistency in the evidence (Verde & Tol, 2009; Q. Wang et al., 2016). A key factor that determines this impact is the difference in energy use patterns across countries. In lower income countries, households spend a larger part of their income on formal energy goods and services that progressively increases the overall expenditure with the added carbon price. A low initial share of expenditure spending on energy is primarily on account of the poor having limited access to energy, particularly electricity. In higher income countries, this share of expenditure on energy products is low.

When assessing the impact of emissions pricing in developing countries – which can vary depending on the level of household income – the consequences for income and social inequality are at the center of concerns. The effect of carbon pricing on poverty and inequality has been systematically reviewed through approaches of consumption, employment/income, health, and revenue recycling modes (Shang, 2021). Table 4 comprehensively summarized literature on the different effects through channels of consumption, income/employment, revenue recycling and health. The effect of imposing carbon pricing on consumption takes place in the form of passing on the added price to consumer prices (which could be less, equal to or more than the carbon price); the responses of firms and industries by switching to energy efficient processes and adopting low-carbon technologies; effects of international trade making imported goods and services priced similar or to cheaper than domestic items (in the absence of global carbon pricing); and demand responses from consumers with various behavioural changes across income groups. The income effect of carbon pricing is observed with negative impacts on jobs in the fossil fuel sector, particularly coal which for many countries provides a large share of local employment. On the other hand, if carbon pricing increases low-carbon investments such as in renewables, this could result in more green jobs in the market.

Table 4 Review of distributional impacts through different channels

Main Channel	Sub-channel	Findings and Issues	References
Consumption	Pass-throughs	The literature finds large variations in the estimates of pass-throughs across sectors. The overall impact on consumer prices is still unclear.	Ganapati et al., 2020; Kotchen, 2021
	Production responses by firms	Carbon pricing could lead to large reduction in production costs and consumer prices, as firms adopt existing low-carbon technologies, develop new low-carbon innovations, and switch fuels toward those with low-carbon content. Quantitative estimate of the overall impact, however, is still lacking.	Aghion et al., 2016; Calel & Dechezleprêtre, 2016; Jaffe et al., 2002; Lilliestam et al., 2021; Sager, 2019
	Leakages, including through trade and incomplete coverage of carbon pricing schemes	Research quantifying this effect is still limited.	Sager, 2019
	Demand responses by consumers	Demand responses can help mitigate the impact of carbon pricing on households. However, to what extent such responses differ by income and other household characteristics is still unclear.	Dimitropoulos et al., 2018; Muller & Yan, 2018; West & Williams, 2004; Zhu et al., 2019

Main Channel	Sub-channel	Findings and Issues	References
Income/Employment	Destruction of brown jobs	The impact can be large for certain sectors, communities and even countries.	Fiscal Monitor, 2019; Morris, 2016
	Creation of green jobs	There is some evidence that carbon pricing can lead to a shift of employment from carbon intensive to non-carbon intensive sectors. The distributional implication of such a shift, however, is unclear.	Hille & Möbius, 2019; Yamazaki, 2017
	Income gain due to climate improvements	The poor likely can benefit more from climate improvements. However, further evidence is still needed.	Hsiang et al., 2019
	Structural changes in factor income and demand for skills	Results from general equilibrium models suggest that the inequality effect from structural changes in factor income could be large. Part of the results are driven by the assumption on government transfers, which are part of household income. In addition, the results may be sensitive to parameter value assumptions. Research on the impact of carbon pricing on demand for skills is still scarce.	Beck et al., 2015; Fullerton & Heutel, 2010; Goulder et al., 2019; Marin & Vona, 2019; Rausch et al., 2011
Health	Reduction in air pollution	The health co-benefits from reduction in air pollution is found to be substantial, and there is indicative evidence that the poor and the disadvantaged may benefit more. However, little empirical evidence is available from existing carbon pricing schemes.	Burke and Nishitateno, 2015; Hsiang et al., 2019; Parry et al., 2020
	Reduction in traffic-related injuries and fatalities	There is little research on how the effects differ by population groups.	Burke and Nishitateno, 2015
Revenue Recycling	Tax cuts	The distributional impact of a PIT cut depends on the design; the distributional impact of a CIT cut is still being debated.	Fuest et al., 2018; Nallareddy et al., 2018
	Boosting public investment in human capital and infrastructure	The distributional impacts would highly depend on the design of the policies. Programs to expand access to education and healthcare are likely to be pro-poor. There is still limited evidence on the distributional impact of infrastructure investment, including green investment.	(Coady and Dizioli, 2018; Furceri and Li, 2017
	Targeted or universal cash transfers	Both targeted and universal transfers can help mitigate the poverty and distributional impacts of carbon pricing. There are, however, trade-offs in terms of fiscal cost, coverage, and work incentives. The appropriate measure would be country specific, depending also on administrative capacity.	Coady and Le, 2020

Source: (D. Coady & Dizioli, 2018; Furceri & Li, 2017).

In the short term, the effects can be negative on consumption and employment with higher incidence of costs on price of goods and electricity prices, while positive on revenue recycled for income tax reduction or social/cash lump sum transfer, and health co-benefits in the form of decreased air pollution, accidents and lower mortality at fuel sites, and better overall productivity. Long term benefits can be witnessed only with the shift towards low-carbon technologies, with more green jobs in renewable energy sectors.

1.4.5.1.1 Regional studies on distributional effects

Distributional effects of carbon pricing

Studies on distributional effects of carbon pricing for LMICs have given mixed results. Progressive impacts of carbon pricing have been found for South Africa (van Heerden et al., 2006), Pakistan (Shah & Larsen, 1992), China (Brenner et al., 2007), India (Datta, 2010), Indonesia (Yusuf et al., 2008), Vietnam (Nurdianto & Resosudarmo, 2016), and Mexico (Renner, 2018). On the other hand, regressive or mixed distributions were found for South Africa (Devarajan et al., 2011), Indonesia, Malaysia, and the Philippines (Nurdianto & Resosudarmo, 2016), and Brazil (da Silva Freitas et al., 2016). An assessment of carbon price incidence on different income groups in 87 LMICs found that on average a carbon price of USD 30/tCO2 displayed a progressive effect on countries with a per capita income of below USD 15000 per annum (Dorband et al., 2019).

A key result that emerged from multiple studies of distributional effects of carbon pricing was that the effects are highly country specific (Price, 2020; Steckel et al., 2021). The impact depends not only on the consumption patterns of energy (rather than food, goods or services) (Dorband et al., 2019), but also on the level of carbon intensity of the energy systems in the countries (the emission profile) as well as their level of development. For instance, for countries with low-carbon emissions, a carbon price can avoid build-up of emission-intensive capital stocks, but it is important to note a plausible negative impact on development goals such as disrupting clean cooking transitions (as higher fuel costs will make biomass and firewood cheaper fuel options).

The analysis of distribution incidence of carbon pricing (a carbon price of USD 40/tCO2) for nine LMICs – Argentina, Bolivia, Ethiopia, India, Indonesia, Nigeria, Peru, South Africa, and Vietnam, finds that the variation in the effects of carbon pricing was more within expenditure quintiles, than across quintiles. That is, independent of the income levels, certain households are more affected by the carbon price than the median household in a specific quintile (Steckel et al., 2021). In a study for Nigeria, the introduction of an economy wide USD 30/tCO2 carbon tax, accompanied by a revenue recycling scheme, reveals a similar incidence on consumption such as there is greater heterogeneity within income groups (horizontally) than across groups (vertically) (Dorband et al., 2022). The study confirms progressivity in distributional effects, such that relative to their disposable income, low-income households would experience smaller consumption effects from the higher consumer prices than richer households.

Distributional effects of energy subsidy reforms

Fossil fuel subsidy reforms (FFSR) are more commonplace in developing countries that have not piloted or planned any direct emission pricing mechanism so far. A review of distributional impacts of FFSR for different developing countries finds that welfare losses are significant for all households on average (Arze del Granado et al., 2012; D. Coady et al., 2015). Removal of subsidies across all energy carriers simultaneously would result in an equal distribution of welfare losses (ie. as a percentage of income loss) across all household income groups.

In the case of Indonesia, the welfare impact depended on the magnitude of household consumption behaviour, the nature of subsidies, tariff structure, and the subsidized energy carrier. Progressive distributional effects were found in the case of gasoline subsidy cuts, while for electricity, LPG, and kerosene the impact were marginally regressive (Renner, 2018). A similar effect was found in the case of China, where the distributional effect of transport fuel (oil products) subsidy removal had the strongest and the coal subsidy removal had the weakest progressive effect. The electricity subsidy removal had a regressive effect with a greater impact on low-income households. Further, indirect impacts of energy subsidy removal were greater than direct impacts, such that the rise in energy prices resulting from subsidy removal would increase the price of other commodities, causing a cost-driven inflation despite lags (Jiang et al., 2015). In Argentina, despite the shift from the flat subsidy mechanism (ie: energy subsidies were universally assigned without a targeted mechanism), which was primarily pro-poor, to the social tariff mechanism, which was targeted and pro-poor, the energy subsidy reform led to a relatively stable distributional incidence. That is, the subsidies continue to be progressive and pro-rich. This effect was attributed to selection criteria of the beneficiaries under the social tariff scheme (Giuliano et al., 2020) that comprised a large exclusion (of poor households) and inclusion (of richer households) errors. The fossil fuel subsidy reform in Ecuador was faced with public protests and an ultimate reversal of the reform. However, an analysis of distributional effect found the subsidy removal to be regressive for diesel and LPG, progressive for gasoline, and neutral for electricity. For a progressive and feasible reform, compensation through cash and in-kind transfers were identified as possible solutions (Schaffitzel et al., 2020).

A case study of energy subsidy reform in Indonesia, Iran, Dominican Republic and Ecuador, where subsidies were regressive and often favoured the rich, highlighted that the success of any energy subsidy reform hinged on a well-structured revenue recycling program – in terms of targeted cash or lump-sum transfers programs, and in some cases creating an enabling environment by informing the public of the reforms well in advance (Moayed et al., 2021).

Box: A systematic review of revenue recycling schemes and the public support for carbon pricing policies

Removing fossil fuel subsidies and putting a price on carbon are seen as key market-based instruments to internalise negative externalities by correcting the price a consumer pays to engage in a polluting activity, and to encourage producers to move towards cleaner energy production methods (Fairbrother 2017; Maestre-Andres et al 2019; Dorband et al. 2022). As of 2020, around 40 countries had previously performed fossil fuel subsidy reforms to some extent; and as of 2022, 82 national and subnational governments implemented a carbon tax or emissions trading schemes (Kuehl et al. 2021; World Bank, 2022). Since the costs of increasing fossil fuels are highly visible to the public, it is no surprise that some recent attempts by governments to implement such policies have been met with strong public opposition, e.g. the 'yellow vests' protests in France (2018), as well as unrest in Ecuador (2019), Nigeria (2020), and India (2021). Thus, to increase the likelihood of successfully implementing a carbon pricing policy, understanding how to garner public support is a precondition. Further, focusing on the optimal use of revenue generated from carbon pricing policies, by way of revenue recycling schemes, can influence the support for policies.

We conduct a systematic review to identify, document, and evaluate survey-based evidence that examines public attitudes for different revenue recycling mechanisms and the level of support for carbon pricing policies.

Table 5 Unique revenue recycling scheme by category

Sr. No.	Revenue Recycling Category	Revenue Recycling Type
1	Direct Transfers	Lump sum transfers to all citizens
		Direct transfers only to low-income households
		Redistribution towards affected households, particularly low-income households, elderly, and large families
		Support citizens with higher energy cost
2	Combination direct transfer and green spending	Half of the revenues as transfers to all households and half to support the development of climate projects
		Half of the revenues as transfers to low-income households and half to support the development of climate projects
		Half of the revenues transferred to all and half for energy efficient transportation
3	Green Spending	Environmental protection
		Environmental measures
		Environmental measures such as subsidizing investment in clean infrastructure and green innovation for tackling air pollution

		Developing climate projects (e.g. investing in public transport, planting trees, subsidies for renewable energy).
		Subsidies for all households for low carbon technologies
		Subsidies for low-income households for low carbon technologies
		Mitigating environmental impacts of climate change
		Mitigation projects such as mass transit and renewable energy that create local co-benefits
		Policies targeting energy efficiency
		Investment in green energy infrastructure
		Investment in climate-friendly transport infrastructure
		Financing renewable energy projects
		Research and development of clean energy technologies
		Research and development of renewable energy technology
4	Tax Reductions	Income tax reduction for all
		Tax reduction for low-income households
		Tax reduction linked to the amount an individual pays into the carbon tax
		Tax reduction linked to the amount an individual pays into the carbon tax
		Equal tax rebate for all
		Tax rebates only to those paying the CO2 tax
		Goods and services tax reductions
		Other tax reductions
5	General Budget	Increasing fiscal revenue
		Reducing budget deficit
		Federal government's general fund to be appropriated, just like the income tax.
6	Others	Using revenue to target behaviour change
		Reducing distributional effects of the tax

The review reveals that 41 out of 46 RR schemes showed an increase in public support for carbon pricing policies. That is, when revenue recycling is included as a package within carbon pricing policies, it increased the support for climate policy by the general public. Further, RR schemes from the categories of green spending and tax reductions were elicited more frequently than from the other four categories in the studies analysed, representing 70 percent of all schemes presented to (surveyed) respondents.

A stark result of the review was the concentration of studies amongst developed countries. The review covered 11 countries including Australia, Canada, Germany, Italy, Norway, Spain, Sweden, Switzerland, UK, USA, and Turkey as the country from a developing country perspective. Carbon pricing policies have mainly been implemented in developed countries. While a few countries in the global south are considering introducing similar pricing/taxation policies, the dialogues around what to do with the revenue from the collected taxes and prices is not prevalent on a national or sub- national level. At the same time, while studies have examined the willingness to pay for carbon tax (in the case of India - Gupta, 2016) and economic and distribution effects of carbon tax when including revenue recycling options (for Peru - Malerba et al., 2021, and China, Cote D'Ivoire and Ethiopia - Timilsina, 2022) they do not look at the (public) support for these policies in the presence of a revenue recycling scheme which is a key evaluation criteria for our review. As such, these have not been included in this study.

1.5 Methods and approaches to policy assessment

1.5.1 Introduction

Assessing policy pathways for energy transitions provides the effectiveness of measures and instruments that are developed for achieving national level climate and energy targets. The use of models allows us to test for policy interventions and changes to existing policies that are introduced in the economy – such as the carbon tax in South Africa – and see what the ramifications of this change are to corresponding social, economic, political, and environmental parameters.

A range of methodologies and models can be used to assess the policy implications ex-ante, or before the implementation of the policies, as well as ex-post analysis. Ex-ante modelling works with scenarios with projections of different policy options and mixes and provide impacts of proposed policies on different indicators. Through cost-benefit and multi-criteria analysis, ex-ante methods can allow for policy prioritization. Ex-post on the other hand, provides an understanding of policies and their relations with other variables in the system and allows for performance comparisons. Insights from ex-post analysis can help refine targets and objectives for future planning.

As energy supply becomes one of the central political challenges globally, the rise in the number of energy policy studies has also supported the development of energy models to assist policymakers and leaders in handling the complexities of the energy-economy interactions and implications. The wake of the oil crisis in the seventies made industry and policymakers realize the importance of long-term strategic energy planning (Helm, 2002) and scenario planning that would facilitate possible futures with alternate fuel compositions, growth rates and demand profiles. Over the years, the scope of the energy models used have evolved to account for the dynamic demand-side factors that were previously treated as exogenous to the models, and the development of sectors and fuels inclusive to energy and economic systems. The models range from engineering models of different energy conversion technologies (eg. refineries), sectoral models involving the demand and supply of single fuels, energy system models that detail out the entire energy system, to models that describe the energy system as an integral part of the overall economy (Rath-Nagel & Voss, 1981).

This section reviews the impact assessment or analysis methods to provide a knowledge base of existing approaches and promote further development of analytical methods that align with implications thinking.

Top-down modelling approaches

On the economy level, several quantitative tools are used to assess energy policy options. Most commonly, Energy System Models are used for energy policy analysis or to carry out medium to long term energy planning. These models help assess the interactions between technical and economic characteristics of different energy technologies, and the subsequent implications of these technologies on national climate goals such as energy security, energy access and affordability, and the environment. Economy-wide models have been useful in assessing various scenarios that look at the impact of policies and shocks on economic parameters such as employment, national budgets, trade implications, and consumption patterns. Commonly, policies such as the introduction of fuel taxes and carbon taxes and emission gap regulations have been assessed through economy-wide models. These models include partial equilibrium models (which focus on a part of the economy – agent, market or sector), general equilibrium (GE) models (that examine how producers and consumers in the economy interact, such as CGE), macroeconomic models (similar to GE models but with aggregation), static and dynamic models (varying in the time dimension), and a new modelling approach such as agent-based modelling (Davies & van Seventer, 2019) To estimate on a disaggregated scale of household and individual impact of macroeconomic policy choices and shocks, Social Economic Microsimulations offer insights on policies related to taxes and subsidies, direct transfers, increased access to modern energy, and their impact on poverty eradication, levels of inequality, food security and energy access indicators.

Going deeper into the criteria for model assessment, in reviewing methodologies and models that support country-led efforts in evaluating green economy policies UNEP (2014) identifies key data frameworks and modeling approaches. The review is based on how adequately the methods and models represent and include a strong set of criteria that are crucial in policy formulation for a green economy transition:

Inclusion of economic aspects such as manufactured capital and competitiveness, social aspects such as social equity and human well-being and environmental dimensions such as ecological scarcity and environmental risks were criteria considered for model assessment. Other criteria included climate change impacts and the corresponding mitigation and adaptation measures, and the analysis of investment and policy issues that bring in green economy considerations.

The evaluation of how the methods and models are developed was done based on their applicability to a country context (reflecting local conditions), ease of customization, transparency in accessing and interpreting results, level of data intensity, sectoral coverage, and multi-stakeholder involvement.

The use and support of models in policymaking process was assessed on time-horizons (short-, medium-, long-term impacts) captured by the models, their maintenance and use efforts involved, their complementarity with other methods and models, what kind of audience they target, and what stages of policymaking the models support.

Table 6 provides a comparative assessment of the methods and models that have been used to assess the transitions to green economy based on the abovementioned criteria. Additionally, specific models have been found to be used for sectoral analysis across countries. For instance, the I-O framework is used by most countries for the analysis of green jobs, system engineering models are useful for energy and water sector planning, InVEST models for natural capital assessment, CGE modelling for budgetary purposes, and Threshold 21 for long-term planning.

Table 6 Review of models for green economy analysis; relevance to the green economy definition and assessment

		Representation of key pillars (and capitals) of sustainable development										Analysis of climate change			GE intervention analysis	
		Economic dimension				Social Dimension			Environmental Dimension							
Model	Scope of Analysis	Economic capital	Sustainable Consumpt. and production	Competitiveness	Capital misallocation	Human capital	Human well-being	Social equity	Natural capital	Ecological scarcities	Environmental risks	CC impacts	CC mitigation	CC adaptation	Investment analysis	Policy Analysis
Input-Output (I-O)	Macro, with high level of sectoral disaggregation, for monetary and physical flows	✓	✓	✓		✓									✓	
Energy and other system engineering models	Sectoral analysis, with high level of detail	✓	✓										✓	✓	✓	✓
Geographical information system (GIS) and InVEST	Highly geographically disaggregated, with analysis ranging from local to national						*		✓	✓	✓	✓	✓	✓		✓
Computable general equilibrium (CGE)	Macro, with sectoral disaggregation	✓		✓		*		✓							✓	✓
CGE and system engineering (energy and natural resources)	Macro, with sectoral detail	✓	✓	✓	✓	*	*	✓	*	✓		*	✓	✓	✓	✓
System dynamics (SD) models (e.g., Threshold21)	Macro, with the possibility to add sectoral detail with social, economic and environmental variables	✓	✓	*	✓	✓	*	✓	*	✓	*	*	✓	✓	✓	✓

*The * indicates the possibility to include basic variables and to address the criteria more extensively with information generated by other models.*

Source: UNEP, 2014

Assessed sectors/policies	Methods and Models	Potential impact -outcome areas	Countries in assessment	Reference/Source
Decarbonisation Policies				
Asia				
RE Generation	Statistical and Econometric modelling (ex-post)	Economic growth	South Asia - Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, and Sri Lanka	Anser et al., 2021
Impact on emission levels using Energy Modelling				
RE capacity in power capacity mix; Energy policies in building and industry	Long-range Energy Alternatives Planning (LEAP) system (ex-ante)	CO_2 emission levels	Greater Mekong Sub-region (GMS) - Cambodia, Laos, Thailand and Vietnam; Thailand	Pagnarith & Limmeechokchai, 2011; Chaichaloempreecha et al., 2019
Low-carbon society – EE and fuel switch in residential, industry and transport	Extended Snapshot Tool (ExSS) (ex-ante)	Socio-economic indicators and CO_2 emission levels	Thailand	Winyuchakrit et al., 2011
Emission trading and carbon capture and storage (CCS)	Computable General Equilibrium (CGE) Model (ex-ante)	CO_2 emission levels	Thailand	Thepkhun et al., 2013
RE generation and EE – industry and buildings	Least-cost power generation expansion plans (PGEPs) model and mix integration linear programing (MILP) model (ex-ante)	CO_2 emission levels and generation mix	Thailand	Promjiraprawat & Limmeechokchai, 2012
Africa				
Small-scale RE projects	Strategic Niche Management Framework (ex-post)	MDG 1 Eradication of Extreme Poverty, MDG 7 Environmental Sustainability	Madagaskar and Tanzania	Balkema et al., 2010
Solar energy projects	Case Study and Systematic combining (ex-post)	Environmental and Socio-economic indicators	Kenya	Göras & Mohajer, 2016
Rural Electrification	Descriptive statistics and Econometric modelling (ex-post)	Energy use, Education, Income and Expenditure	Rwanda	Bensch et al., 2010
	Sustainability Assessment Framework (ex-post)	Sustainability of projects – technical, social, economic, institutional, and environmental	Kenya, East and South Africa	Boliko & Ialnazov, 2019; Ilskog & Kjellström, 2008
	Statistical and Econometric modelling (ex-post)	Employment	South Africa	Dinkelman, 2011
Solar Thermal Energy	Descriptive statistics, content analysis, adapted causal loop diagrams (ex-post)	Poverty reduction and environmental protection and conservation of natural resources	Egypt, South Africa, Namibia, Mozambique,	Andreas et al., 2018
Impact on emission levels using Energy Modelling				

Decarbonisation policies – reduced coal use and increased RE mix	Global energy system model (GENeSYS-MOD) (ex-ante)	Employment	South Africa	Hanto et al., 2021
Electricity Tariff reforms	Qualitative, observational, experimental, CGE modelling (ex-post)	Consumption, Households, firms and industries, utilities, governments, and economies	Africa	Klug et al., 2022
Latin America				
Sustainable Urban Public Transport policies	Multi-criteria decision making: Analytic Hierarchy Process (AHP) (ex-post)	Traffic, environmental impact, social impact, and economic impact.	Ecuador	Aldas et al., 2018
Electricity generation	Life-cycle assessment (LCA) (ex-ante)	Environmental performance	Ecuador	Ramirez et al., 2020
Global South				
Sustainable Transport: Bus Rapid Transit (BRT)	Accessibility measurement and Distributional cost-benefit analysis (ex-post)	Vertical transport equity: income, social class, transportation ability and need	Global South	Venter et al., 2018

Source: Author's compilation

Reviews of the empirical or model-based evidence related to the impacts of energy transition and technologies have been narrowly focused on emphasizing studies that apply specific methods – quasi-experimental or experimental impact evaluation designs – to extract causal attributions, or study only single type of technology in a specific context (Bayer et al., 2020; Bos et al., 2018).

A review of modern and traditional energy use in LMICs identified quantitative approaches and methods used for the assessment of impact on households, public service, firms and business, and the environment (Jeuland et al., 2021). The review focuses on both the approach from energy technologies (such as grid electricity, traditional and improved fuels/stoves, solar, wind, and hydro) as well as the energy services (cooking, lighting, heating/cooling, transport, agriculture, and income generation) to examine the various methods of assessment. The methods are categorised as econometric/statistical analysis, cost-benefit analysis, life-cycle assessments, non-economic modelling simulations and financial analysis. Further, the majority of the empirical designs used in the reviewed papers were observational, while quasi-experimental, experimental, or natural experimental evaluation designs were uncommon in evidence.

Methods of impact evaluation have been categorised as observational and experimental (randomized control trials). While experimentally designed studies (with control and treatment groups) allow for testing causal hypothesis through random assignment, studies using observational data employ research techniques including difference-in-difference, matching, and instrument variables (Bernard, 2012; Ravallion, 2001). Similar methods were identified through a systematic review of impact assessment on household electricity access in developing countries on outcomes including energy expenditure, total income, savings, business, and education (Bayer et al., 2020). The majority of the studies assessing the impact of electricity access on welfare use observational data, relying thus on descriptive or econometric methods for evaluation. A similar set of methods – observational, experimental, qualitative and modelling - were identified in a systematic review of the impact of electricity tariff reforms in South Africa (Klug et al., 2022). The review assessed the impact of tariff reforms in terms of payment, structure, and rate on outcomes such as consumption, conservation behaviour, private sector investment, household welfare, poverty, employment, cost recovery, technology adoption, customer satisfaction, and non-technical losses[5].

1.6 Research gaps, missing knowledge, and data gaps

The relevance of regional and sectoral contexts in transitioning to a low-carbon economy suggests new research and policy directions. At the same time, the landscape of low carbon policy instruments is limited in its scope on account of several identified research and knowledge gaps. This section discusses the areas of research missing in literature that warrant increased consideration.

Public (social) and political acceptance studies: There is a need to undertake more studies that create a link between the social or public support and political acceptance of climate policies in the global south. These can be achieved through assessment of voter behaviour, analysing what matters and holds priority for policymakers, etc. Given the small number of global south countries with implemented emission pricing mechanisms, any analysis on the (distributional) impacts of carbon pricing were ex-ante in nature (Koh et al., 2021). Similarly, any ex-post analysis of revenue recycling options as viable solutions for public acceptance, that also rely on survey data, are concentrated on developed country experiences so far. While some studies have shown the implications of carbon pricing schemes on voting behavior in developed countries (an indicator for political acceptance of specific carbon pricing tools), those studies are largely lacking in the context of the global south. This limits the understanding of whether and how inclusion of revenue recycling in the policy design would affect its social and political acceptability in a developing country context.

Political Actors and vested interests: Taking the political economy into account can alter first best considerations for (climate) policy making. Yet, in countries of the global south only very limited evidence is available that contributes to the understanding of the political economy of energy transitions in general and climate policies in particular. Conceptually, limited knowledge is available on how carbon pricing (and other climate policies) would work given the political realities of the global south, including high levels of the informal sector, a low tax rate, or high shares of informal fuel use. Empirically, understanding existing actor networks and vested interests, which is key for successful policy design, is largely lacking in country-specific contexts. This lack of knowledge also prevents a profound discussion on how to deal with potential losers of an energy transition (including workers, incumbents, shareholders) and how to effectively compensate those in order to gain public and political acceptance (see also previous point).

Gendered impacts: Policy impacts across sectors and regions have predominantly been assessed from an economic, social, welfare, and environmental perspective. The aspect of gender in terms of equality, equity or empowerment gets engulfed within socio-demographic characteristics and does not receive an independent assessment. Gender roles and their interaction with energy and development policies are commonly studied among urban poor and rural population studies, and in the context of energy poverty and access to improved cooking and lighting energies. Analysis in other sectors – industrial, renewable, transport, and urban demographics is limited. Moreover, the differentiated impact of climate and energy policies on men and women is also heavily understudied. In cases where gender was examined, the factor is narrowly defined; for instance, decision-making power in the household, or access to finance. Exploring the multi-dimensionality of gender will allow a deeper assessment of gender implications.

Comparative assessments across regions: Studies on impact assessment of similar policies differ in research design, methodology and data characteristics used for the analysis. On a broader policy level, energy-economic models permitted comparability, but this was not possible for specific policy instruments targeted in sectors and implemented on a sub-national level. This limits the lessons and insights that can be gained from comparing processes, policies, or outcomes. It is understood that the heterogeneity in infrastructure, institutional capacity, and growth levels across countries and regions determine the characteristics of the policy portfolio suited for implementation in those regions. But the comparison of policies across similar impact categories can highlight the best practices, common challenges, and lessons on what worked where, while also providing the scope to explore replicability of policy design and processes, or business models.

Data availability at regional levels: Publicly available data on various policies and their specific details is limited, particularly for some West African countries, parts of East Asia, and many countries in Latin America. Detailed survey

5 Refers to losses due to electrical energy that is consumed but not invoiced (Savian et al., 2021)

data for empirical analysis can be difficult to obtain and may not always be open access. This reduces the scope of policy assessments to scenario- and assumptions-based modelling practices, with less practical, on-the-ground relevance.

1.7 Opportunities for high-impact research to accelerate low-carbon transition

The review of actors, low-carbon policies, their impacts, and the methods used for assessing those impacts have provided several entry points for immediate and relevant high-impact research, particularly in the global south.

Evidence based on ex-post policy assessments: Expanding the evidence base on ex-post policy assessments, particularly in underrepresented regions with limited policy coverage, is needed for better representation of existing energy-climate policies and their impacts. Learning from other policy experiences in other developing countries and past transitions in developed countries, on what kind of policy characteristics work and which do not, and under what conditions, can improve future policy design and planning processes. Mixed results in key outcomes such as income inequality, employment, gender (and its intersectionality with energy) and energy affordability merit the need for more ex-post policy assessments that also provide regional and developmental contexts to the outcomes (Lamb et al., 2020). Other areas of investigation include comparing impact of individual policies with policy mixes and using comparative case study methodologies to facilitate useful policy assessments.

Deeper investigation of political economy: The potential economic efficiency of a policy is irrelevant if the policy is politically unfeasible. It is the political and institutional actors that operate within the political context that ultimately decide which energy policies will be pursued by the country (Biber et al., 2017b). An understanding of how political feasibility alters over time in the context of sequenced choices and providing a comprehensive picture on the politics around resource governance is important. This can be enhanced with increased case study evidence on a sectoral level and an integrated perspective to analyse the politics of transition that involves investigating distributional aspects, institutional capacity for compensating, and the role of incumbents (for instance using the Actor-Objective-Context Framework, (Jakob et al., 2020)).

Comparing scientific results and policy outcomes: Ex-ante assessments create opportunities for policy deliberation and learning based on the new assessed knowledge, while ex-post assessments provide insights on how policies performed on the ground. For comprehensive policy learning, a comparison of ex-post evidence from various policies and scheme implementations with existing modelling results in different policy instruments such as integrated assessment modelling etc, and is a plausible direction for future research. Comparing insights from policy reports and those with academic literature will help explain any differences in projections/simulations of policy impact with their actual performances. It will also allow identification of what policies or policy packages work and how, that contributes to future design and planning. Additionally, exploring an increased number of pilot or experimental roll-outs of policies, enhancing the ability to evaluate them, and using and adapting that information by the policymakers towards full implementation.

Database Development: Data availability is crucial for the reproducibility of knowledge and ensuring transparency in policy choices made in energy transition. The current insufficient and disorganized state of the data available for extensive and comparative analysis provides opportunities for future research in multiple dimensions:

- Harmonizing disaggregated datasets at national, sub-national, and policy or project levels can allow for development of data frameworks and standardization of survey structures/templates for data gathering. This would ensure data consistency for the composition of reliable and useful indicators to compare regional dynamics.
- The planning of energy generation and distribution is done based on what the energy is used for. Access to disaggregated, high-resolution electricity consumption data associated with various energy services, will deepen consumption analysis to adequately represent consumer-based energy practices and behaviours. The data will support knowledge building and validation, but also provide important inputs to decide on demand-side management strategies, tariff planning, future electricity mixes, and decarbonisation pathways.
- Climate policies that levy a cost on consumers are more often unpopular. Carbon pricing is the poster child for such opposed policies. Public surveys on social acceptability of climate policies, such as emission pricing, will better explain the nuances of opinion involved in various social strata. Further, these surveys can also explore public preferences for different types of environmental or economic projects for investing collected revenue from carbon taxes to allow for better policy design, planning, and timing of implementation.

1.8 Conclusion

Through an exploratory analysis of the low-carbon policy space, this paper brings together the evidence base on key pillars of policymaking and assessment, that includes actors and institutions, policy mechnaisms and frameworks, and methods of assessment. As a result, we are able to identify how far we've progressed in energy transitions policy research, what the shortcomings and existing gaps are, and what the future path of research looks like.

A key finding has been the importance of actors (including experts, social groups, policymaking citizens etc.) and their role in the path to a low-carbon society. An analysis of the actors of decarbonisation highlighted the urgency to deconstruct the political economy of energy transitions; that in turn varies significantly across regions. Identifying the various actors across sectors, their underlying interests in operating, and their role in promoting or imepeding decarbonisation policies, can be necessary to strategically tackle implementation challenges when it comes to their political feasilibity. The pace of decarbonisation will be impacted by the changes in the socio-technical systems (identified by the multi-level perspective) that are underpinned by political and social dynamics. A strand of this research extends to analysing the perspective of public opinion or special interest groups in supporting climate policies, such as carbon pricing. Any rise in consumer prices as a result of carbon taxes or fossil fuel subsidy removal have faced severe opposition on account of the perceived fairness of what the distributional impacts are and increasing inequality. Most of the research on public attitudes to mitigation policies, specifically carbon taxes, have been done in high-income democracies. Understanding the extent of social and political acceptance of introducing emission-based pricing in low and middle-income countries is only sparse. Identifying the cross-national entry points to making climate policies politically and socially acceptable are a high priority in the research agenda.

An enabling policy environment benefits from the knowledge of ex-post policy assessments. Insights and lessons from how past policies have performed under different contexts can provide information on the unintended effects and on adjusting policy accordingly to achieve better outcomes in the future. These could be assessments of individual policies or a mix of climate and energy policies that is often bundled in implementation. More research in the direction of better understanding outcomes such as social equity, income inequality, employment and energy affordability could help improve policy environments. Additionally, comparing ex-ante and ex-post assessments of a similar portfolio of policies allows for consistencies in the policymaking process. Needless to state, much of the ex-post policy assessment evidence – case studies and population – remains focused on the Western, Educated, Industrialized, Rich, and Democratic (WEIRD) countries, necessitating the need to shift or add focus to the Global South nations.

Finally, the existence of enabling environments for low carbon policies also hinges on the avaialability of consistent, detailed and comparative data. Harmonising databases, coordinating design of surveys, and making available data at the most disaggregated level can enhance the quality and structure of data needed for future analysis.

It is well understood that ambitious and diverse low carbon targets cannot be achieved without an enabling policy environment. There are several elements that make up the contours of a favourable policy environment. An integrated approach is important to effectively address the effects of climate change - which may be felt locally - with policy profiles and designs that are context specific.

References

Acheampong, A. O., Dzator, J., & Savage, D. A. (2021). Renewable energy, CO2 emissions and economic growth in sub-Saharan Africa: Does institutional quality matter? Journal of Policy Modeling, 43(5), 1070–1093. https://doi.org/10.1016/j.jpolmod.2021.03.011

AfDB. (2022). African Economic Outlook 2022. Abidjan, Côte d'Ivoire: African Development Bank

Aghion, P., Dechezleprêtre, A., Hémous, D., Martin, R., & Van Reenen, J. (2016). Carbon Taxes, Path Dependency, and Directed Technical Change: Evidence from the Auto Industry. Journal of Political Economy, 124(1), 1–51. https://doi.org/10.1086/684581

Agutu, C., Egli, F., Williams, N. J., Schmidt, T. S., & Steffen, B. (2022). Accounting for finance in electrification models for sub-Saharan Africa. Nature Energy, 1–11.

Ahmed, J., Almeida, E., Aminetzah, D., Denis, N., Henderson, K., Katz, J., Kitchel, H., & Mannion, P. (2020). Agriculture and climate change: Reducing emissions through improved farming practices (p. 52). Mckinsey & Company.

Aidt, T. S. (2010). Green taxes: Refunding rules and lobbying. Journal of Environmental Economics and Management, 60(1), 31–43. https://doi.org/10.1016/j.jeem.2010.04.001

Aklin, M., & Urpelainen, J. (2018). Renewables: The Politics of a Global Energy Transition. MIT Press.

Aldas, D., Reyes, J., Morales, L., Pazmiño, P., Núñez, J., & Toaza, B. (2018). Impacts Analysis towards a Sustainable Urban Public Transport System: Proceedings of the 7th International Conference on Operations Research and Enterprise Systems, 38–46. https://doi.org/10.5220/0006537700380046

Aldy, J. E., & Stavins, R. N. (2012). The Promise and Problems of Pricing Carbon: Theory and Experience. The Journal of Environment & Development, 21(2), 152–180. https://doi.org/10.1177/1070496512442508

Alfarargi, S. (2021). Climate action and the right to development: A participatory approach (A Policy Brief from the United Nations Special Rapporteur on the Right to Development, p. 20) [Policy Brief]. United Nations Human Rights Special Procedures. https://www.ohchr.org/sites/default/files/2021-12/Policy_Brief_RTD_Climate_Action.pdf

Andersen, M. S. (2019). The politics of carbon taxation: How varieties of policy style matter. Environmental Politics, 28(6), 1084–1104. https://doi.org/10.1080/09644016.2019.1625134

Andreas, K., Demel, K., Buchinger, J., & Sponring, M. (2018). Impact Assessment Solar Thermal Energy (Impact Study Report Contract no: 2559-02/2013; p. 62). Austrian Development Agency.

Anser, M. K., Shabbir, M. S., Tabash, M. I., Shah, S. H. A., Ahmad, M., Peng, M. Y.-P., & Lopez, L. B. (2021). Do renewable energy sources improve clean environmental-economic growth? Empirical investigation from South Asian economies. Energy Exploration & Exploitation, 39(5), 1491–1514. https://doi.org/10.1177/01445987211002278

Arze del Granado, F. J., Coady, D., & Gillingham, R. (2012). The Unequal Benefits of Fuel Subsidies: A Review of Evidence for Developing Countries. World Development, 40(11), 2234–2248. https://doi.org/10.1016/j.worlddev.2012.05.005

Asian Development Bank. (2021). Greening Markets: Market-Based Approaches for Environmental Management in Asia (0 ed.). Asian Development Bank. https://doi.org/10.22617/TCS210239-2

Balkema, A. J., van Dijk, S., Heijnen, S., Verbong, G. P. J., Romijn, H. A., & Huntjens, E. (2010).

An impact assessment methodology for small scale renewable energy projects in developing countries funded under Dutch policies defined to contribute to the Millennium Development Goals. 11.

Ball, J. (2018). Why Carbon Pricing Isn't Working: Good Idea in Theory, Failing in Practice. Foreign Affairs, 97(4), 134–146.

Balmaceda, M. M. (2018). Differentiation, materiality, and power: Towards a political economy of fossil fuels. Energy Research & Social Science, 39, 130–140. https://doi.org/10.1016/j.erss.2017.10.052

Bayer, P., Kennedy, R., Yang, J., & Urpelainen, J. (2020). The need for impact evaluation in electricity access research. Energy Policy, 137, 111099. https://doi.org/10.1016/j.enpol.2019.111099

Beck, M., Rivers, N., Wigle, R., & Yonezawa, H. (2015). Carbon Tax and Revenue Recycling: Impacts on Households in British Columbia (SSRN Scholarly Paper No. 2492766). https://doi.org/10.2139/ssrn.2492766

Bensch, G., Kluve, J., & Peters, J. (2010). Rural Electrification in Rwanda – An Impact Assessment Using Matching Techniques (SSRN Scholarly Paper No. 1735399). https://doi.org/10.2139/ssrn.1735399

Bernard, T. (2012). Impact Analysis of Rural Electrification Projects in Sub-Saharan Africa. World Bank Research Observer, 27(1), 33–51. https://doi.org/10.1093/wbro/lkq008

Best, R., & Zhang, Q. Y. (2020). What explains carbon-pricing variation between countries? Energy Policy, 143, 111541. https://doi.org/10.1016/j.enpol.2020.111541

Bhatia, M., & Angelou, N. (2015). Beyond Connections: Energy Access Redefined [Working Paper]. World Bank. https://openknowledge.worldbank.org/handle/10986/24368

Bhuiyan, M. A., Zhang, Q., Khare, V., Mikhaylov, A., Pinter, G., & Huang, X. (2022). Renewable Energy Consumption and Economic Growth Nexus—A Systematic Literature Review. Frontiers in Environmental Science, 10. https://www.frontiersin.org/article/10.3389/fenvs.2022.878394

Biber, E., Kelsey, N., & Meckling, J. (2017a). The Political Economy of Decarbonization: A Research Agenda. 605-None.

Biber, E., Kelsey, N., & Meckling, J. (2017b). The Political Economy of Decarbonization: A Research Agenda. BROOKLYN LAW REVIEW, 82(2), 40.

Boliko, C. M., & Ialnazov, D. S. (2019). An assessment of rural electrification projects in Kenya using a sustainability framework. Energy Policy, 133, 110928. https://doi.org/10.1016/j.enpol.2019.110928

Bos, K., Chaplin, D., & Mamun, A. (2018). Benefits and challenges of expanding grid electricity in Africa: A review of rigorous evidence on household impacts in developing countries. Energy for Sustainable Development, 44, 64–77. https://doi.org/10.1016/j.esd.2018.02.007

Brenner, M., Riddle, M., & Boyce, J. K. (2007). A Chinese sky trust?: Distributional impacts of carbon charges and revenue recycling in China. Energy Policy, 35(3), 1771–1784. https://doi.org/10.1016/j.enpol.2006.04.016

Brunner, S., Flachsland, C., & Marschinski, R. (2012). Credible commitment in carbon policy. Climate Policy, 12(2), 255–271. https://doi.org/10.1080/14693062.2011.582327

Burke, M. J., & Stephens, J. C. (2018). Political power and renewable energy futures: A critical review. Energy Research & Social Science, 35, 78–93. https://doi.org/10.1016/j.erss.2017.10.018

Burke, P. J., & Nishitateno, S. (2015). Gasoline Prices and Road Fatalities: International Evidence. Economic Inquiry, 53(3), 1437–1450. https://doi.org/10.1111/ecin.12171

Caldecott, B. (2017). Introduction to special issue: Stranded assets and the environment. Journal of

Sustainable Finance & Investment, 7(1), 1–13. http://dx.doi.org/10.1080/20430795.2016.1266748

Calel, R., & Dechezleprêtre, A. (2016). Environmental Policy and Directed Technological Change: Evidence from the European Carbon Market. The Review of Economics and Statistics, 98(1), 173–191. https://doi.org/10.1162/REST_a_00470

Carattini, S., Kallbekken, S., & Orlov, A. (2019). How to win public support for a global carbon tax. Nature, 565(7739), 289–291. https://doi.org/10.1038/d41586-019-00124-x

Chaichaloempreecha, A., Chunark, P., & Limmeechokchai, B. (2019). Assessment of Thailand's Energy Policy on CO2 Emissions: Implication of National Energy Plans to Achieve NDC Target. 14.

Coady, D., & Dizioli, A. (2018). Income inequality and education revisited: Persistence, endogeneity and heterogeneity. Applied Economics, 50(25), 2747–2761. https://doi.org/10.1080/00036846.2017.1406659

Coady, D., Flamini, V., & Sears, L. (2015). The Unequal Benefits of Fuel Subsidies Revisited: Evidence for Developing Countries [IMF Working Paper]. https://www.imf.org/en/Publications/WP/Issues/2016/12/31/The-Unequal-Benefits-of-Fuel-Subsidies-Revisited-Evidence-for-Developing-Countries-43422

Coady, D., & Le, N.-P. (2020). Designing Fiscal Redistribution: The Role of Universal and Targeted Transfers (Working Paper No. 2020/105). International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2020/06/26/Designing-Fiscal-Redistribution-The-Role-of-Universal-and-Targeted-Transfers-49502

Coady, P. D., Gillingham, R., Ossowski, R., Piotrowski, J., Tareq, S., & Tyson, J. (2010). Petroleum Product Subsidies: Costly, Inequitable, and Rising (p. 20). International Monetary Fund.

Coase, R. H. (1960). The Problem of Social Cost. The Journal of Law & Economics, 3, 1–44.

Cremer, H., Gahvari, F., & Ladoux, N. (1998). Externalities and optimal taxation. Journal of Public Economics, 70(3), 343–364. https://doi.org/10.1016/S0047-2727(98)00039-5

Criqui, P., Jaccard, M., & Sterner, T. (2019). Carbon Taxation: A Tale of Three Countries. Sustainability, 11(22), Article 22. https://doi.org/10.3390/su11226280

Crocker, Thomas. D. (1966). The Structuring of Atmospheric Pollution Control Systems. The Economics of Air Pollution, 61, 81–84.

da Silva Freitas, L. F., de Santana Ribeiro, L. C., de Souza, K. B., & Hewings, G. J. D. (2016). The distributional effects of emissions taxation in Brazil and their implications for climate policy. Energy Economics, 59, 37–44. https://doi.org/10.1016/j.eneco.2016.07.021

Dales, J. H. (1968). Pollution, property & prices. University of Toronto P.

Datta, A. (2010). The incidence of fuel taxation in India. Energy Economics, 32, S26–S33. https://doi.org/10.1016/j.eneco.2009.10.007

Davies, R., & van Seventer, D. (2019). Using economy-wide modelling for South African policy analysis: An introduction. SA-TIED Working Paper, 61, 25.

de Gouvello, C., Finon, D., & Guigon, P. (2020). Reconciling Carbon Pricing and Energy Policies in Developing Countries. World Bank, Washington, DC. https://doi.org/10.1596/33490

Deng, Z., Li, D., Pang, T., & Duan, M. (2018). Effectiveness of pilot carbon emissions trading systems in China. Climate Policy, 18(8), 992–1011. https://doi.org/10.1080/14693062.2018.1438245

Devarajan, S., Go, D. S., Robinson, S., & Thierfelder, K. (2011). Tax Policy to Reduce Carbon Emissions in a Distorted Economy: Illustrations from a South Africa CGE Model. The B.E. Journal of Economic Analysis & Policy, 11(1). https://doi.org/10.2202/1935-1682.2376

Diluiso, F., Walk, P., Manych, N., Cerutti, N., Chipiga, V., Workman, A., Ayas, C., Cui, R. Y., Cui, D., Song, K., Banisch, L. A., Moretti, N., Callaghan, M. W., Clarke, L., Creutzig, F., Hilaire, J., Jotzo, F., Kalkuhl, M., Lamb, W. F., … Minx, J. C. (2021). Coal transitions—part 1: A systematic map and review of case study learnings from regional, national, and local coal phase-out experiences. Environmental Research Letters, 16(11), 113003. https://doi.org/10.1088/1748-9326/ac1b58

Dimitropoulos, A., Oueslati, W., & Sintek, C. (2018). The rebound effect in road transport: A meta-analysis of empirical studies. Energy Economics, 75, 163–179. https://doi.org/10.1016/j.eneco.2018.07.021

Dinkelman, T. (2011). The Effects of Rural Electrification on Employment: New Evidence from South Africa. American Economic Review, 101(7), 3078–3108. https://doi.org/10.1257/aer.101.7.3078

Dorband, I. I., Jakob, M., Kalkuhl, M., & Steckel, J. C. (2019). Poverty and distributional effects of carbon pricing in low- and middle-income countries – A global comparative analysis. World Development, 115, 246–257. https://doi.org/10.1016/j.worlddev.2018.11.015

Dorband, I. I., Jakob, M., Steckel, J. C., & Ward, H. (2022). Double progressivity of infrastructure financing through carbon pricing—Insights from Nigeria. World Development Sustainability, 1, 100011. https://doi.org/10.1016/j.wds.2022.100011

Doytch, N., & Narayan, S. (2021). Does transitioning towards renewable energy accelerate economic growth? An analysis of sectoral growth for a dynamic panel of countries. Energy, 235, 121290. https://doi.org/10.1016/j.energy.2021.121290

Duggal, V. K. (2021). Carbon Pricing. Asian Development Bank. https://www.adb.org/sites/default/files/institutional-document/691951/ado2021bn-carbon-pricing-developing-asia.pdf

Dyarto, R., & Setyawan, D. (2021). Understanding the political challenges of introducing a carbon tax in Indonesia. International Journal of Environmental Science and Technology, 18(6), 1479–1488. https://doi.org/10.1007/s13762-020-02925-4

Edenhofer, O., Franks, M., & Kalkuhl, M. (2021). Pigou in the 21st Century: A tribute on the occasion of the 100th anniversary of the publication of The Economics of Welfare. International Tax and Public Finance, 28(5), 1090–1121. https://doi.org/10.1007/s10797-020-09653-y

Edenhofer, O., Kalkuhl, M., Requate, T., & Steckel, J. C. (2020). How assets get stranded: The impact of climate policy on capital and fossil fuel owners. Introduction to the JEEM special section on climate policy and political economy. Journal of Environmental Economics and Management, 100.

Fairbrother, M. (2022). Public opinion about climate policies: A review and call for more studies of what people want. PLOS Climate, 1(5), e0000030. https://doi.org/10.1371/journal.pclm.0000030

Fiscal Monitor. (2019, October). How to Mitigate Climate Change. International Monetary Fund. https://www.imf.org/en/Publications/FM/Issues/2019/09/12/fiscal-monitor-october-2019

Fredriksson, P. G., & Svensson, J. (2003). Political instability, corruption and policy formation: The case of environmental policy. Journal of Public Economics, 87(7), 1383–1405. https://doi.org/10.1016/S0047-2727(02)00036-1

Fritz, V., Levy, B., & Ort, R. (Eds.). (2014). Problem-Driven Political Economy Analysis: The World Bank's Experience. The World Bank. https://doi.org/10.1596/978-1-4648-0121-1

Fuest, C., Peichl, A., & Siegloch, S. (2018). Do Higher Corporate Taxes Reduce Wages? Micro Evidence from Germany. American Economic Review, 108(2), 393–418. https://doi.org/10.1257/aer.20130570

Fullerton, D., & Heutel, G. (2010). Analytical General Equilibrium Effects of Energy Policy on Output and Factor Prices (Working Paper No. 15788). National Bureau of Economic Research. https://doi.org/10.3386/w15788

Furceri, D., & Li, G. B. (2017). The Macroeconomic (and Distributional) Effects of Public Investment in Developing Economies. IMF. https://www.imf.org/en/Publications/WP/Issues/2017/10/20/The-Macroeconomic-and-Distributional-Effects-of-Public-Investment-in-Developing-Economies-45222

Ganapati, S., Shapiro, J. S., & Walker, R. (2020). Energy Cost Pass-Through in US Manufacturing: Estimates and Implications for Carbon Taxes. American Economic Journal: Applied Economics, 12(2), 303–342. https://doi.org/10.1257/app.20180474

Geels, F. W. (2014). Regime Resistance against Low-Carbon Transitions: Introducing Politics and Power into the Multi-Level Perspective. Theory, Culture & Society, 31(5), 21–40. https://doi.org/10.1177/0263276414531627

Geels, F. W., Sovacool, B. K., Schwanen, T., & Sorrell, S. (2017). Sociotechnical transitions for deep decarbonization. Science, 357(6357), 1242–1244. https://doi.org/10.1126/science.aao3760

Giuliano, F., Lugo, M. A., Masut, A., & Puig, J. (2020). Distributional effects of reducing energy subsidies: Evidence from recent policy reform in Argentina. Energy Economics, 92, 104980. https://doi.org/10.1016/j.eneco.2020.104980

Godinho, C. (2022). What do we know about the employment impacts of climate policies? A review of the ex post literature. WIREs Climate Change, n/a(n/a), 22. https://doi.org/10.1002/wcc.794

Göras, A., & Mohajer, C. (2016). Impact assessment of solar energy projects in rural areas: A case study in Kenya. Chalmers Univeristy of Technology. https://publications.lib.chalmers.se/records/fulltext/241704/241704.pdf

Goulder, L. H., Hafstead, M. A. C., Kim, G., & Long, X. (2019). Impacts of a carbon tax across US household income groups: What are the equity-efficiency trade-offs? Journal of Public Economics, 175, 44–64. https://doi.org/10.1016/j.jpubeco.2019.04.002

Hanto, J., Krawielicki, L., Krumm, A., Moskalenko, N., Löffler, K., Hauenstein, C., & Oei, P.-Y. (2021). Effects of decarbonization on the energy system and related employment effects in South Africa. Environmental Science & Policy, 124, 73–84. https://doi.org/10.1016/j.envsci.2021.06.001

Harrison, K. (2010). The Comparative Politics of Carbon Taxation. Annual Review of Law and Social Science, 6(1), 507–529. https://doi.org/10.1146/annurev.lawsocsci.093008.131545

Hayes, K., & Hafstead, M. (2020). Carbon Pricing 103: Effects across Sectors.

Resources for the Future: Carbon Pricing, 5.

Helm, D. (2002). Energy policy: Security of supply, sustainability and competition. Energy Policy, 30(3), 173–184. https://doi.org/10.1016/S0301-4215(01)00141-0

Hille, E., & Möbius, P. (2019). Do energy prices affect employment? Decomposed international evidence. Journal of Environmental Economics and Management, 96, 1–21. https://doi.org/10.1016/j.jeem.2019.04.002

Hsiang, S., Oliva, P., & Walker, R. (2019). The Distribution of Environmental Damages. Review of Environmental Economics and Policy, 13(1), 83–103. https://doi.org/doi: 10.1093/reep/rey024

Hughes, L., & Urpelainen, J. (2015). Interests, institutions, and climate policy: Explaining the choice of policy instruments for the energy sector. Environmental Science & Policy, 54, 52–63. https://doi.org/10.1016/j.envsci.2015.06.014

Ilskog, E., & Kjellström, B. (2008). And then they lived sustainably ever after?—Assessment of rural electrification cases by means of indicators. Energy Policy, 36(7), 2674–2684. https://doi.org/10.1016/j.enpol.2008.03.022

Inchauste, G., & Victor, D. G. (2017). The Political Economy of Energy Subsidy Reform. Washington, DC: World Bank. https://doi.org/10.1596/978-1-4648-1007-7

IPCC. (2022). Summary for Policymakers. In: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change.

IRENA. (2017). Accelerating the Energy Transition through Innovation, a working paper based on global REmap analysi [Working Paper]. IRENA. https://www.irena.org/publications/2017/Jun/Accelerating-the-Energy-Transition-through-Innovation

Islam, Md. M., Irfan, M., Shahbaz, M., & Vo, X. V. (2022). Renewable and non-renewable energy consumption in Bangladesh: The relative influencing profiles of economic factors, urbanization, physical infrastructure and institutional quality. Renewable Energy, 184, 1130–1149. https://doi.org/10.1016/j.renene.2021.12.020

Jaffe, A. B., Newell, R. G., & Stavins, R. N. (2002). Environmental Policy and Technological Change. Environmental and Resource Economics, 22(1), 41–70. https://doi.org/10.1023/A:1015519401088

Jagers, S. C., Lachapelle, E., Martinsson, J., & Matti, S. (2021). Bridging the ideological gap? How fairness perceptions mediate the effect of revenue recycling on public support for carbon taxes in the United States, Canada and Germany. Review of Policy Research, 38(5), 529–554. https://doi.org/10.1111/ropr.12439

Jakob, M., Flachsland, C., Christoph Steckel, J., & Urpelainen, J. (2020). Actors, objectives, context: A framework of the political economy of energy and climate policy applied to India, Indonesia, and Vietnam. Energy Research & Social Science, 70, 101775. https://doi.org/10.1016/j.erss.2020.101775

Jakob, M., & Steckel, J. C. (2022). The Political Economy of Coal: Obstacles to Clean Energy Transitions (1st ed.). Routledge. https://doi.org/10.4324/9781003044543

Jenner, S., Groba, F., & Indvik, J. (2013). Assessing the strength and effectiveness of renewable electricity feed-in tariffs in European Union countries. Energy Policy, 52, 385–401. https://doi.org/10.1016/j.enpol.2012.09.046

Jeuland, M., Fetter, T. R., Li, Y., Pattanayak, S. K., Usmani, F., Bluffstone, R. A., Chávez, C., Girardeau, H., Hassen, S., Jagger, P., Jaime, M. M., Karumba, M., Köhlin, G., Lenz, L., Litzow, E. L., Masatsugu, L., Naranjo, M. A., Peters, J., Qin, P., … Toman, M. (2021). Is energy the golden thread? A systematic review of the impacts of modern and traditional energy use in low- and middle-income countries. Renewable and Sustainable Energy Reviews, 135, 110406. https://doi.org/10.1016/j.rser.2020.110406

Jeuland, M., Ohlendorf, N., Saparapa, R., & Steckel, J. C. (2020). Climate implications of electrification projects in the developing world: A systematic review. Environmental Research Letters, 15(10), 103010. https://doi.org/10.1088/1748-9326/abb0ed

Jiang, Z., Ouyang, X., & Huang, G. (2015). The distributional impacts of removing energy subsidies in China. China Economic Review, 33, 111–122. https://doi.org/10.1016/j.chieco.2015.01.012

Kabel, T. S., & Bassim, M. (2019). Literature Review of Renewable Energy Policies and Impacts. European Journal of Marketing and Economics, 2(2), 28. https://doi.org/10.26417/ejme-2019.v2i2-68

Kahan, D. M. (2015a). What is the 'Science of Science Communication'? SSRN Electronic Journal. https://doi.org/10.2139/ssrn.2562025

Kahan, D. M. (2015b). Climate-Science Communication and the Measurement Problem: Climate-Science Communication and The Measurement Problem. Political Psychology, 36, 1–43. https://doi.org/10.1111/pops.12244

Kahneman, D., & Tversky, A. (1979). Prospect Theory: An Analysis of Decision under Risk. Econometrica, 47(2), 263–291. https://doi.org/10.2307/1914185

Kalkuhl, M., Steckel, J. C., & Edenhofer, O. (2020). All or nothing: Climate policy when assets can become stranded. Journal of Environmental Economics and Management, 100, 102214. https://doi.org/10.1016/j.jeem.2019.01.012

Karapin, R. (2012). Explaining Success and Failure in Climate Policies: Developing Theory through German Case Studies. Comparative Politics, 45(1), 46–68. https://doi.org/10.5129/001041512802822879

Kazenergy. (2017). National Energy Report. KAZENERGY Association. https://www.kazenergy.com/upload/document/energy-report/National_Energy_Report-ENGLISH_03.09.pdf

Khan, J., & Johansson, B. (2022). Adoption, implementation and design of carbon pricing policy instruments. Energy Strategy Reviews, 40, 100801. https://doi.org/10.1016/j.esr.2022.100801

Khanna, T. M., Baiocchi, G., Callaghan, M., Creutzig, F., Guias, H., Haddaway, N. R., Hirth, L., Javaid, A., Koch, N., Laukemper, S., Löschel, A., Zamora Dominguez, M. del M., & Minx, J. C. (2021). A multi-country meta-analysis on the role of behavioural change in reducing energy consumption and CO2 emissions in residential buildings. Nature Energy, 6(9), Article 9. https://doi.org/10.1038/s41560-021-00866-x

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., & Stern, N. (2018). Making carbon pricing work for citizens. Nature Climate Change, 8(8), Article 8. https://doi.org/10.1038/s41558-018-0201-2

Klug, T., Beyene, A. D., Meles, T. H., Toman, M., Hassen, S., Hou, M., Klooss, B., Mekonnen, A., & Jeuland, M. (2022). A Review of Impacts of Electricity Tariff Reform in Africa. SSRN Electronic Journal. https://doi.org/10.2139/ssrn.4105354

Koch, N., Naumann, L., Pretis, F., Ritter, N., & Schwarz, M. (2022). Attributing agnostically detected large reductions in road CO2 emissions to policy mixes. Nature Energy, 7(9), Article 9. https://doi.org/10.1038/s41560-022-01095-6

Koh, J., Johari, S., Shuib, A., Matthew, N. K., & Siow, M. L. (2021). Impacts of Carbon

Pricing on Developing Economies. International Journal of Energy Economics and Policy, 11(4), Article 4.

Kotchen, M. J. (2021). The producer benefits of implicit fossil fuel subsidies in the United States. PNAS, 118(14). https://doi.org/10.1073/pnas.2011969118

Lamb, W. F., Antal, M., Bohnenberger, K., Brand-Correa, L. I., Müller-Hansen, F., Jakob, M., Minx, J. C., Raiser, K., Williams, L., & Sovacool, B. K. (2020). What are the social outcomes of climate policies? A systematic map and review of the ex-post literature. Environmental Research Letters, 15(11), 113006. https://doi.org/10.1088/1748-9326/abc11f

Leahy, S., Clark, H., & Reisinger, A. (2020). Challenges and Prospects for Agricultural Greenhouse Gas Mitigation Pathways Consistent With the Paris Agreement. Frontiers in Sustainable Food Systems, 4. https://www.frontiersin.org/article/10.3389/fsufs.2020.00069

Lema, R., Bhamidipati, P. L., Gregersen, C., Hansen, U. E., & Kirchherr, J. (2021). China's investments in renewable energy in Africa: Creating co-benefits or just cashing-in? World Development, 141, 105365. https://doi.org/10.1016/j.worlddev.2020.105365

Leroutier, M. (2022). Carbon pricing and power sector decarbonization: Evidence from the UK. Journal of Environmental Economics and Management, 111, 102580.

Levi, S., Flachsland, C., & Jakob, M. (2020). Political Economy Determinants of Carbon Pricing. Global Environmental Politics, 20(2), 128–156. https://doi.org/10.1162/glep_a_00549

Lilliestam, J., Patt, A., & Bersalli, G. (2021). The effect of carbon pricing on technological change for full energy decarbonization: A review of empirical ex-post evidence. WIREs Climate Change, 12(1), e681. https://doi.org/10.1002/wcc.681

Lo, A. Y. (2016). Challenges to the development of carbon markets in China. Climate Policy, 16(1), 109–124. https://doi.org/10.1080/14693062.2014.991907

Lockwood, M., Kuzemko, C., Mitchell, C., & Hoggett, R. (2017). Historical institutionalism and the politics of sustainable energy transitions: A research agenda. Environment and Planning C: Politics and Space, 35(2), 312–333. https://doi.org/10.1177/0263774X16660561

Maestre-Andrés, S., Drews, S., & van den Bergh, J. (2019). Perceived fairness and public acceptability of carbon pricing: A review of the literature. Climate Policy, 19(9), 1186–1204. https://doi.org/10.1080/14693062.2019.1639490

Malm, A. (2013). The Origins of Fossil Capital: From Water to Steam in the British Cotton Industry. Historical Materialism, 21(1), 15–68. https://doi.org/10.1163/1569206X-12341279

Marin, G., & Vona, F. (2019). Climate policies and skill-biased employment dynamics: Evidence from EU countries. Journal of Environmental Economics and Management, 98, 102253. https://doi.org/10.1016/j.jeem.2019.102253

Menanteau, P., Finon, D., & Lamy, M.-L. (2003). Prices versus quantities: Choosing policies for promoting the development of renewable energy. Energy Policy, 31(8), 799–812. https://doi.org/10.1016/S0301-4215(02)00133-7

Mildenberger, M., Lachapelle, E., Harrison, K., & Stadelmann-Steffen, I. (2022). Limited impacts of carbon tax rebate programmes on public support for carbon pricing. Nature Climate Change, 12(2), Article 2. https://doi.org/10.1038/s41558-021-01268-3

Moayed, T., Guggenheim, S., & Chamier. (2021). From Regressive Subsidies to Progressive Redistribution: The Role of Redistribution and Recognition in Energy Subsidy Reform. Path Finders, 32.

Moe, E. (2010). Energy, industry and politics: Energy, vested interests, and long-term economic growth and development. Energy, 35(4), 1730–1740. https://doi.org/10.1016/j.energy.2009.12.026

Montgomery, W. D. (1972). Markets in licenses and efficient pollution control programs. Journal of Economic Theory, 5(3), 395–418. https://doi.org/10.1016/0022-0531(72)90049-X

Montrone, L., Steckel, J. C., & Kalkuhl, M. (2022). The type of power capacity matters for economic development-Evidence from a global panel. Resource and Energy Economics, 101313.

Moore, N., Glandon, D., Tripney, J., Kozakiewicz, T., Shisler, S., Eyres, J., Zalfou, R., Leon, D., Kurkjian, V., Snilstveit, B., & Perdana, A. (2020). Effects of Access to Electricity Interventions on Socioeconomic Outcomes in Low- and Middle- Income Countries [Independent Evaluation: SR-01]. ndependent Evaluation Department (IED) and the International Initiative for Impact Evaluation (3ie).

Morris, A. (2016, April 25). Build a better future for coal workers and their communities. Brookings. https://www.brookings.edu/research/build-a-better-future-for-coal-workers-and-their-communities/

Muller, C., & Yan, H. (2018). Household fuel use in developing countries: Review of theory and evidence. Energy Economics, 70, 429–439. https://doi.org/10.1016/j.eneco.2018.01.024

Nallareddy, S., Rouen, E., & Suárez Serrato, J. C. (2018). Corporate Tax Cuts Increase Income Inequality (NBER Working Papers 24598). National Bureau of Economic Research.

Nurdianto, D. A., & Resosudarmo, B. P. (2016). The Economy-wide Impact of a Uniform Carbon Tax in ASEAN. Journal of Southeast Asian Economies (JSEAE), 33(1), 1–22. https://doi.org/10.1353/ase.2016.0009

Oh, H., Hyon, J., & Kim, J.-O. (2017). Korea's approach to overcoming difficulties in adopting the emission trading scheme. Climate Policy, 17(8), 947–961. https://doi.org/10.1080/14693062.2016.1213696

Ohlendorf, N., Jakob, M., Minx, J. C., Schröder, C., & Steckel, J. C. (2021). Distributional Impacts of Carbon Pricing: A Meta-Analysis. Environmental and Resource Economics, 78(1), 1–42. https://doi.org/10.1007/s10640-020-00521-1

Ohlendorf, N., Jakob, M., & Steckel, J. C. (2022). The political economy of coal phase-out: Exploring the actors, objectives, and contextual factors shaping policies in eight major coal countries. Energy Research & Social Science, 90, 102590. https://doi.org/10.1016/j.erss.2022.102590

Ordonez, J. A., Jakob, M., Steckel, J. C., & Fünfgeld, A. (2021). Coal, power and coal-powered politics in Indonesia. Environmental Science & Policy, 123, 44–57.

Ostrom, E. (2010). A Multi-Scale Approach to Coping with Climate Change and Other Collective Action Problems. Solutions, 1.

Oye, K. A., & Maxwell, J. H. (1994). 8. Self-Interest and Environmental Management. Journal of Theoretical Politics, 6(4), 593–624. https://doi.org/10.1177/0951692894006004008

Pagnarith, K., & Limmeechokchai, B. (2011). Renewable energy utilization and CO2 mitigation in the power sector: A case study in selected GMS countries. 9.

Pahle, M., Burtraw, D., Flachsland, C., Kelsey, N., Biber, E., Meckling, J., Edenhofer, O., & Zysman, J. (2018). Sequencing to ratchet up climate policy stringency. Nature Climate Change, 8(10), 861–867. https://doi.org/10.1038/s41558-018-0287-6

Parry, I., Shang, B., Vernon, N., Wingender, P., & Narasimhan, T. (2020). Evaluating policies to implement the Paris Agreement: A toolkit with application to China. Handbook on the Economics of Climate Change, 32–67.

Peñasco, C., Anadón, L. D., & Verdolini, E. (2021). Systematic review of the outcomes and trade-offs of ten types of decarbonization policy instruments. Nature Climate Change, 11(3), 257–265. https://doi.org/10.1038/s41558-020-00971-x

Pigou, A. C. (1929). The Economics of Welfare (Third). Macmillian and Co.

Price, R. (2020). Lessons learned from carbon pricing in developing countries (K4D Helpdesk Report No. 799; p. 20). Institute of Development Studies.

Promjiraprawat, K., & Limmeechokchai, B. (2012). Assessment of Thailand's Energy Policies and CO2 Emissions: Analyses of Energy Efficiency Measures and Renewable Power Generation. Energies, 5(8), Article 8. https://doi.org/10.3390/en5083074

Pryor, J., Santikarn, M., & Fernandez, Haizea. S. (2021). The role of a carbon price in tackling road transport emissions [Discussion Paper]. World Bank, Washington, DC.

Rafaty, R. (2018). Perceptions of Corruption, Political Distrust, and the Weakening of Climate Policy. Global Environmental Politics, 18, 106–129. https://doi.org/10.1162/glep_a_00471

Ramirez, A. D., Boero, A., Rivela, B., Melendres, A. M., Espinoza, S., & Salas, D. A. (2020). Life cycle methods to analyze the environmental sustainability of electricity generation in Ecuador: Is decarbonization the right path? Renewable and Sustainable Energy Reviews, 134, 110373. https://doi.org/10.1016/j.rser.2020.110373

Rath-Nagel, St., & Voss, A. (1981). Energy models for planning and policy assessment. European Journal of Operational Research, 8(2), 99–114. https://doi.org/10.1016/0377-2217(81)90249-6

Rauner, S., Bauer, N., Dirnaichner, A., Dingenen, R. V., Mutel, C., & Luderer, G. (2020). Coal-exit health and environmental damage reductions outweigh economic impacts. Nature Climate Change, 10(4), 308–312.

Rausch, S., Metcalf, G. E., & Reilly, J. M. (2011). Distributional Impacts of Carbon Pricing: A General Equilibrium Approach with Micro-Data for Households (Working Paper No. 17087). National Bureau of Economic Research. https://doi.org/10.3386/w17087

Ravallion, M. (2001). The Mystery of the Vanishing Benefits: An Introduction to Impact Evaluation. The World Bank Economic Review, 15(1), 115–140. https://doi.org/10.1093/wber/15.1.115

RECAI. (2020). Renewable Energy Country Attractiveness Index. E&Y. https://assets.ey.com/content/dam/ey-sites/ey-com/en_gl/topics/power-and-utilities/ey-recai-56-country-index.pdf

Renner, S. (2018). Poverty and distributional effects of a carbon tax in Mexico. Energy Policy, 112, 98–110. https://doi.org/10.1016/j.enpol.2017.10.011

Rosenbloom, D., Markard, J., Geels, F. W., & Fuenfschilling, L. (2020). Opinion: Why carbon pricing is not sufficient to mitigate climate change—and how "sustainability transition policy" can help. Proceedings of the National Academy of Sciences, 117(16), 8664–8668. https://doi.org/10.1073/pnas.2004093117

Sager, L. (2019). The Global Consumer Incidence of Carbon Pricing: Evidence from Trade. Grantham Research Institute on Climate Change and the Environment Working Paper, 320.

Savian, F. de S., Siluk, J. C. M., Garlet, T. B., do Nascimento, F. M., Pinheiro, J. R., & Vale, Z. (2021). Non-technical losses: A systematic contemporary article review. Renewable and Sustainable Energy Reviews, 147, 111205. https://doi.org/10.1016/j.rser.2021.111205

Schaffitzel, F., Jakob, M., Soria, R., Vogt-Schilb, A., & Ward, H. (2020). Can government transfers make energy subsidy reform socially acceptable? A case study on Ecuador. Energy Policy, 137, 111120. https://doi.org/10.1016/j.enpol.2019.111120

Schallenberg-Rodriguez, J. (2017). Renewable electricity support systems: Are feed-in systems taking the lead? Renewable and Sustainable Energy Reviews, 76, 1422–1439. https://doi.org/10.1016/j.rser.2017.03.105

Schmalensee, R., & Stavins, R. N. (2017). Lessons Learned from Three Decades of Experience with Cap and Trade. Review of Environmental Economics and Policy, 11(1), 59–79. https://doi.org/10.1093/reep/rew017

Schmidt, T. S. (2014). Low-carbon investment risks and de-risking. Nature Climate Change, 4(4), 237–239. https://doi.org/10.1038/nclimate2112

Shah, A., & Larsen, B. (1992). CarbonTaxes, the Greenhouse Effect, and Developing Countries. World Bank, WPS 957, 42.

Shang, B. (2021). The Poverty and Distributional Impacts of Carbon Pricing: Channels and Policy Implications (IMF Working Paper WP/21/172; p. 32). IMF - Strategy, Policy and Review Department. https://www.imf.org/en/Publications/WP/Issues/2021/06/25/The-Poverty-and-Distributional-Impacts-of-Carbon-Pricing-Channels-and-Policy-Implications-50222

Singh, K. (2016). Business innovation and diffusion of off-grid solar technologies in India. Energy for Sustainable Development, 30, 1–13. https://doi.org/10.1016/j.esd.2015.10.011

Skovgaard, J., Ferrari, S. S., & Knaggård, Å. (2019). Mapping and clustering the adoption of carbon pricing policies: What polities price carbon and why? Climate Policy, 19(9), 1173–1185. https://doi.org/10.1080/14693062.2019.1641460

Steckel, J. C., Edenhofer, O., & Jakob, M. (2015). Drivers for the renaissance of coal. Proceedings of the National Academy of Sciences, 112(29), E3775–E3781. https://doi.org/10.1073/pnas.1422722112

Steckel, J. C., Hilaire, J., Jakob, M., & Edenhofer, O. (2020). Coal and carbonization in sub-Saharan Africa. Nature Climate Change, 10(1), 83–88. https://doi.org/10.1038/s41558-019-0649-8

Steckel, J. C., Renner, S., & Missbach, L. (2021). Distributional Impacts of Carbon Pricing in Low- and Middle-Income Countries. CESifo Forum, 22(5), 7.

Stevens, D. (2021). Institutions and Agency in the Making of Carbon Pricing Policies: Evidence from Mexico and Directions for Comparative Analyses in Latin America. Journal of Comparative Policy Analysis: Research and Practice, 23(4), 485–504. https://doi.org/10.1080/13876988.2020.1794754

Thepkhun, P., Limmeechokchai, B., Fujimori, S., Masui, T., & Shrestha, R. M. (2013). Thailand's Low-Carbon Scenario 2050: The AIM/CGE analyses of CO2 mitigation measures. Energy Policy, 62, 561–572. https://doi.org/10.1016/j.enpol.2013.07.037

Tong, D., Zhang, Q., Zheng, Y., Caldeira, K., Shearer, C., Hong, C., Qin, Y., & Davis,

S. J. (2019). Committed emissions from existing energy infrastructure jeopardize 1.5 °C climate target. Nature, 572(7769), 373–377. https://doi.org/10.1038/s41586-019-1364-3

Trebilcock, M. J. (2014). Dealing with losers: The political economy of policy transitions. Oxford University Press, USA.

UNDP. (2016). Fuel Taxes. UNDP. https://www1.undp.org/content/dam/sdfinance/doc/fuel-tax

UNEP. (2014). Using models for Green Economy Planning (PAGE: Green Economy Toolkit for Policymakers).

UNESCAP. (2021). Systematic Review of the Socio-economic Impacts of Rural Electrification (Research Report ST/ESCAP/2937). United Nations. https://www.unescap.org/sites/default/d8files/knowledge-products/Systematic-Review-of-the-Socio-economic-Impacts-of-Rural-Electrification%2026%20Feb.pdf

Unruh, G. C. (2000). Understanding carbon lock-in. Energy Policy, 28(12), 817–830. https://doi.org/10.1016/S0301-4215(00)00070-7

Urpelainen, J. (2013). A model of dynamic climate governance: Dream big, win small. International Environmental Agreements: Politics, Law and Economics, 13(2), 107–125. https://doi.org/10.1007/s10784-012-9174-1

van Heerden, J., Gerlagh, R., Blignaut, J., Horridge, M., Hess, S., Mabugu, R., & Mabugu, M. (2006). Searching for Triple Dividends in South Africa: Fighting CO_2 pollution and poverty while promoting growth. The Energy Journal, 27(2), 113–141.

Venter, C., Jennings, G., Hidalgo, D., & Valderrama Pineda, A. F. (2018). The equity impacts of bus rapid transit: A review of the evidence and implications for sustainable transport. International Journal of Sustainable Transportation, 12(2), 140–152. https://doi.org/10.1080/15568318.2017.1340528

Verde, S. F., & Tol, R. S. J. (2009). The distributional impact of a carbon tax in Ireland. Economic & Social Review, 40(3), 317–338.

Wang, P., Liu, L., Tan, X., & Liu, Z. (2019). Key challenges for China's carbon emissions trading program. WIREs Climate Change, 10(5), e599. https://doi.org/10.1002/wcc.599

Wang, Q., Hubacek, K., Feng, K., Wei, Y.-M., & Liang, Q.-M. (2016). Distributional effects of carbon taxation. Applied Energy, 184, 1123–1131. https://doi.org/10.1016/j.apenergy.2016.06.083

West, S. E., & Williams, R. C. (2004). Estimates from a consumer demand system: Implications for the incidence of environmental taxes. Journal of Environmental Economics and Management, 47(3), 535–558. https://doi.org/10.1016/j.jeem.2003.11.004

Winyuchakrit, P., Limmeechokchai, B., Matsuoka, Y., Gomi, K., Kainuma, M., Fujino, J., & Suda, M. (2011). Thailand's low-carbon scenario 2030: Analyses of demand side CO2 mitigation options. Energy for Sustainable Development, 15(4), 460–466. https://doi.org/10.1016/j.esd.2011.09.002

Yamazaki, A. (2017). Jobs and climate policy: Evidence from British Columbia's revenue-neutral carbon tax. Journal of Environmental Economics and Management, 83, 197–216. https://doi.org/10.1016/j.jeem.2017.03.003

Yu, X., & Lo, A. Y. (2015). Carbon finance and the carbon market in China. Nature Climate Change, 5(1), Article 1. https://doi.org/10.1038/nclimate2462

Yusuf, A. A., Economy and Environment Program for Southeast Asia, & International

Development Research Centre (Canada). (2008). Distributional impact of environmental policies: The case of carbon tax and energy pricing reform in Indonesia (No. 2008-RR1). Economy and Environment Program for Southeast Asia.

Zhu, J., Fan, Y., Deng, X., & Xue, L. (2019). Low-carbon innovation induced by emissions trading in China. Nature Communications, 10(1), Article 1. https://doi.org/10.1038/s41467-019-12213-6

Appendix

Table Review of methodologies for green economy assessments; contribution to the policy process, complementarity and stakeholder participation

Methodology	Main strengths in assessing the green economy	Main trade-offs relative to the green economy	Problem identification	Policy formulation	Policy assessment	Policy M&E	Complementarity	Accessibility – participation
Static								
Indicators	Support the entire policy cycle, quantify trends	Require harmonization; primarily limited to (quantitatively) measurable variables	✔	✔	✔	✔	✔	✔
Input-Output	Represent value chain impacts, and ripple effects across sectors	Data intensive; material flows not generally available	✔	✔	✔	✔		
Social Accounting Matrix	Estimates economic flows across the main economic actors	Covers exclusively monetary flows; lacks feedback		✔	✔			✔
Grographic Information System	Captures local trends, based on geographical maps; fully accounts for natural resources and ecosystem services	Data intensive; may miss economic dimensions; uneven data resolution may pose challenges	✔	✔	✔	✔	✔	✔
Dynamic (projections)								
Econometrics	Entirely based on historical trends; quick implementation	Traditional modelling lacks the explicit representation of feedback and does not capture possible emerging dynamics. Time series modelling has the potential to solve these issues.	✔		✔	✔	✔	✔
Optimization	Supports the estimation of target; understanding key limits of the system	Provides an "end" with little insight on the "means"; not viable for highly dynamic and cross-sectoral systems		✔	✔			✔
System Dynamics	Focuses on structure to drive behaviour; horizontal sectoral representation; knowledge integrator (ad hoc)	Highly reliant on knowledge available in other fields; relatively long implementation time for national models	✔	✔	✔		✔	✔