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

# Sustainable Energy Transitions

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# 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 also 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 an inherently 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 is commissioned by SIE as part of a larger initiative to develop an actionable research agenda that the IDRC can support to achieve a low-carbon transition with gender equity in the Global South.

Sustainable Energy Transitions 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 Marc Jeuland from Duke University, Marcela Jaime from Universidad de Concepción, Carlos Chávez from Universidad de Talca, Walter Gómez from Universidad de La Frontera in Temuco, Cesar Salazar from Universidad del Bio-Bio, Mauricio Oyarzo from Universidad de Concepción, Cristóbal Vasquez from University of Concepción, Adolfo Uribe from Universidad de Talca, Marta Talevi from Vrije Universiteit Amsterdam and Erin Litzow from University of British Columbia. The EfD Global Hub staff supporting the authors was Alejandro Lopez Feldman.

This paper focuses on sustainable energy transitions, with a particular emphasis on gendered and intersectional aspects, which are central to the idea of inclusive LCT. It draws mainly on a recent systematic review carried out by the Sustainable Energy Transitions Initiative, as well as on information gathered specifically for this report regarding ongoing policy processes and priorities from stakeholders in a sample of LMICs. 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 contribution by research to a much needed low-carbon transition with gender equity in the Global South in this crucial Decade of Action.

**This paper focuses on sustainable energy transitions, with a particular emphasis on gendered and intersectional aspects, which are central to the idea of inclusive LCT.**

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# Sustainable energy transitions

## 1.1 Motivation: The critical development role of energy transitions, and the appropriateness of a low-carbon trajectory objective for LMICs.

Reaching universal access to energy by 2030 while moving towards net-zero emissions in developing and emerging economies is a daunting challenge. Globally, 800 million people still do not have access to electricity, 600 million of whom live in sub-Saharan Africa (IEA et al. 2021), and many more have only intermittent supplies and low consumption levels (Nordhaus et al. 2016). A considerably larger number, 2.6 billion people globally (or 33% of total population), lack any access to clean cooking technology, and stacking[1] of clean and dirty fuels remains common among many others (Masera et al. 2000, Price et al. 2021). Even as these deficiencies in access persist, countries are setting out ambitious agendas to advance clean, affordable energy for all by 2030 in their Nationally Determined Contributions (NDCs) and Long-Term Strategies (LTSs), to achieve net-zero emissions by 2050. Indeed, the energy sector is at the core of the low-carbon transition (LCT) concept. Unsurprisingly, many NDCs have identified renewable energy as a top priority, as well as improvements in energy efficiency. International investment initiatives, such as the Global Environmental Facility (GEF), and the UN's Climate Promise, are supporting these actions across the Global South. The new attention on the LCT certainly presents new opportunities, yet numerous and interlinked challenges continue to impede the move away from traditional energy sources and towards more sustainable ones.

For example, it is now well established that electricity generation from renewables is today cost-competitive with more traditional fossil-fuel-based generation in many locations (NEA 2010, Kåberger 2018). Nonetheless, institutional frameworks, business models, and financing mechanisms for aggressively scaling decentralized renewable solutions are still in their infancy (Engelken et al. 2016), and the cost of capital for such investments therefore remains very high (Agutu et al. 2022). This high cost is closely related to structural bottlenecks and institutional failures – and in certain locations, high corruptibility, and regulatory lapses (Kabel and Bassim 2020). Successful templates for renewables expansion often create trade-offs themselves, especially with equity; for example, profitable business models needed to effectively stimulate expansion often come at the cost of lower inclusivity and access for the poorest in society, for women and marginalized groups, or for more geographically isolated rural communities (Bardouille et al. 2012, Friebe et al. 2013). Public projects or public-private partnerships have experienced high failure rates owing to classic problems related to site selection concerns; insufficient stakeholder involvement; and deficient planning, implementation, and long-term management (Ikejemba et al. 2017). Meanwhile, evidence suggests that, despite clear environmental benefits, distributed renewables and more inclusive electrification strategies may not be supportive of productive uses and income generation (Peters et al. 2019, Jeuland et al. 2021). This can engender significant challenges to these investments' long-term sustainability. Regarding the transition to clean cooking, cost concerns and underdeveloped supply chains (relative to readily available biomass fuel alternatives) remain enormous challenges (Jeuland et al. 2018, Pattanayak et al. 2019). Indeed, even in regions having access to electricity and clean cooking fuels, problems with reliability and continuing reliance on traditional, polluting fuels remain. Exacerbating all these difficulties, the COVID-19 pandemic has upended many livelihood activities globally and exposed the deep inequities existing in access to opportunities.

At the outset, there is a need to acknowledge that insistence on the need for a LCT in developing countries risks exacerbating an already deeply unequal global energy situation. To be sure, renewable energy generation may now be cost-competitive with carbon intensive technology, but that does not mean that it is on an equal footing, given financing challenges and the political economy and institutional advantages of incumbent technologies and distribution systems (Sergi et al. 2018, Agutu et al. 2022). Though disputes arise over the causal nature of the link between energy consumption and economic growth, evidence

[1] The concept of fuel stacking suggests that, with increasing income, households do not fully switch to different fuel types, but rather use an energy mix or as of a menu (Kroon et al 2013).

is overwhelming that these increase in tandem. The idea that developing countries today can achieve less carbon-intensive GDP growth by harnessing new and more environmentally benign technologies than those used in already industrialized countries, however, is weak and controversial (van Benthem 2015, Fetter 2020). Recent work shows that electrification that provides anything more than basic energy services (e.g., lighting, phone charging, and consumption of television services) without increasing emissions remains rare indeed, despite the rise of solar energy solutions (Jeuland et al. 2020). An energy justice and inclusion lens demands more (Jenkins et al. 2018).

There is thus an urgent need for research that clarifies ways to overcome these interlinked challenges, and that thereby facilitates a more inclusive and sustainable energy access transition in low- and lower-middle-income countries, especially as it improves outcomes for women, youth, marginalized groups, and other disenfranchised populations. Such research would support the generation of new and timely data and evidence, leveraging methodologies appropriate for the task of confronting the multiple constraints holding back progress today. It should be centered on a goal of identifying and scaling effective public, private, and non-governmental sector actions that advance equity. In particular, approaches that advance the sustainability of energy uses and address structural inequalities are sorely needed, where the latter pertain to gender, ethnic/racial, socio-cultural, and other inequalities of opportunity. Such research should also speak to the unique challenges of this moment, considering the continuing effects of the COVID-19 pandemic and supply chain vulnerabilities from similar problems with global interconnections (e.g., geopolitical and climate-related shocks), and the need for coordinated recovery. The costs and drivers of such challenges mainly, and increasingly, have environmental dimensions.

## 1.2 Summary of systematic review findings and other recent literature: The paradox of energy transitions; bright and dark spots.

In this section, we draw on recent work – primarily evidence from systematic and other reviews – to discuss key lessons on the drivers and impacts of energy transitions. We focus particularly on what is known about LCT dynamics, as well as how those dynamics intersect with concerns over inclusion and equity. This allows us to identify a set of critical knowledge gaps that must be tackled to support accelerated progress in achieving an energy transition that is both equitable and sustainable, or that at least improves the balance of these attributes. Given the important role that distributed renewable energy generation technologies are expected to play in meeting energy transitions goals, much of the discussion relates to what is known about the potential of such technologies, relative to the conventional, fossil-fuel-based paradigm that relies so heavily on centralized generation and transmission via high-capacity grids. Distributed energy generation refers to a variety of technologies that generate electricity at or near where it will be used.

### 1.2.1 Drivers of energy transition

There is a rich literature on the drivers, determinants, and barriers of energy transitions, which speaks to the diffusion and adoption of specific energy technologies in low-income contexts. That body of work, which began to flourish in the 1990s with contributions from social and policy scientists, makes clear that the traditionally dominant techno-engineering perspective on energy transitions has proven insufficient to explain many important dynamics. Early lessons were provided by descriptive analyses of cross-national and within-country patterns of energy data that revealed the close correlation between income, urbanization, relative fuel prices, supportive government policies, and use of modern energy. Reaching populations in isolated and rural locations has proven especially challenging, owing to the twin challenges of high costs and risks, and the low demand in such areas (Bazilian et al. 2010), which is often but not exclusively a reflection of low ability to pay. As this body of work matured, critical reviews and systematic analyses enriched understanding of the most critical determinants, specific to electrification, improved cooking stoves, and energy-efficient technology.[2]

Though each of these studies offers somewhat different perspectives, they highlight a set of common determinants—low cost of solutions, higher income and education, urbanization and connectedness, efficient and equitable

[2] The energy transitions outcomes analyzed in the quantitative empirical literature vary, but the majority look at energy technology adoption (e.g., appliances or cooking stoves) or electrification (grid, off-grid, etc.) as a simple binary measure. Some papers consider the drivers of energy or electricity consumption or consider the dynamics of use of multiple devices (i.e., stacking), and more recently the World Bank introduced the multi-tier framework for cooking and electricity access (Bhatia and Angelou 2015), though literature investigating the drivers of a more multi-dimensional concept remains scarce.

subsidies that benefit the poor, learning from neighbors and peers, financing or access to credit, greater economic empowerment (especially among women), and more future-oriented or health-risk-reducing preferences. While awareness-raising is often advocated, the effective features of social marketing and behaviour change campaigns remain poorly understood (Lewis and Pattanayak 2012), and evidence from other domains suggests modest effects (Brown et al. 2017). Supply-side and institutional barriers and enablers are also understudied except in more qualitative assessments, which highlight the importance of standards, effective implementation, and supply chain development (Barnes 2007, Puzzolo et al. 2016).

Meanwhile, social impediments to adoption are many, and include lack of demand (Mobarak et al. 2012, Lee et al. 2016) and inadequate tailoring of technology to satisfy local preferences (Jeuland et al. 2019). Behavioural phenomena, such as income effects, may lead to mixed adoption, or parallel use (i.e., stacking) of clean and polluting technology, as these often provide services with differentiated quality or reliability (Turner 2013). Even when demand is high, underdeveloped markets or poor implementation by intermediary organizations may impede the transition, along with lack of maintenance services (Usmani et al. 2018, Barnes 2019). And yet, once well-accepted energy solutions take root, their dissemination can sometimes proceed at an exceptional pace, reaching large portions of the population in a matter of decades (Smil 2010, Sovacool 2016). The reasons for such nonlinear technology adoption dynamics remain poorly understood, however. Thus, it remains relevant and pertinent to continue to assess the conditions under which solutions are readily adopted and deliver benefits in the real world, using rigorous empirical evaluation methods. Particularly vital is to shed light on the mechanisms underlying successes and failures (Hedström and Ylikoski 2010).

With regard to electricity specifically, expanding access has historically been dependent on grid extension to provide connections to new areas, which was capital intensive and dependent on the actions of highly centralized utilities and regulating institutions (Sergi et al. 2018), as well as heavily subsidized (Kojima and Trimble 2016). In this sense, a particularly beneficial feature of the dramatic decline in the costs of solar generation has been the decoupling of access from highly concentrated electricity service provision, increasing the likelihood of solutions – largely off-grid – reaching remote and isolated locations (IEA 2017). Still, decentralized solutions face many of the same challenges as grid extension, as well as additional new challenges. Absent substantial investment in battery storage, off-grid solar suffers the same (or worse) intermittency problems as grid power; moreover, most off-grid systems have insufficient capacity to power services other than basic lighting, phone charging, and consumption of radio or television programming (Scott 2017, Cross and Neumark 2021). Technological limitations of specific solutions, coupled with the growing realization that better frameworks are needed for characterizing the quality dimensions of electricity (moving beyond binary access), have spurred interest in better characterization of these multiple dimensions (e.g., the Multi-Tier Framework (World Bank 2015)). Other renewable energy technologies, meanwhile, are poorly represented in studies conducted in the lower- and middle-income-country (LMIC) context.

On the barriers side, existing literature and frameworks focus on myriad factors within the following dimensions: political and institutional; economic and financial; social; technical and management; technology diffusion; and rural infrastructure. Political and institutional challenges arise from the top-down nature of the power sectors in many countries, shifting priorities, and difficulty retaining skilled human capital (Sergi et al. 2018). On the financial side, access to capital is a major barrier, and few energy consumers in low-income countries can afford to pay the tariffs needed to recover the costs of installing and operating systems providing substantial power, which substantially limits private sector participation and development of sustainable business models (Barnes 2007, Engelken et al. 2016). Infrastructure that is needed to make better use of energy – roads, markets, etc. – is often lacking in remote areas, and difficult to extend due to low population density and difficult terrain. Technical challenges arise from the structure of traditional housing, which is often unsuitable for wiring, and persistent gaps in provision of trained maintenance personnel, services, and replacement parts (Hazelton et al. 2014, Engelken et al. 2016). Lower cost systems or lifeline tariffs, while affordable and socially more acceptable, mostly fail to provide sufficient energy to spur economic activity, locking in low levels of consumption in a way that perpetuates rather than alleviates energy poverty.

An additional impediment to energy transition in many (especially lower-income) countries, which relates to both financial and technical constraints, relates to the difficulty of sourcing equipment that is primarily manufactured in upper-middle-income or high-income countries. Many countries are unable to mobilize the capital needed to establish local manufacturing, recruit human capital and expertise needed to operate it, or find suitable labor with skills in manufacturing,

and must therefore rely on relatively more expensive imports. Meanwhile, intellectual property rights restrictions limit knowledge transfer further: many of the most promising technologies are protected by patents and other laws, and lower-income countries have limited resources for negotiating licensing agreements that would allow them to benefit from these innovations. The cost of imports is further driven up by trade barriers (e.g., tariffs, import quotas, and other barriers) that make it difficult to import technology. Addressing these and other challenges requires more international cooperation, technology transfer programs, and identification of policies that promote technology development and innovation.

### 1.2.2 Economic, environmental, health, and social impacts of energy use

A recent systematic review carried out by the Sustainable Energy Transitions Initiative offers a powerful framework and starting point for considering the complexity of impacts of past and ongoing energy transitions in lower- and middle-income countries (LMICs) (Jeuland et al. 2021). That review highlighted the paradox of energy transitions; that is, energy interventions often have mixed impacts across domains and parties, leaving some behind and damaging the environment even as they accompany and drive economic growth. The energy services framework applied in the review (Figure 1) served to highlight how different services relate to specific technologies, and those services in turn imply tradeoffs across impact categories. In particular, persistent energy poverty and polluting energy transitions both have massive implications for human livelihoods, development and opportunity, local environmental quality and ecosystem health, and the stability of the future climate, but the welfare implications of these various impacts have often been in conflict (for example, when transitions that support income generation involve heavy dependence on coal). Thus, the review concluded that access to modern energy services does not always improve environmental and development outcomes.

Focusing on specific technologies and services, there is very strong support for the idea that traditional household cooking technology is damaging. Nonetheless, the impact of improved cooking technologies under real-world conditions remains surprisingly ambiguous, owing to both incomplete adoption and technological shortcomings for the solutions that are most frequently taken up (Beltramo and Levine 2013, Bonan et al. 2017). Meanwhile, electricity grids that rely mainly on fossil fuels for generation induce important tradeoffs between improved productivity and income, on the one hand, and health and local and global environmental quality, on the other, due to the contribution of combustion of such fuels to air pollution and climate change (Zhang et al. 2010). The authors therefore conclude that tradeoffs are especially common between income and other development (e.g., health or environmental quality) outcomes. In some domains (e.g., health care delivery), and for some technologies (e.g., decentralized renewables), evidence is thin, inconsistent, or even invisible in the literature—meaning that there is a dearth of studies supporting (or contradicting) widely held beliefs about impacts. Among the eight types of energy services considered, there is a very clear concentration of literature on cooking. There is also asymmetry in the types of impacts studied, with individual or household health and climate effects receiving substantial attention, and less consideration of implications for gender equity, household education and income, and local environmental quality; or addressing the agriculture or service sectors and the quality of public services. Other hard-to-measure outcomes, related to social cohesion and political participation, are also understudied.

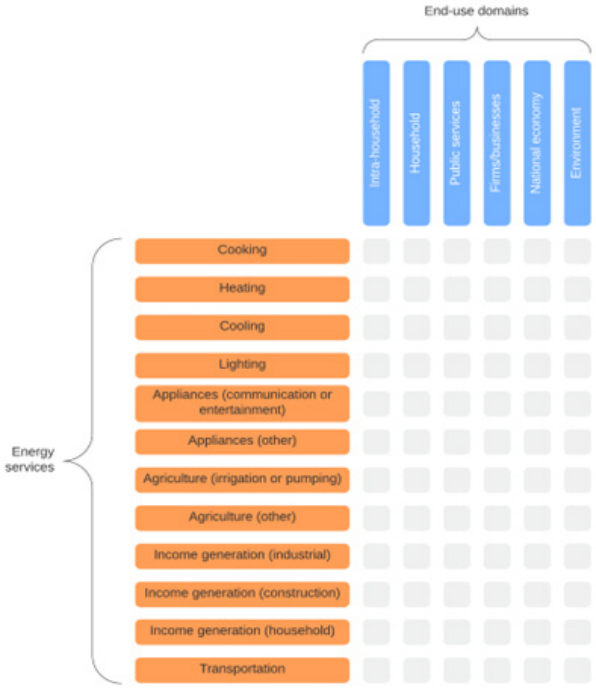



*Figure 1 The energy services and users framework applied in Jeuland et al. (2021) review of the impacts of energy interventions and transitions*

Other reviews of impacts of energy transitions or interventions have been more narrowly focused on studies

that apply particular methods[3], and/or consider only a single type of technology in a particular context.[4] A classical problem discussed in this energy impacts literature concerns the role of electrification and energy consumption in increasing individuals' or firms' incomes, as well as national GDP, given the bidirectional relationship between income and energy use, including energy consumption from renewables (Menegaki 2014, Shakouri and Khoshnevis Yazdi 2017). The justification for a specific contextual focus, meanwhile, would seem to emerge from the reality that the appropriateness of different solutions varies across locations. As such, a broad focus can make it difficult to glean insights and extract lessons, given the complexity and nonlinearity in the various pathways leading from enhanced "energy access" to impacts. And yet, comparisons across technologies and settings are valuable precisely because they provide a richer and more nuanced understanding of the role of energy in fostering development and environmental sustainability, and thereby help to inform better interventions.

In Section 3, we dig deeper into the public database from the comprehensive Jeuland et al. (2021) review, as well as other literature, to explore questions more germane to the sustainability and inclusivity of energy transitions and the implications of those aspects for a suite of development and other outcomes.

### 1.2.3 Evidence across regions and development levels

An important source of heterogeneity in — and bias in potential extrapolation of study results on— the impacts of energy access might arise from regional differences, due to variation in settlement patterns and density, general economic conditions, institutions, culture, and/or appropriateness of different energy technologies. Here we summarize and augment several findings from the Jeuland et al. (2021) review that relate to such regional differences, which correlate somewhat with differences in income levels. In that comparison, Jeuland et al. commented on a limited set of outcomes for which there is sufficient econometric research to support such comparisons.

Regarding the regional distribution of impacts of traditional and improved cookstoves, studies of impacts on health most commonly consider South Asian contexts (where the related burden of disease is highest), while those on air quality are relatively more common in the East Asia and Pacific regions. Traditional stove technology is universally (across all regions) found to have negative impacts on air quality and health, but there is substantial regional heterogeneity in the impacts of improved stoves. Specifically, evidence of positive impacts of improved cookstoves on health is much weaker in South Asia and sub-Saharan Africa, relative to the other, higher-income regions. This may reflect a tendency to promote more rudimentary improved technologies (so-called "transitional" options) that are less likely to deliver health benefits, in lower-income countries or locations (Bensch and Peters 2015, Gebreegziabher et al. 2018), relative to middle- and even upper-income countries (Shen et al. 2015, Coelho et al. 2018, Pattanayak et al. 2019). It may also reflect differences in how beneficiaries at different income levels use improved technology – stacking it more or less alongside traditional alternatives – or are able to maintain that use over time. Finally, evidence concerning the impact of cooking technology on gender equity, a commonly discussed issue in the literature, is extremely thin, with few statistically significant impacts identified, except with respect to negative effects of traditional technology in South Asia.

For electricity access, there is strong evidence across regions—primarily from cross-country comparisons—of a positive relationship between energy and national income, and many such results are statistically significant. Micro-level impacts are less consistently positive, however. For firm income, for example, there have been few statistically significant and positive results from sub-Saharan Africa and Latin America and the Caribbean, and results are also somewhat inconsistent in South Asia (relative to East Asia and the Pacific, Europe and Central Asia, and the Middle East and North Africa). Impacts on household productivity and income indicators are also less consistently positive in sub-Saharan Africa and South Asia. There is relatively little evidence of impacts on education, but these impacts are generally positive except in sub-Saharan Africa. Finally, the impacts of electricity access and consumption on the environment (both climate and air quality) have been studied extensively in East Asia and the Pacific and are generally negative. Evidence related to environmental quality elsewhere is thin, and more mixed, perhaps owing to differences in the timing of grid expansion and the fact that energy consumption is much higher in the former region, and thus induces a tradeoff between

[3] For example, Bos et al. (2018) and Bayer et al. (2020) consider only quasi-experimental or experimental impact evaluations.

[4] For example, grid extension in rural parts of sub-Saharan Africa, as in Bos et al. (2018) and also in Peters and Sievert (2016).

development and environmental degradation. For off-grid renewables, evidence is more limited, but these technologies have not clearly been linked to productivity and income gains: impact estimates are only slightly more positive than negative, and few results are statistically robust. Most results pertaining to environmental impacts are slightly positive, except for hydropower, where impact estimates are mostly negative and concentrated in East Asia and the Pacific and Latin America and the Caribbean, and tend to focus on large installations, which are most disruptive of the natural environment and existing social and economic systems (Jeuland 2020).

Looking to complementary literature, the most extensive prior review work of the consequences of energy technology development has considered the socioeconomic impacts of rural electrification in sub-Saharan Africa, perhaps because this is a somewhat controversial yet policy-relevant question (IEG 2008). For one, Africa is where electricity connection rates are lowest in the world, and the reviews clearly aim to inform policymakers about what they might expect to achieve with greater investments. Second, this prior work suggests rather muted impacts on development, at least compared to those observed in other regions, and especially in relation to the investment needed to achieve universal access (Bernard 2010, Peters and Sievert 2016, Bos et al. 2018). Nonetheless, nearly all of these studies consider impacts of new connections over a relatively short evaluation period, whereas productivity benefits may only arise over the longer term and in locations with other advantages (Cabraal et al. 2005, Fetter and Usmani 2019). Furthermore, several (though not all) of these reviews do find substantial gains in consumption (especially watching television), perceived quality of life, time savings, and time reallocation away from domestic chores (Bernard 2010, Bonan et al. 2017, Bos et al. 2018). Regarding electrical appliance use, little is known about which types of household energy appliances are most impactful; a few scattered studies outside of Africa mention refrigeration, or access to media (Gonzalez-Eiras and Rossi 2007, Jensen and Oster 2009, La Ferrara et al. 2012).

Differences in sub-Saharan Africa relative to other contexts may emerge from several interrelated challenges and contextual realities. One important factor is low population density; rural African households in particular often take up new connections slowly due to high connection costs or unsuitability of their home infrastructure (Bos et al. 2018), consume relatively small amounts of electricity (Peters and Sievert 2016, Bos et al. 2018), and increasingly already use renewable devices for lighting such that substantial in-house pollution reductions documented elsewhere do not materialize (Peters and Sievert 2016). In addition, rural micro-enterprises are hampered by other barriers, especially those related to market access (Peters and Sievert 2016). The observation of no increase in firm creation and hence labour demand is also confirmed by Dinkelman (Dinkelman 2011) in South Africa, though this study does find an increase in female labour supply. In the absence of rising demand for labour (due to lack of firm creation), wages fall, and welfare effects are unclear.

A final point worth noting is that the depth and distribution of impacts studied varies considerably across country income categories, perhaps reflecting the varying importance of different energy services, and differential synergies with other variables such as education and urbanization, as a function of development. The energy-related opportunities that exist, as well as the problems observed in rural versus urban contexts are substantively different. In particular, the poorest and most remote populations live in rural areas, so affordability and willingness to pay for electricity, and ability to then use it productively is often the most significant impediment to achieving both access and positive impacts on socioeconomic status. Urban areas, meanwhile, face fewer connectivity or access issues, but still face affordability challenges, especially when considering the need to apply cost-reflective tariffs overall. The variation in outcomes may also reflect energy access challenges and energy transitions trajectories that are correlated with region (i.e., comparative advantages for particular generation technologies orother aspects of technological appropriateness). Relative to their shares of global population, upper middle-income countries (UMICs) are overrepresented, with 56.1% of impact studies and 62.2% of the services studied. Both lower-middle-income (LoMICs) and low-income countries (LICs) are somewhat underrepresented by population and services.[5] The impacts and services covered vary across these categories in ways that are consistent with energy use patterns and sustainable

[5] While LMIC is a broader income classification including low-income, lower-middle-income and upper-middle-income countries, the concepts of LICs, LoMICs and UMICs denote the group of countries within each income category, separately.

development goal (SDG) priorities.[6] In particular, energy use in LICs is primarily for residential services demanded by households, and household impacts and services are well represented in literature considering these poorest countries. In LMICs and UMICs, energy consumption is considerably higher, and the relative sectoral balance shifts towards transport and industry. Finally, climate outcomes are much more studied in UMICs, relative to poverty alleviation outcomes in LICs and LoMICs. The services and impact categories in LoMICs and UMICs look somewhat similar, though gender equality receives more attention in LoMICs. The conception of which energy services are customary for well-being differs across societal contexts; when societies grow richer their members escalate expectations of what constitutes energy justice (Walker et al. 2016). Accordingly, UMICs are particularly over-represented in studies of cooling, transportation, and non-household income. LICs and LMICs are relatively well represented in studies of cooking, lighting, and household-based income generation. These distributions may arise from a perception that cooling and transportation services are part of a minimum standard of living in relatively wealthier countries, but not in relatively poorer countries.

### 1.2.4 Evidence across energy technologies

In this section, we further summarize the disaggregated evidence from Jeuland et al. (2021) on impacts, according to technology. In studies of traditional cookstoves (n=698) that consider impacts, the evidence for most categories is overwhelmingly negative, especially showing that these technologies harm health (air quality and personal health), climate, forest and ecosystem quality, and gender empowerment. The one exception is for poverty indicators: while traditional cooking mostly involves increased time costs, reflecting the time burden of fuel collection, evidence shows slightly positive effects for consumption and overall income, because traditional technologies and fuels are not purchased and hence are often more affordable. The full economic opportunity costs from the time burden of fuel collection (i.e., negative effects on income and productivity) have scarcely and rather inconsistently been studied and quantified (Krishnapriya et al. 2021). On the other hand, the evidence for benefits from a broad and heterogeneous set of improved stove options (n=395 studies) is rather mixed. Notably, there are comparable numbers of studies finding improvements and a lack thereof in terms of air quality, climate emissions, personal health, and forest and ecosystem quality, and the results are not so clearly different for different levels of solutions (e.g., clean fuels vs. simple improved biomass stoves), likely reflecting the strong influence of behaviour on outcomes. Evidence for poverty reduction is slightly more positive than negative, especially for consumption and expenditure, but increases in consumption sometimes reflect increased spending on commercial fuels. A small number of studies have found evidence for improvements for firms (local production of stoves), and agriculture and gender empowerment (due to time savings being used for agriculture, and especially benefitting women, including through stove marketing (Shankar et al. 2015)).

For grid electricity, evidence in the environmental and health impact domains is mostly negative, though impacts of grid electricity on electricity users' health are often positive, owing to positive changes in income and quality of life. This is because the traditional paradigm of fossil-based generation dominates and produces large amounts of air pollution and climate harm. Similarly, impacts on consumption, household income, time allocation, education, gender empowerment, firm productivity and income, public services, and national GDP are predominantly positive. Still, there are almost equal numbers of statistically significant positive impacts and non-statistically significant positive impacts for these various indicators, pointing to some ambiguity and potential heterogeneity in the strength of the positive linkages. The evidence for the various off-grid renewables is substantially different, however. While impacts are mostly deemed positive from a qualitative perspective, remarkably few quantitative evaluations identify statistically significant positive impacts. Unlike grid electricity, and contradicting many engineering modelling studies (Sarkar et al. 2018), there are very few field evaluations linking off-grid solar to national or firm income, productivity, air quality, or health, and few studies linking wind and biogas to development outcomes. What studies do exist generally examine a shift from no to renewable electricity access, and not shifting away from alternatives such as diesel or unreliable grid power. Finally, like grid-based electricity, hydropower – typically large projects in the

[6] The review highlights linkages to the following SDGs: No poverty (SDG 1); zero hunger (SDG 2); good health and well-being (SDG 3); quality education (SDG 4); gender equality (SDG 5); decent work and economic growth (SDG 8); industry, innovation and infrastructure (SDG 9); climate action (SDG 13); and life on land (SDG 15).

literature, rather than micro-hydro and run-of-river projects – presents important tradeoffs, mostly appearing to improve air quality, the climate, firms, household consumption, and national income; while harming ecosystems and forests, and having mixed impacts on agriculture, household income, and health.

### 1.2.5 Prominent controversies or disagreements in the literature

The results of prior literature and the Jeuland et al. (2021) review on the impacts of energy access and technology call attention to several current themes and debates in the researcher and practitioner communities. We summarize them here, before diving deeper in the next section.

First, as noted above, there is much evidence on the negative impacts of traditional cooking technology, but findings are less consistent about the positive impacts of improved cookstoves—on health, time savings, or other aspects of individual and household well-being. Given the prevalence of solid fuel and traditional stove use for cooking in LMICs, this service deserves to be, and is, extremely well covered in existing literature, especially in the poorest settings. Unfortunately, many studies on cooking services provide only marginal value relative to implementers' needs for evidence, adding to a body of evidence that is already robust (e.g., showing that traditional stove use harms air quality and health, or documenting household-level barriers to adoption of improved stoves). What implementers need are studies that would more effectively help overcome serious supply chain, information, and behavioural obstacles that inhibit improved stove use and impacts, which remain decidedly mixed in the literature. Besides policies, the importance of complementary conditions (robust supply chains, market connectivity, access to financing) warrants attention. Finally, questions of affordability, credit or liquidity constraints (Berkouwer and Dean 2022), and the role of subsidies are especially important for determining impacts among the ultra-poor who rely most on traditional stoves.

Second, electricity access in general appears strongly linked to increased income and productivity (at household, firm, and national levels) and negative environmental consequences, but a closer look at this evidence reveals that it does not extend consistently to all regions, technologies, and solutions. Several prominent articles from various settings raise questions about the causal relationship between energy access and a range of development outcomes (Peters et al. 2011, Burlig and Preonas 2016, Lenz et al. 2017), which is important to understand for donors and governments making investments. As with improved cooking technology, contextual factors and complementary economic conditions may play an important role in mediating productive use (Morrissey 2018, Fetter and Usmani 2019). Even more specifically, there is much buzz about the potential of off-grid solar for reaching customers that are expected to remain disconnected from conventional energy solutions for some time, but few if any studies show that off-grid renewable technologies help raise incomes, despite many advocates' expectations and claims to the contrary (GOGLA and Altai Consulting 2018). Institutional, planning, and management failures of renewable projects have been documented in several countries, meanwhile (Ikejemba et al. 2017). Consumer demand and willingness to pay for electricity are often low; much more research is needed on whether innovative service delivery models and improvements in battery storage can be leveraged to reliably deliver energy services that would translate into larger impacts. In general, it seems that the appropriateness of these different technologies for providing the energy services that beneficiaries want has not received sufficient attention. A key advantage of the energy services framework is that it helps to clarify what should be expected from specific interventions. It can also reorient analyses towards identifying which specific appliances help produce the greatest improvements in development and well-being outcomes.

Finally, a general thread that emerges from reviews is that there is substantial heterogeneity in the impacts of energy in LMICs, but that understanding of the reasons for that heterogeneity is limited. Researchers need to work harder to craft studies – with practitioners – that speak to mechanism (i.e., "why") questions, or need to leverage datasets to carry out systematic hypothesis testing using meta-analysis of studies carried out in different contexts. To the extent possible, this work should be complemented by detailed qualitative work that also documents and explores the role of differences in institutions, culture, and other contextual features that moderate or confound impacts over space and time, as these aspects limit generalizability from one context to another. Moreover, while energy studies can be found that cover all regions with LMICs, some locations, especially in UMICs, have received disproportionate attention. Competent studies carried out in specific countries in which no or very few studies exist should be seen as valuable even if they are less innovative in addressing other gaps. Firm-level and national-level impacts are particular gaps in most LICs. More comparative work that looks for consistencies and divergences across different contexts would also be valuable, as there are many important lessons to be learned from countries and communities at different stages of energy transitions.

## 1.3 Revisiting and digging deeper into gaps identified in prior work.

Building on the prior section, we now turn our attention to several issues – drawing on the prior discussion of gaps and research needs– that require additional review effort because they are so closely linked to the concept of inclusive LCTs. They are:

- Intra-household and gender implications of energy interventions, policies, and transitions;
- The appropriate role of distributed renewables for LCT electrification, which, when successfully implemented and managed, have clearly positive environmental implications but ambiguous development impacts and social sustainability (Peters et al. 2019, Jeuland et al. 2020, Jeuland et al. 2021);
- The importance of supply chain improvements and enabling or complementary conditions; and
- The urgency of finding robust solutions for making progress in the lowest-income countries and in last-mile settings where research is sparse and energy access goals are lagging, especially in Africa.

### 1.3.1 Intra-household and gender implications of energy interventions, policies, and transitions

Considering the gender and energy nexus specifically, there are clear connections between SDG 5 (gender equality) and SDG 7 (universal access to modern energy). These linkages are broadly acknowledged (Fukuda-Parr 2016), but relevant theory and evidence remain incomplete and poorly organized. Critical knowledge gaps lead to missing opportunities for progress from interventions, on the one hand, and to tradeoffs that may be unintended or underappreciated, on the other. For example, access to clean energy can potentially reduce drudgery and shift women's time use, as well as provide access to information and communication that shifts social norms and enhances reproductive rights (Jensen and Oster 2009), contributing to empowerment and ultimately to gender equality (Clancy et al. 2012). Yet there is also evidence that intra-household decision-making, and persistent and deeply embedded asymmetries in decision-making power, affect choice of modern energy services in ways that may harm development and reinforce existing inequities (Pachauri and Rao 2013, Fingleton-Smith 2018). The connections between energy access and gendered empowerment are bidirectional: women's empowerment may be both furthered by energy access and use even as it also encourages adoption and use of modern energy technologies. So too are the connections between energy poverty and the marginalization of women.

As noted previously, and despite a mixed track record of success (e.g., for improved cookstoves), arguments for promotion of low-carbon, sustainable energy have most often been built around health and/or environmental benefits (Martin et al. 2014, Forouzanfar et al. 2016), while development outcomes are less clearly tied to clean energy (relative to fossil-fuel-based energy generation). Yet this narrative has neglected the potentially sizeable benefits that come when women in especially energy-poor households (where the alternative is use of biomass or very dirty fossil fuels like coal and diesel) have clean energy (Barnes and Samad 2018). Women in such households are especially disadvantaged: drudgery and time-use associated with solid fuel collection and cooking using inefficient stoves impose heavy time and health burdens on them, given their primary responsible for household cooking (Köhlin et al. 2011, Jeuland and Pattanayak 2012, Jagger and Das 2018). Similarly, lack of access to electricity stifles households' ability to adopt labour-saving domestic appliances that would particularly aid women (Köhlin et al. 2011), who typically spend disproportionate amounts of time providing unpaid domestic work and caregiving because of deeply held social norms, attitudes, stereotypes about appropriate gender roles, and a lack of alternative livelihood opportunities (Gornick and Meyers 2003). These inequities constrain women's ability to devote time to education (Rogers 2014), income-generating activities (DeGraff et al. 2017), and leisure (World Bank 2012), all of which contribute to agency and empowerment, and more broadly to growth and poverty reduction (Cuberes and Teignier 2014).

Moreover, gender is intersectional, interlocking with multiple axes of power and inequality such as class, ethnicity, age, and race (Cho et al. 2013, Azocar and Ferree 2016, Lieu et al. 2020). Lack of access to renewable energy among these marginalized groups may be the result of structural discrimination and policies that favour an unequal distribution of the needed investment capital for the transition to clean energy. Literature dealing with the intersection between gender and other forms of social differences is scarce but recently growing (Nguyen et al. 2019, Churchill et al. 2020, Keady et al. 2021, Newell 2021, Hsu and Fingerman 2021, Ojong 2021, Tidwell and Tidwell 2021, Ngarava et al. 2022). Higher energy vulnerability is suggested among non-white, rural, poor, and ethnic minority populations (Sunter et al. 2019, Churchill et al. 2020, Ngarava et al. 2022). These are the groups that face the most severe barriers that slow down energy security regardless the level of society development. Overall, findings imply that environmental and energy injustices may also have

their roots in racial and ethnic discrimination/privileges, unequal distribution of income, and geographical location (Sunter et al. 2019, Johnson et al. 2020, Tidwell and Tidwell 2021). Research gaps on how gender intersects with religion, disabilities, and sexual orientation to shape the adoption of clean energy still remain under-researched (Ojong 2021). The study of these disparities is important, as a transition to a low-carbon future, while desirable from a climate change perspective, does not guarantee that pre-existing inequalities in energy systems will be reduced. Thus, a failure to consider these complex interconnections may reinforce the privileged position of some groups of the population while worsening the opportunities of marginalized populations for access to clean and affordable energy. Thus, clean/renewable energy interventions should be redesigned to address gender issues interacting with other form of social disparities.

Furthermore, a holistic vision of development-enhancing energy projects would focus on livelihood benefits in addition to health and environmental ones, especially those reaching women (Krishnapriya et al. 2021). Existing development finance instruments have largely ignored such benefits, but designing and implementing policy and investment instruments that recognize, value, and respond to energy poverty and asymmetric burdens are key to achieving SDGs related to both gender equality (SDG 5) and access to clean energy (SDG 7). Realizing this, organizations such as SE4All (2020), International Network on Gender and Sustainable Energy (ENERGIA 2020), and Practical Action (2019) have underscored energy access and gender nexus in their current programming agendas. Given that affordability of improved technology remains a major obstacle for households in particular (Jeuland et al. 2018, Thakur et al. 2019), instruments that relax liquidity and budget constraints – particularly for women who tend to suffer lower access to economic resources – are desperately needed.

To be sure, empowerment, especially economic empowerment, has often been found to improve the uptake of cleaner technology. Measures of increased bargaining power, greater perception of risk and environmental awareness, social status, and empowerment of women predict higher adoption of more efficient cooking technologies, cleaner-burning fuels, and other forms of sustainable energy technology adoption (Fingleton-Smith 2018, Alem et al. 2020, Choudhuri and Desai 2020). Economic resources (such as access to credit and property rights) and access to information and transport similarly have a positive impact on adoption of electrical energy services by women (Burke and Dundas 2015; Pachauri and Rao 2013). Due to their relatively disadvantaged position, however, women tend to be more sensitive to price than men, are less willing to spend money on cooking technologies, and are more likely to put the needs of the household above their own personal preferences (Miller and Mobarak 2013, Zahno et al. 2020). In the existing empirical literature, it is unclear whether women's employment outside the home spurs adoption of time-saving technologies, or whether the adoption of such technologies facilitates women's employment outside the home (Dinkelman 2011, Grogan and Sadanand 2013, Winther et al. 2017), but the direction of these relationships is important to identify effective interventions. For electrification, results tend to agree that women's employment increases with electrification as compared to men's, but women continue doing most of the unpaid caregiving work (Pueyo and Maestre 2019). Inconclusive evidence is also found for improvement in women's job quality and earnings (Dinkelman 2011, van de Walle et al 2013, Dasso and Fernandez 2015, Akpandjar and Kitchens 2017). The relative employment effects of traditional versus clean energy technology on different groups also requires further study. For example, while some argue that clean energy sector jobs are likely to be more permanent and plentiful than alternative jobs in traditional sectors (e.g., coal mining or the oil and gas industry), hard evidence on the question, and implications for empowerment along gender lines or across other inequities, is limited.

Meanwhile, women's engagement in the energy sector has been found to encourage clean energy solutions at the household level (Shankar et al. 2020). This could be linked to women having a stronger presence in the renewable energy sector, as compared with the conventional fossil fuel sector, where gender imbalances are significantly large (IRENA 2019). Nonetheless, women remain underrepresented in the renewable energy sector, facing barriers like those observed in non-traditional occupations and, while in the sector, are more likely to be employed in lower paid and non-technical positions, compared with men, who mostly occupy technical, managerial, or policymaking positions (IRENA 2013). Similar results were found in a study focusing on the Middle East and North Africa region (BNEF, CEBC and IRENA 2017). Literature mainly focuses on the reproductive role and labour of women as users of energy for household food provision, and how energy transition has affected female labour supply. However, women cannot obtain benefits from the adoption of low-carbon technology only in their care roles but not in their productive roles, which relate closely to the labour demand side (Johnson et al. 2020). In particular, gender considerations are rarely examined in the analysis of

the causes of the underrepresentation of women entrepreneurs and employees in new and more profitable business models in the energy sector (Pueyo and Maestre 2019). Some studies have suggested that energy firms with a higher gender diversity better promote women's economic empowerment (Pearl-Martinez and Stephens 2016). Although evidence from North America points out that gender labour composition in the renewable energy sector tends to be more heterogeneous than in the fossil fuel industry, the renewable energy sector still has lower female participation than other areas of the economy (Allison et al. 2019). More studies of how existing structural gender differences — choices of productive activities, locations, and access to assets, finance, markets, infrastructure — translate into gender barriers are needed to understand the low rate of female employment in energy production (Glemarec et al 2016, A. Pueyo and DeMartino 2018, Pueyo and Maestre 2019), as well as their role in female entrepreneurship. Decentralized and small-scale energy business models have presented some advantages over large-scale energy interventions as more sustainable solutions for equalizing the gender benefits of energy transition (Stock and Birkenholtz 2020).

A more complete characterization of women's energy-related empowerment is sorely needed to design interventions that are responsive to both SDG 5 and 7 objectives. Such a characterization would account for the complexities and measurement challenges of key constructs, such as tackling the multiple quantitative and qualitative dimensions of both energy access (World Bank 2015) and gender empowerment (Kabeer 1999, Malhotra and Schuler 2005, Alkire et al. 2013, Donald and Goldstein 2020). For example, measures of empowerment of women and other marginalized groups must acknowledge that this concept reflects agency on multiple fronts: economic, socio-cultural, familial/interpersonal, legal, political, cognitive, and psychological (Stromquist 1999, Varghese 2011). Conversely, most studies on electricity apply an indicator measure for electricity access, making it difficult to identify the impacts of specific energy services, and to identify the specific mechanisms at play. An overlap of empowerment- and energy-relevant concepts could draw on prior work in other sectors, e.g., agriculture, where the Women's Empowerment in Agriculture Index (WEAI) (Alkire et al. 2013) recognizes women's and men's achievements in different domains to create an individual, multifaceted empowerment profile specific to the agriculture sector. There is no comparable measure in the energy literature, however, and this lacuna impedes empirical investigation of gendered aspects of energy access and energy use, which to date mostly relies on crude proxies for resources or social power (Das et al. 2020).

Of particular note in this puzzle are intra-household inequities, which favour consumption of energy services that men value – entertainment and communications (which require only fairly low-quality tier 2 power) – at the expense of household productivity benefits that tend to benefit women (that are only supported by higher tier power) – especially use of labour-saving household appliances such as refrigerators, washing machines, and efficient cooking appliances.[7] The conundrum with promoting the latter set of technologies is that they both require high levels of power and do not directly increase income. Rather, income benefits come only if those women saving time are able to dedicate their saved hours to productive purposes (Dinkelman 2011), such as increasing paid labour or raising own household income. Intra-household inequities in access to energy services also affect other dimensions besides energy use, suggesting that the traditional "one-size-fits-all" approach of providing energy access may not effectively meet the goal of sustainable energy for all (Zhang et al. 2022). There is evidence that electrification has greater benefits when labour opportunities for underemployed segments in society – particularly youth and women – increase in parallel with gains in access (Fetter and Usmani 2019) and can improve their standard of living (Acheampong et al. 2021).

Also important are longer term, human capital development impacts, which take substantial time to manifest. Many theories of change related to energy intervention emphasize the difference that lighting makes for children studying at night during their early schooling years, and the savings of time that children experience (presumably for reallocation to studies) when reliance on traditional energy sources is reduced (Kanagawa and Nakata 2008, Blomstedt et al. 2018). Evidence that definitively shows such impacts and improvements in school performance, however, remains surprisingly scarce and is not always consistent (Furukawa 2014, Barron and Torero 2017, Grimm et al. 2017, Karimu

[7] The concept of tier power denotes the energy services that can be obtained at different levels of power achieved by a household. Lower power tiers are associated with low-quality energy, whilst high power tiers are associated with high-quality energy services

et al. 2018). However, there is some evidence of an increase in the average number of years of education in households that adopted solar panels (Diallo and Moussa 2020). Gender differences between children in terms of the benefits of lighting for studying may also arise, as girls bear a larger burden of household chores (Ojong 2021). Another less explored benefit of lighting that is relevant for women and young girls is the reduction of risk of sexual violence when not walking in darkness (Ulsrud 2020).

### 1.3.2 The role of distributed renewables for decarbonization: environmental, social and development impacts of electrification

There are major questions about the appropriate role that distributed renewable energy technologies can play in LCTs that also aim to enhance access to modern energy and its myriad benefits. To be sure, renewables are generally viewed as enhancing environmental sustainability, though questions remain especially about a) recycling and disposal of batteries, especially in the context of solar-based generation where storage is critical, as well as their impacts (Ortega-Arriaga et al. 2021, Cross and Murray 2018), and b) hydropower installations that interrupt river flow or migration of riverine species. The systematic review discussed previously puts a spotlight on the environmental challenges that accompany hydropower projects (Jeuland et al. 2021). However, that corresponding literature should not automatically be considered representative, as hydropower-related literature displays a distinct anti-project bias (Jeuland 2020). In terms of small run-of-river hydropower plants, Kuriqi et al. (2021), via systematic literature review, highlight a set of potential structural and non-structural mitigation measures to address the several ecological impacts such as fish injuries, aquatic habitat degradation, and connectivity loss. Among these measures, environmental flows are fundamental for fluvial ecosystem conservation. Another systematic review developed by Ortega-Arriaga et al. (2021) acknowledges that important analytical gaps in environmental impacts associated with different electrification strategies should be considered in a comprehensive way to optimize mitigation, adaptation, and biodiversity in the energy sector. For instance, there is little evidence of the impacts of utility scale solar PV on ecosystems, land use, biodiversity, or local communities, or of the impacts of disposal and recycling of PV systems and batteries.

A different and more significant concern, however, is that most distributed energy systems, at least in LMICs, provide relatively low quality electricity access, categorized as tier 3 or below using the Multi-Tier Framework (World Bank 2015). That level of access often fails to support the energy services required for income generation, productivity enhancement, and broader economic development. A similar issue arises from grid-based electrification when electricity consumption remains low (Bos et al. 2018). From a sustainability perspective, higher capacity systems fail to recover costs from low levels of consumption and must be heavily subsidized, while more affordable systems keep households locked into meeting only very basic needs, e.g., lighting, phone charging, and limited communications and entertainment. Alternative models that successfully provide public finance and subsidies to support deployment of renewables while maintaining affordability for low-income consumers at sufficient scale to reach electrification goals have yet to be demonstrated, with many planning and management challenges remaining evident (Ikejemba et al. 2017).

It has therefore proven difficult to decouple development-enhancing energy access from more carbon-intensive technologies, because the latter tend to capture a disproportionate share of energy sector subsidies. A prominent narrative in the energy sector is then that pollution-intensive energy development remains essential for emerging economies, even as coal-powered generation is declining (Moss 2021, Steckel and Jakob 2021, Jakob and Steckel 2022). This work highlights that, in these settings and in the presence of vested interests, incumbents have accumulated political influence and substantial interests to delay the adoption of alternative energy sources, even though these are less expensive than coal. Political economy factors play a key rolein explaining why some countries keep using and expanding their coal capacity (Ohlendorf et al. 2022).

Refuting this narrative will require new financial mechanisms that support a different, decentralized energy development model (Phillips et al. 2020). Ultimately, what will be needed is much more mobilization of subsidies to support off-grid renewables infrastructure development, and a dedicated focus on creating the conditions needed for maintaining and renewing such systems over time (e.g., with sufficient tariff collection and training and retention of skilled operators) (Peters et al. 2019). Such conditions can only emerge if energy services are used to raise incomes and energy consumers' ability to pay. Particular care and attention must also be given to last-mile and marginal customers who will always struggle to afford electricity, either through cross-subsidization from more able consumers or targeted subsidies supported by grants or general tax revenue. Such customers' connections and consumption have nearly always been subsidized under the traditional fossil fuel grid model of energy infrastructure development (Pellegrini and Tasciotti

2013). To be sure, there are inherent tensions in policies that support energy consumption by the poor. On the one hand, low-carbon options from renewable energy are increasingly cost-competitive and have gained market share at the expense of coal, although such solutions remain largely unaffordable for most poor consumers. On the other hand, vested interests continue to strongly limit competition and entry, especially in the presence of state-controlled markets, driving up the cost of energy for all consumers. Yet these incumbents are also better able to serve the poor, owing to the large public sector subsidies they receive. In this sense, supporting power market reform is key and could provide an important impetus for clean energy transition (Steckel and Jakob 2021).

### 1.3.3 The role of complementary conditions and supply infrastructure

There are several aspects related to complementarities in energy sector development, to which this section seeks to draw attention. First is the role of supplying institutions, both utilities (in the context of centralized grid-based services and utility-scale distributed models) and non-utility actors (especially vital for disseminating appliances or cooking fuels and stoves). Second, the role of complementary infrastructures that enable better and more productive use of energy, including roads and market connections, employment opportunities (which themselves relate to the local labour market, regulatory environment, and overall economic conditions), and demand for services such as tourism, as well as access to other inputs for agricultural or industrial production. Finally, there are complementarities associated with energy-related harms (specifically pollution), such as the siting or locating of polluting energy installations in lower-income or otherwise disadvantaged areas, commonly referred to as environmental justice problems. We discuss each of these in succession.

Regarding the first of these, which encompasses energy access or technology-supplying institutions, we have previously discussed the challenge facing decentralized energy service provision, given the natural monopolies that lead to a supply model dominated by utilities. Other than fully decentralized solar home systems and household cookstoves, there are large economies of scale in the provision of electricity and most clean cooking fuels (LPG, ethanol, biogas, and electricity). In the absence of strong regulation or government influence over suppliers, this leads to inefficient rent seeking and rationing of services that especially deprive poor and rural customers of adequate service. In this context, there has not been sufficient work exploring the effectiveness of different alternative supply models. In the context of improved cooking technology, Usmani et al. (2018) show that involvement of trusted local suppliers substantially boosts adoption, owing to reduced transaction costs and increased trust. For women-centric technologies, involving women in the supply chain can pay dividends, as they are better able to market and convince households to adopt the improvements (Shankar et al. 2020, Klege et al. 2021). The means of distribution, provision of information, and financing to reduce tight liquidity constraints are often necessary complements as well (Lewis et al. 2015, Krishnapriya 2016, Pattanayak et al. 2019).

Meanwhile, though many utilities underperform in delivering reliable electricity, consumers would be willing to pay higher tariffs in exchange for supply improvements (Meles et al. 2021). Increased accountability and ability for consumers to express their dissatisfaction with existing service quality is crucial to delivering sustained improvements in power supply, which otherwise only occur occasionally as political elections approach (Min and Golden 2014, Baskaran et al. 2015, Mahadevan 2019). This has important implications for inclusive LCTs, since marginalized and rural populations often most lack political voice and influence, and therefore likely receive inferior service.

The second aspect highlighted above, the role of complementary conditions and infrastructures, is now hypothesized to be of central importance in determining whether extending energy access supports development (Morrissey 2018, Fetter and Usmani 2019). An emerging consensus is that modern energy access may be a necessary but not sufficient condition for development (Burlig and Preonas 2016, Lee et al. 2020). This is important for the inclusive LCT concept because it further emphasizes a point made in the previous section on decentralized renewables, that is, that the somewhat higher cost of environmentally sustainable energy technology must be supported by cross-subsidization of the poorest communities where such complementary conditions are lacking. Alternatively, provision of energy access must occur in tandem with other interventions that address persistent poverty traps. Such interventions might include stronger social safety nets, cash transfers that facilitate investments in human capital and labour productivity, and insurance against adverse economic shocks (climatic, health-related, accidents, etc.) (Devereux 2002, Ward and Makhija 2018, Barrett et al. 2019).

Third, there is ample evidence of environmental injustice, i.e., the idea that polluting industries, which are pervasive in the energy sector, tend to get located in low-income or otherwise disenfranchised communities. In the rich world, descriptions of such patterns have focused especially on race

and class (Mohai et al. 2009). In an international version of this argument, richer societies dump polluting industries onto lower-income societies (Schroeder et al. 2008). LCTs, while apparently environmentally benign, raise a new set of challenges related to electronic and battery-related disposal (Lawhon 2013, Ozoegwu and Akpan 2021). Policies for regulating such harms are lacking in LMICs today, and poorly enforced, and there is a need for research that clarifies how emerging challenges can be addressed.

### 1.3.4 Transformation opportunities: Targeting developing and last-mile communities whose energy use and environmental policies are lagging

A clear message from the Jeuland et al. (2021) review is that the impacts of energy sector interventions have not been studied equally in all contexts. There is a particular lack of representation of settings in Africa, where energy access is lagging most, and where the concept of LCTs is perhaps most challenging due to the low levels of population consumption of energy (Hamburger et al. 2019). Of course, there are large relevant differences between countries in Africa that need more attention, including culture, wealth, and natural environments (Apfel et al. 2021). Indeed, within the literature on LCTs more generally, the disproportionate focus on the developed and richer world is even more pronounced than in the broader energy literature (Sovacool 2014a). Within studies on the Global South, more viewpoints from local researchers are also needed (Sovacool 2014b). Affordability and sustainability tradeoffs must be more thoroughly studied in the Global South because the realities of these two objectives in that context are so dramatically different from those facing the developed world. Political and social processes in developing countries, which are key for sustainable energy transitions, also appear to be under-researched (Apfel et al. 2021).

More broadly, recent literature has suggested that applying the tools of environmental and energy economics may be different in a developing country context (Jack 2017, Fowlie and Meeks 2021). The differences include what is studied, how it is studied, and what is found (Jack 2017). This implies that targeted research in developing countries is challenging, but also scientifically novel on its own. Furthermore, the differences also apply to studying energy transition issues and the energy sectors (Fowlie and Meeks 2021). This may be due to differences in the policy problems that need to be addressed, data availability, and related methodologies. Of course, one important challenge is that precisely those countries where energy use and environmental policies are lagging are likely to lack sufficient local research capacities, and consequently are usually underrepresented in research.

Targeting energy-related research in developing countries whose energy access and use are lagging is also important because it could have a larger impact. For example, there is recent evidence that energy poverty — restricted access to a poor-quality supply of energy — may represent important welfare losses in a developing-countries context (Aweke and Navrud 2022). Moreover, lower-middle and low-income countries are the ones that are expected to have the largest increase in energy demand (and related environmental impacts) in the future, while at the same time facing the most severe market failures and barriers to development of the energy sector. This explains why the empirical research agenda on energy and policies for energy efficiency is already increasingly focusing on these countries (Fowlie and Meeks 2021). Also, enhancing energy access, energy transitions, and energy efficiency in LMICs may contribute more significantly to productivity, which may involve uneven benefits between specific groups, as differentiated by gender, location, age, income, etc. (see, for example, Krishnapriya et al. 2021, and Johnson et al. 2019).

Climate change could be another important reason for targeting energy-related research in developing countries whose energy use and environmental policies are lagging. Developing countries are likely to be the ones that value relatively less the benefits of controlling greenhouse emissions in the present, have larger costs of pollution control, and face the greater market failures and political challenges for reforms (Greenstone and Jack 2015). This in turn implies that it is much more efficient to reduce emissions in rich countries, while expanding and improving scientific research – on both mitigation and adaptation – in lower-income countries may lead to new innovations that bring these countries' emissions trajectories onto a more sustainable path in the long term, while also creating opportunities to increase social welfare for their populations.

### 1.3.5 Bridging the gaps

Revisiting the research gaps identified by the literature provided us with important lessons. First, because policy instruments aimed at improving energy access and energy transitions have the potential to generate heterogeneous impacts in different subgroups of the population, identifying the more vulnerable groups arises as a key aspect for the design of tailored interventions. This requires, among other things, an assessment of which instruments have been successful under certain conditions, as well as the characteristics of the groups that benefited from those policies. Second, evidence shows that the blindness of many interventions regarding

specific gender-energy needs negatively affects the adoption of energy innovations. Thus, devoting efforts to work across disciplines and considering multiple intersecting social identities are crucial to overcome the negative consequences of systemic oppression on energy issues (Cannon et al. 2021, Anditi et al. 2022). Third, evidence on the energy-gender nexus points out that gender inequality does not only limit women's exposure to energy innovations and increase adverse outcomes for women and children, but also discourages the introduction of gender-sensitive energy policies, thereby creating a self-reinforcing system that perpetuates that inequality (Anditi et al. 2022).

## 1.4 Connections to local policy processes and priorities

A complementary approach that we use here to identify research gaps consists of gathering information regarding ongoing policy processes and priorities from stakeholders in a sample of LMICs. For this purpose, and to maximize coverage (and capture the heterogeneity across different regions and development status) while managing resource and time constraints, we focus on the 13 countries participating in the EfD network: Ethiopia, Tanzania, Kenya, Nigeria, Ghana, Uganda, South Africa, China, India, Vietnam, Colombia, Chile, and Costa Rica. These countries span the lower, lower-middle, and upper-income country categorizations of development status, and represent all major developing regions. While we acknowledge the necessity and importance of focusing on ongoing policy processes of lower-income countries, the analysis of lower-middle and upper-income countries in our sample allows us to understand important challenges that lower-income countries are likely to face when advancing in the development path. One of these challenges relates to the vicious circle of income inequality, energy poverty, and income poverty, factors that, altogether, impede equitable access to clean energy sources (UN DESA et al. 2019). Another challenge relates to the need to improve energy efficiency, because of its link with poverty reduction, energy affordability and sustainable development. We also acknowledge that the chosen sample of countries leads to some bias in the types of locations that are represented; particularly notable omissions include countries in Francophone Africa and the Middle East.

The two-stage methodology – which allows for a richer understanding of gaps in policy-oriented research that complements the perspective obtained from the literature – was grounded in the following activities:

*1. Design and implementation of a centres survey:*

We began the study by designing a questionnaire aimed at gathering baseline information from each of the EfD centres. By putting the same set of questions before network members in each centre, we expected to identify recent and ongoing local policy processes and priorities relating to the energy transitions process, while ensuring comparability across the studied dimensions. This questionnaire also allowed us to take stock of current research concentration, as shown in ongoing and completed research projects, scientific publications, numbers of researchers devoted to the analysis of energy issues, and identification of key stakeholders. Because of its importance in the framework of this project, special attention was given to the energy-gender nexus. To manage time effectively and avoid the need for extensive consultation of historic records in each centre, the period of recall for the questions covered the years 2019-2021. The questionnaire, which was administered during January-March 2022, can be downloaded here.

*2. Interviews targeting EfD centres:*

We next deepened our analysis and insights by designing and conducting a series of virtual focus group discussions with the main energy researchers in each of the EfD centres. The overarching objective of this exercise was to provide greater insight into the policy processes and priorities articulated by each centre in the surveys, and to gather information regarding the extent to which research projects and activities undertaken were aligned with those country priorities. Because semi-structured interviews allow discussing issues that may be problematic in a written survey, an important part of the interview focused on the energy-gender nexus more specifically, and on the concept of intersectionality.

Altogether, these activities provide us with a rich understanding of policy priorities that can be translated into research gaps that highlight and complement aspects from the literature. This information allows articulation of a more comprehensive, and LMIC-focused, research agenda that can support low-carbon and gender equity transitions in the Global South. Finally, it is envisioned that identified gaps will be validated and prioritized through workshops and other activities designed for this purpose in the framework of the project.

### 1.4.1 State of the art on energy transitions: Insights from the centres survey

The centres study allowed us to gather information on four aspects in particular: (i) energy-related research, (ii) work on the energy-gender nexus, (iii) interactions with relevant policymakers, and (iv) collaboration with key stakeholders.

Comparing the behaviour of centres across the studied dimensions provides a good picture of the nodes of existing knowledge, local capabilities of researchers, and perceptions of impact of their work, while identifying perceptions for research needs on low-carbon energy transitions.[8] In the following subsections we summarize our main findings. Detailed responses completed by the participant centres are available upon request.

Table 1 summarizes the research topics that have been addressed by this collective set of centres. As documented, this research has been focused on four issues: (i) off-grid electricity, (ii) renewable energy, (iii) grid electricity, and (iv) energy and climate change. Studied topics have followed, in most cases, a microeconomic approach, and research is perceived to have been demand responsive, i.e., has addressed policy issues identified by researchers as relevant in their countries. In addition, researchers have identified other topics where more research is warranted. These include: (i) household air pollution (i.e., indoor pollution generated by the combustion of solid or fossil fuels in the dwellings), (ii) ambient air pollution, (iii) gender and human capital dimensions of energy use and transitions, (iv) energy efficiency, and (v) energy aspects of transportation, among other issues. It is also perceived that, despite the ongoing work, more research is needed to address multiple research gaps in the domain of grid electricity provision.

Centres also self-reported their own engagement in ongoing and finished projects related to energy transitions, from which we derived a distribution across topics, shown in Table 2. Ongoing projects are mainly related to cooking energy services, renewables, household air pollution, energy and climate change/carbon offsets, gender and human capital, transportation, and energy efficiency, with concentration in sub-areas such as solar electricity, willingness to pay, and environmental policy. This suggests that research grant proposals targeting these key areas have often been successful, providing much-needed evidence regarding these unstudied areas in the context of LMICs. Despite this, the energy-gender nexus has not typically been the central focus of researchers' attention even when projects have implicit gender dimensions, with only two projects specifically motivated by gender links, on energy and education, and gender aspects of the gas/oil sectors, respectively. As of today, gender-sensitive and focused research remains rare.

**Table 1 Energy issues addressed by the sample of countries under study**

| | **Number of Centres:** | |
|---|---|---|
| **Topic** | **Currently studied topic** | **Should be studied** |
| Cooking energy services | 6 | 3 |
| Off-grid electricity | 9 | 3 |
| Grid electricity | 8 | 5 |
| Renewables | 10 | 3 |
| Household air pollution | 4 | 8 |
| Ambient air pollution | 4 | 7 |
| Energy and climate change/carbon offsets | 7 | 5 |
| Gender and human capital | 2 | 7 |
| Transportation | 7 | 5 |
| Energy efficiency | 7 | 4 |
| Refining energy transition concepts, theories, and measurements | 6 | 4 |
| Other, please specify: | | |
| - Mining | 1 | 0 |
| - Carbon prices | 1 | 1 |
| - Energy and non-energy-input substitution | 1 | 0 |
| - Carbon neutrality | 1 | 1 |
| - Electromobility | 1 | 0 |
| - Energy storage | 1 | 0 |
| - Demand-side management and its linkages with energy efficiency and infrastructure | 0 | 1 |

Note: own elaboration based on countries' responses. Frequency denotes the number of countries that are either working on a given topic or denoting the need of conducting research in a topic that has not been addressed in the past.

[8] Note that the information presented in this section corresponds to the responses provided by the participant centres during the studied period. Although figures were compared with official EfD records, they may not reflect the work done by researchers over a larger period of time, nor account for the work conducted by other researchers not associated with EfD.

**Table 2 Distribution of ongoing and finished projects on energy among the studied countries**

| Topic/area | Sub-topic/Sub-area | EfD Centre/ Country | Number of ongoing projects | Number of finished projects | Total number of projects |
|---|---|---|---|---|---|
| Cooking energy services | Electricity | Nigeria | 1 | 0 | 1 |
| | Gas/oil | Ghana | 1 | 0 | 1 |
| | Food security | Ethiopia | 1 | 0 | 1 |
| | Electric cooking | India | 1 | 0 | 1 |
| | Air pollution | India | 1 | 0 | 1 |
| Off-grid electricity | Solar panel | Chile | 0 | 1 | 1 |
| | Solar panel | China | 0 | 1 | 1 |
| | Solar panel | Ethiopia | 0 | 1 | 1 |
| | Solar panel | Vietnam | 1 | 0 | 1 |
| Grid electricity | Electricity | Ghana | 1 | 1 | 2 |
| Renewables | Financial instruments | Kenya | 0 | 2 | 2 |
| | Generation | Kenya | 0 | 1 | 1 |
| | Prices | Kenya | 0 | 1 | 1 |
| | Shared metering | South Africa | 1 | 0 | 1 |
| | Environmental policy | Chile | 0 | 1 | 1 |
| | Environmental policy | Colombia | 1 | 0 | 1 |
| Household air pollution | Willingness to pay | Chile | 0 | 1 | 1 |
| | Willingness to pay | Central America | 0 | 1 | 1 |
| | Willingness to pay | Colombia | 0 | 1 | 1 |
| | Industry | Colombia | 0 | 1 | 1 |
| | Employment | South Africa | 0 | 1 | 1 |
| | Industry | China | 1 | 0 | 1 |
| Energy and climate change/ carbon offsets | Environmental policy | Colombia | 1 | 0 | 1 |
| | Gas/oil | Colombia | 0 | 1 | 1 |
| | Environmental policy | Colombia | 1 | 0 | 1 |
| | Choice | Ghana | 0 | 1 | 1 |
| Gender and human capital | Education | Colombia | 1 | 0 | 1 |
| Transportation | Gas/oil | South Africa | 0 | 1 | 1 |
| | Prices | Colombia | 0 | 1 | 1 |
| | Environmental policy | Colombia | 2 | 0 | 2 |
| | Market | South Africa | 0 | 1 | 1 |
| Energy efficiency | Modelling | Colombia | 1 | 0 | 1 |
| | Water desalination | Colombia | 1 | 0 | 1 |
| | Financial instruments | Kenya | 0 | 1 | 1 |
| | Financial instruments | Colombia | 0 | 1 | 1 |
| | Willingness to pay | Colombia | 0 | 1 | 1 |
| | Behavioural aspects | Colombia | 0 | 1 | 1 |
| | Industry | Kenya | 0 | 1 | 1 |
| | Electricity | Ghana | 1 | 0 | 1 |
| Refining energy transition concepts, theories, and measurements | Access to clean energy (SDG 7) | South Africa | 0 | 1 | 1 |

Note: own elaboration based on countries' responses.

The geographic distribution of research grants is displayed in Figure 2 and suggests that the work has been heavily concentrated in South Asia and some countries in Latin America, while some regions in Africa are underrepresented. The latter is particularly noteworthy given the large number of EfD centres located in Africa, and the high relative shares of energy researchers in those countries.[9] This situation has three potential explanations that are not mutually exclusive. First, the centres of Uganda, Nigeria, and Ghana did not join the EfD network until 2019, and their shorter time in the network and the subsequent COVID-19 pandemic may have reduced their opportunities to collaborate with other researchers in the network to formulate research projects. Second, researchers in some areas may have benefitted from funding opportunities from regional NGOs or development agencies targeting local energy issues. Third, many relevant research questions affecting the African region have yet to be successfully translated into research projects. In either case, efforts have been undertaken (and must continue) to address energy-related issues and low-carbon and sustainable energy transitions of countries and populations that are at the low end of the research outputs distribution.

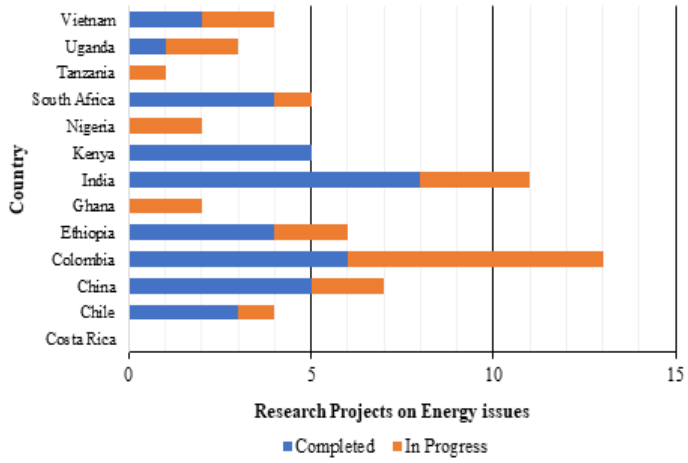



*Figure 2 Granted research projects on energy issues (2019-2021)*

Note: own elaboration based on countries' responses. Frequency denotes the number of countries with ongoing and completed research projects.

Funded research projects have contributed to the generation of knowledge while providing evidence on the main impacts associated with the studied issues. Figure 3 displays the distribution of research outputs during the period 2019-2021. Research products consist mainly of scientific publications in internationally peer-reviewed journals, which have exhibited an upward trend in 2021. Other related activities include guidance of postgraduate theses and discussions in the media (newspapers). Altogether, these activities have contributed to addressing local research gaps, while shedding light on potential research gaps that may need to be investigated in future projects.

[9] Note that figures correspond to the period 2019-2021, which may not be representative of the past distribution of funded projects in the studied countries.

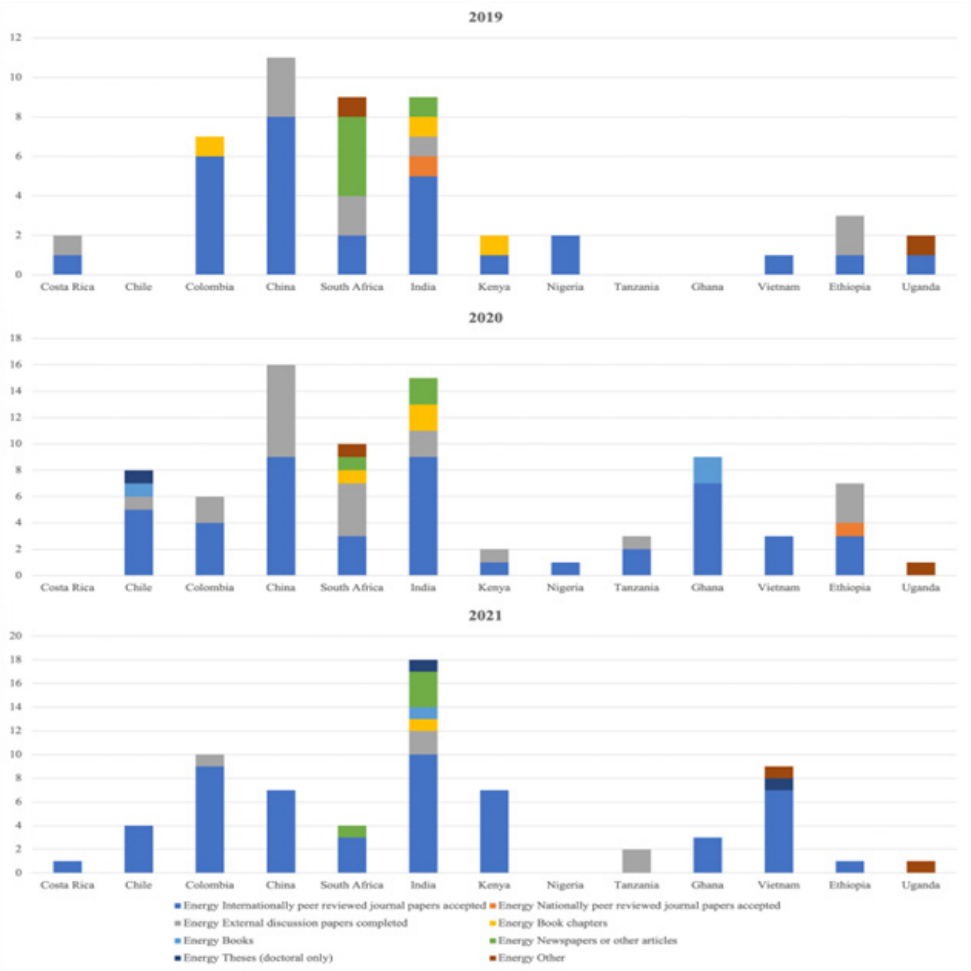



*Figure 3 Scientific publications on energy issues (2019-2021)*
Note: own elaboration based on countries' responses.

In addition, it becomes very relevant to understand the role that women researchers play within the centres/countries of interest. This is because women researchers could bring into the analysis several dimensions that may get unnoticed otherwise, which are especially vital when considering the topic of inclusive low-carbon energy transitions. Figure 4 shows the spatial distribution of the share of female researchers among participant centres. It can be observed that female participation is relatively higher in Asian centres compared with centres located in Africa and some regions of Latin America.

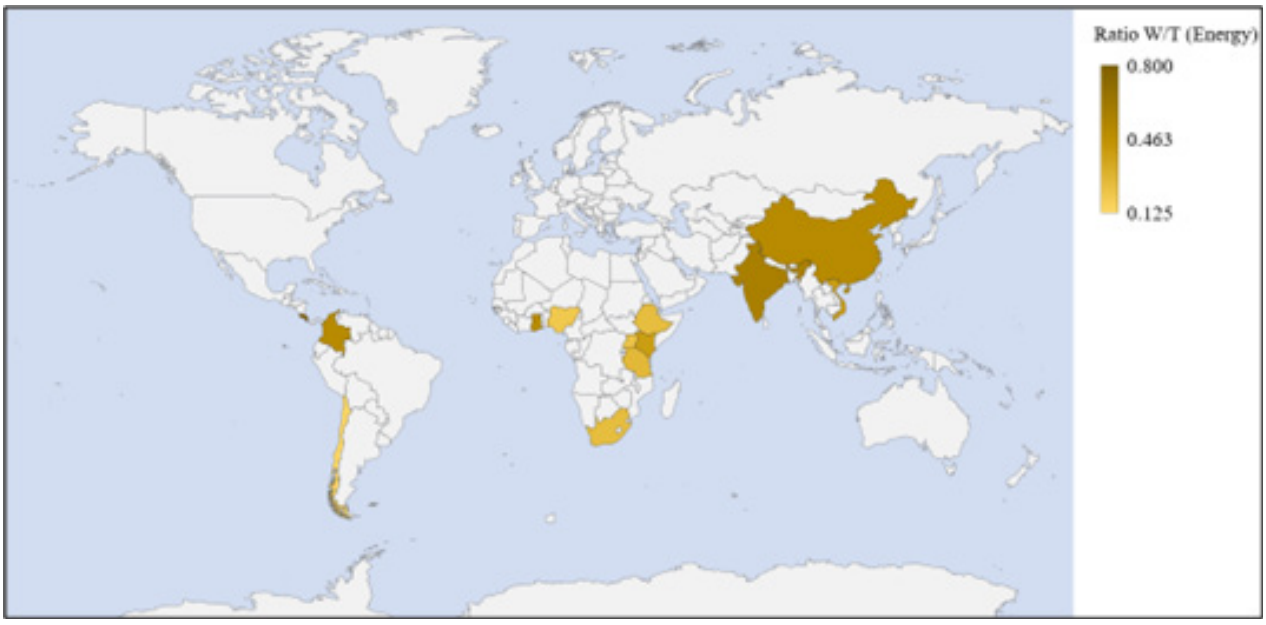



*Figure 4 Distribution of women energy researchers among studied countries.*Note: own elaboration based on centres' responses. Frequency denotes the number of women researchers on energy.

To analyze, descriptively, the link between female participation and a focus on gender aspects of energy transitions, we compute a correlation matrix including the number of research projects addressing issues associated with the energy-gender nexus and the number of male and female researchers. To this end, we generate a dataset based on the information reported by each centre to calculate the Pearson correlation coefficient. [10] The correlation matrix is displayed in Table 3. We observe a positive correlation between the number of female researchers and the number of energy-gender nexus projects conducted by a centre. A similar result is obtained when focusing on the number of female energy researchers. These coefficients are statistically significant at the 5% level. In contrast, the correlation coefficients tend towards zero (and are statistically not significant) when focusing on the number of male researchers and male energy researchers, respectively. Despite the limited number of research projects addressing these issues, this exercise sheds light on the importance of enhanced female participation as a potential mechanism to propose and understand the gender aspects of sustainable energy transitions.

Table 3 Correlation between the number of researchers and the number of energy-gender research projects

| | Number of research projects in the energy-gender nexus | Women researchers by country | Men researchers by country | Women energy researchers by country | Men energy researchers by country |
|---|---|---|---|---|---|
| Number of research projects in the energy-gender nexus | 1 | | | | |
| Women researchers by EfD centre | 0.64** | | | | |
| Men researchers by EfD centre | 0.03 | 0.43 | 1 | | |
| Women energy researchers by EfD centre | 0.64** | 0.24 | -0.04 | 1 | |
| Men energy researchers by EfD centre | -0.04 | -0.30 | 0.01 | 0.22 | 1 |

*Note*: own elaboration based on centres' responses. * $p<0.1$, ** $p<0.05$, *** $p<0.01$.

[10] This coefficient is calculated as follows: $\hat{\rho} = \frac{\sum_i^n [(x_{1i}-\bar{x}_1)(x_{2i}-\bar{x}_2)]}{\sqrt{\sum_{i=1}^n (x_{1i}-\bar{x}_1)^2}\cdot\sqrt{\sum_{i=1}^n (x_{2i}-\bar{x}_2)^2}}$.

As a final point, the last portion of the questionnaire was devoted to gathering information on the relative importance of investigating gender aspects of energy transitions. Despite the importance of these topics based on the empirical literature and the local policy processes, few centres/countries (India and South Africa) recognize its relevance in their research agenda. In contrast, a set of countries (Chile, Nigeria, Ethiopia, Kenya, Tanzania, and Vietnam) acknowledges that the energy-gender nexus should be part of their ongoing research activity, despite not being regarded as relevant in the past. Results highlight the importance of fostering collaboration within and between centres and research teams in the future to identify and address research gaps in this domain. An exercise of this sort could also help in analyzing the extent to which an apparently local problem could also be relevant in other contexts, which could provide important insights to prioritize areas/problems of interest.

### 1.4.2 Ongoing policy processes: Identification of gender gaps through the lenses of intersectionality and gender equity

This section summarizes the main findings of the interviews that were conducted during the period March-May (2022). For this purpose and based on the written survey responses provided by each centre, a second questionnaire was designed and used to guide a semi-structured interview (available here). Interviews were conducted online, via Zoom, and interviewed researchers granted permission for the meeting to be recorded to facilitate the analysis of responses.[11] Because semi-structured interviews allow discussing some issues that may not have received sufficient attention in the centres' written survey responses, we focused parts of the interview on gender aspects of energy transitions, energy access, and intersectionality.[12]

To leverage differences in the ongoing policy processes with the potential of affecting both access and uptake of low-carbon energy sources, we use the World Bank country classification (2022)[13] to split our sample of countries into three groups (i.e., low-income, lower-middle-income and upper-income countries). Each of these groups takes account of a country's development status while allowing for regional comparisons, which could support prioritization of identified gaps and subpopulations of interest. In the following paragraphs, we present the main aspects extracted from each country team interview.

#### *1.4.2.1 Low-income countries*

##### *1.4.2.1.1 Ethiopia*

Cooking energy transition in rural areas is a paramount issue in Ethiopia, as many households lack access to basic electricity, including lighting. Researchers from EfD Ethiopia indicate the need to foster energy transition towards off-grid electricity, moving up the energy ladder, but also to make productive use of energy sources and aid environmental conservation. For example, in terms of agriculture, there are problems with deforestation and soil degradation, making it necessary to have more efficient energy sources and processes.

Moreover, in terms of energy demand and supply, ongoing policy processes are strongly related to the management of the supply of energy, and more specifically the electricity sector (e.g., private and utility aspects, and technical issues). On the other hand, problems related to the demand side indicate that tariff reforms and their impacts on residential and non-residential customers should be addressed, especially in light of current national tariff reform efforts.

Regarding regional differences, researchers of EfD Ethiopia indicated that these problems are ubiquitous in the country, though urban-rural differences arise depending on the problem. For example, in terms of electricity, urban households have been more affected than rural ones, and in terms of cooking, there are differences in cooking habits that reflect cultural differences among regions. Moreover, because women are responsible for cooking, they and their children are most vulnerable. Children of 10 years old, or even less, are often involved in cooking activities, and therefore affected by indoor air pollution (smoke), especially in rural areas. This problem is also present in urban localities, with the difference that households typically have access to electricity (mainly used for lighting), though cooking remains heavily reliant on solid fuels.

Despite the presence of these problems, researchers recognized that there is a need to develop more research in

11 Full transcripts of the interviews are not included in this paper, but the set of recordings can be accessed upon request.

12 Please note that the information presented in this section corresponds to the views and perceptions of the interviewed energy researchers. They may not reflect the work/advances made by national and local governments in relation to gender aspects of energy policy, nor account for the work conducted by other researchers not associated with EfD.

13 This classification was retrieved from https://datahelpdesk.worldbank.org/knowledgebase/articles/906519

the energy domain, to support public policy on energy (and gender) which has been part of the agenda for more than ten years. Indeed, they indicated that they still have a very weak connection with ongoing policy processes in the country, which requires getting involved with more policy actors and more activities. Nevertheless, they have started to make efforts to connect with the government, especially through invitations to participate in policy reports, workshops, and writing of policy briefs that highlight research results.

#### *1.4.2.1.2 Uganda*

Poverty and forest depletion are major problems that relate to energy policy in Uganda, given high levels of deforestation related to cooking activities. Indeed, researchers at the EfD centre in that country indicate that affordability is an issue, especially concerning liquefied petroleum gas (LPG) and other new technologies and fuels, which are still very expensive for much of the population. Researchers recognize the importance of focusing on the affordability of energy transition. A second problem that Uganda faces is air pollution, especially related to the heavy use of motorbikes, mostly in urban areas, which generate health problems among the population.

In terms of region, rural areas are the places where unclean fuels are most heavily used since households have access to cheaper and even free firewood or charcoal. Alternatives like LPG and electricity are not as available in many areas, and the country lacks a fully grid-connected system. This problem must be addressed with policy that incorporates improved biomass cookstoves, especially in the rural context where the negative externalities of traditional technology use for cooking are higher. This problem also has an urban dimension, as households demand charcoal from rural areas, where this fuel is made and then transported to the cities. Urban households also face problems of affordability.

Related to gender, researchers indicated that women are directly affected by the cost of LPG because it is very expensive for them, straining the household budget, even as it lessens time constraints arising from highly gendered domestic responsibilities (e.g., family and work time). Indeed, cooking activities are conducted by women, with very little involvement from men. Improvements on this issue will therefore most benefit women, especially when they along with children are exposed to household air pollution (e.g., respiratory diseases are present more often in both groups than among men). In addition, women's empowerment appears to be very low in Uganda: men dictate which meals will be cooked, and which energy source will be used. This imposes time and other costs on women: cooking with unclean energy sources takes up to 6 hours for some traditional meals, while using LPG or electricity could reduce it and liberate women to engage in other activities (including outside the house). An energy transition in Uganda is therefore crucial for women wanting to expand their activities or work paid jobs, which in turn would increase their empowerment.

Moreover, energy researchers recognized three vulnerable groups via intersectionality that should be studied: (i) women who use charcoal for cooking in poor rural areas; (ii) poor women living in urban areas, especially in slums; (iii) people involved in the food system, e.g., farmers (including women), who are very sensitive to changes in prices, especially when prices for inputs increase.

From the perspective of public policy, changes in energy prices have been targeted, especially at the household level, directly benefiting women, since they are the ones responsible for cooking, and access to cleaner energy sources reduces their cooking time. Moreover, gender is a cross-cutting issue, being currently applied to almost every policy in the country, and researchers at EfD Uganda noted that they have expanded the concept of gender to adopt a more inclusive perspective in their studies, something that could also happen in the government.

In terms of research, existing studies in the context of Uganda do not recognize properly the definition of gender; the concept is generally operationalized as a binary variable (as in many countries analyzed in this study). Researchers recognized that gender issues require greater attention in studies and for incorporation into policymaking.

### *1.4.2.2 Lower-middle-income countries*

#### *1.4.2.2.1 Ghana*

As in Ethiopia, researchers at EfD Ghana indicated that cooking fuels are a key issue in the country. Though the transition to cleaner fuels has begun to accelerate, households still rely heavily on charcoal for this activity. This is particularly related to the low availability of modern fuels (supply-side effect), incompatibility of current technology with new fuels, preferences of households to keep using traditional fuel (for example, not using LPG to cook tilapia), and the high prices for modern fuels. Rural areas are more disadvantaged in terms of energy transition; data indicate that rural households mostly depend on solid fuels. Indeed, even high-income consumers still rely on traditional fuels in rural areas, giving little support to the energy-ladder hypothesis.

Regarding electricity use, the researchers recognize there have been significant gains. However, restrictions remain on the supply side. The government has worked on improving access and security, by supporting plans for mini-grid expansion and improving access to renewables,

but implementation remains slow. Moreover, there are high levels of uptake of stand-alone solutions in rural areas, since these are less connected to grid electricity. This issue is very important to the national agency, which is prioritizing efforts on mini-grid provision.

In terms of gender, there are very large inequalities between women and men, with women devoting most of their time to fuelwood collection for cooking, while men have access to more productive and better-compensated market activities. As in Ethiopia, children are affected along with women; this is even more true in rural areas (urban households have more access to modern fuels). Indeed, in these places, children are involved in cooking activities along with women, and thus affected by air pollution, regardless of age. Differences in terms of gender are even greater because of social norms, since collecting wood may be considered a social interaction activity for women, especially following marriage.

From the policy side, there has not been a strong focus on gender as a priority in energy sector decision-making. Indeed, most energy programs do not include a gender perspective, and the few that consider this issue do not have a clear focus or defined objective (e.g., the renewable energy national plan has no focus on gender). The EfD Ghana researchers think their centre must be more involved on these issues, however, and they recognize the need for strong participation with stakeholders in their country. For example, the centre has participated in several meetings with policy actors and the energy commission, including interactions with the Ministry of Energy, especially regarding energy efficiency and consumption. They have engaged well with policymakers in both formal and informal gatherings, presenting research results.

In terms of research priorities, there is a recognition that Ghana is not transitioning quickly enough to cleaner sources and technologies. For example, the energy ladder theory[14] does not hold in this country, since households tend to use more than one fuel for cooking (e.g., when LPG is not accessible, they move back to more polluting energy sources), and negative outcomes are substantial where modern technologies are inaccessible. Cultural factors are at play in slowing the transition, and research needs to keep focusing on how to reduce negative impacts.

#### *1.4.2.2.2 Nigeria*

Three main ongoing policy issues are recognized in Nigeria: (i) there is limited use of clean cooking energy sources, partly owing to high energy prices for such sources, which leads to reliance on inefficient energy alternatives and results in deforestation; (ii) high indoor and outdoor pollution comes from the incomplete combustion of energy sources, waste, and plastics pollution; and (iii) there are increasing concerns about climate change, since fossil energy sources are large generators of GHG emissions in Nigeria. In addition, the researchers recognized that there are very major challenges in electricity provision, especially in terms of off-grid electricity, mini-grids, and renewable energy. They indicated that there has been some progress on discussions and analyses of these issues in the literature, especially regarding the transition to LPG for cooking, and improved pricing of electricity. However, gaps remain, particularly on the nexus with poverty and gender.

There are special issues related to rurality. Rural households depend heavily on charcoal for cooking, since they are not able to afford LPG. However, the Nigerian government has announced greater use of subsidies for financing LPG, which should support the transition to cleaner sources in the future. Another important problem in both rural and urban areas is transport.

In terms of gender, women and children tend to oversee domestic labour activities, including cooking and fuel collection, while men spend most of their time outside the home. Because of the lack of opportunities to undertake paid jobs outside the house, women face the most acute poverty. These phenomena are intensified in rural areas. Consequently, the most vulnerable group is young women living in rural areas, who are primarily in charge of children. There is thus a clear intersection between gender, heading the household, poverty, age, and rurality. Additionally, access to lighting services is gendered: women rely most heavily on this service for security at night, as well as for studying and productivity, given their many responsibilities during the day. To address these issues, policy plans are increasingly recognizing the energy-gender nexus (e.g., including gender in the climate change agenda). Policies also consider the effects of energy-related pollution, and Nigeria's nationally determined contributions (NDC) for climate goals clearly address the cooking problem and put a

[14] This theory suggests that households completely switch the fuels they use with increasing income (Kroon et al. 2013). Thus, while developing countries are most likely to rely on biomass, as income increases, fuel choices exhibit the following hierarchical ordering: biomass, kerosene, LPG and electricity.

priority on the use of renewable energy.

Finally, the researchers recognized the interaction with many groups in the country to address these issues, including the Nigerian Cooking Alliance, which is building an agenda for policy in Nigeria, working directly with policymakers, and strongly engaging the Ministry of Environment. They recognized that they have identified the gender dimension in energy problems along with policymakers; though these meetings are not necessarily gender-focused, this dimension is nearly always present in discussions.

#### *1.4.2.2.3 Kenya*

EfD researchers in Kenya recognized three main energy problems in the country: (i) air pollution due to carbon emissions from industries and vehicles, (ii) air pollution in the country due to use of solid fuels for cooking and lighting, and (iii) forest degradation due to dependence on fuelwood to produce energy. They also recognized issues related to energy efficiency, energy pricing, and transport, indicating that Kenya has relatively few alternatives for traditional and fossil fuels, and weak or inconsistent incentives favoring LPG. In this sense, they indicate: "we are trying to transition, but it seems that we are taking steps back on that."

Household air pollution due to cooking is a problem throughout the country. Differences may arise based on location: in rural areas, reliance on wood is substantial, while in urban areas commercial fuels such as charcoal, kerosene, and LPG are used both for cooking and lighting, and the electricity generation mix relies on fossil fuels. In general, rural and remote areas in the country struggle with access to energy, especially owing to high energy prices and transportation and fuel availability challenges. Indeed, many households travel long distances to obtain energy sources for cooking.

Researchers indicated that there is an important nexus between gender and energy, since the effects of increasing prices for fuel differ between women and men. Women generally have fewer resources or bargaining power. Moreover, access to cleaner sources of energy is more time-saving for women, given their responsibilities. Indeed, LPG uptake has been shown to sustain and encourage women to spend their time in productive activities. Increasing energy efficiency should therefore be a continuing priority.

In terms of intersectionality, rural women are the most vulnerable group within the country, followed by people living with disabilities and others lacking access to employment. Women living in conflict areas are most affected. Also notably, Kenya is currently facing challenges related to water availability, and has many refugees arriving from neighboring countries. This population of immigrants is very low-income and presents special challenges to the transition to better energy systems. Another important and vulnerable set of groups that should be studied more are women with low educational levels and women who live in rural and urban slums. To address these issues, the government has proposed an agenda for discussion, and researchers expect that this implies increased attention to gender in policymaking.

In terms of research, several topics have been studied in the country, including cooking choices and technology preferences, especially in rural areas. However, there is a need to address the effects of energy pricing on welfare, the share of income spent on energy services, and how these topics are related to gender. The team raised the need to identify vulnerable groups in the country and determine ways to improve the welfare of members of these groups. Regarding EfD Kenya projects, the researchers have participated in three main types of studies related to the energy-gender nexus: (i) domestic financing for decentralized renewable energy; (ii) cost, returns, and investments over renewable electricity generation; and (iii) energy efficiency in the Kenyan manufacturing sector. Moreover, there is an ongoing pilot study on evaluating the benefits of using LPG for cooking in Kenya, with a special focus on gender, which expects to reveal the effects of using improved cooking fuels on health.

The researchers raised the need to improve connections with policymakers to apply the results of these and future projects related to energy. Moreover, they raised the need to create collaborative projects, making sure that these gaps are highlighted and well communicated to stakeholders from the private and public sectors.

#### *1.4.2.2.4 Tanzania*

In Tanzania, residential energy generation heavily relies on the use of biomass, especially firewood and charcoal. This is particularly important in the domain of cooking, with 90% of urban and 99% of rural populations being exposed to high levels of household air pollution. Thus, deforestation and health problems related to air pollution exposure are major environmental issues in the country. The latter is exacerbated in major cities because of the use of obsolete technologies in many industries, and the increasing number of fossil-fuel-dependent and inefficient cars.

Women are most affected by these issues, along with the children they care for. Women tend to be responsible for wood fuel collection, and high levels of deforestation have forced women to walk increasing distances from their homes to find supplies. This increases the risk of attacks not only from violent individuals, but also from wild animals. Indeed,

in terms of intersectionality, researchers recognize that these risks are greatest for women in rural areas and with less education.

The charcoal industry, which mostly uses men, provides access to opportunities that are not available to women. The highly gendered dimension of the charcoal business creates a significant energy-gender nexus problem, whereby some men have a vested interest in perpetuating reliance on polluting fuels in the country. Women and their children, meanwhile, are mostly bearing the costs of this dependence, given their roles in household chores and firewood collection.

Researchers indicated that these topics are partially being addressed in the literature. While there are insufficient studies in Tanzania related to the use of fossil fuels associated with transport air pollution in cities, literature is highly focused on cooking technologies and impacts. More must be studied regarding energy use in: (i) the transportation sector, and the switch to cleaner fuels and their impacts; (ii) small and medium enterprises (SMEs); and (iii) manufacturing industries. Researchers indicated that the gender dimension has been considered in public policy, not only in terms of energy, but also as it relates to water issues. Despite the very binary considerations of gender in these cases, the team indicated that there are intentions to extend the definition of this concept and to consider intersections with other vulnerable groups in the country.

Finally, the EfD Tanzania centre has been heavily involved in raising the discussion on energy issues in the country. Every year, they invite policymakers to interact with them and to present findings about their research, creating an avenue to influence the key issues in the country, including insights and possible reforms. Moreover, they actively contribute in advisory committees, have evaluated energy-related projects (e.g., the Cook Fund Project), and have worked actively on the Energy Policy of Tanzania and with the Vice President's Office (working on an important report during 2018-2019).

#### *1.4.2.2.5 India*

In India, ongoing policy discussions related to energy mainly relate to continuing high generation from coal burning, air pollution sources and impacts, from households, coal-fired power plants, illegal crop burning, vehicles, and other sources. The researchers at this EfD centre also recognized the existence of a food-energy-water nexus problem, especially in agriculture, which has been addressed through a solar pumping project, with small farmers benefitting the most from implementation.

Household air pollution is most severe in rural or semi-urban areas, where many households continue to use firewood to meet their energy needs. Indeed, respiratory problems are common among people most exposed to this energy source, especially women, who are responsible for cooking, and children, who spend more time at home with their mothers or helping with household chores. Given the lack of use of improved cooking technology and the time spent in the house, these groups are most exposed to household air pollution. And despite awareness of this problem, researchers indicated that households do not always recognize it, or are not aware of the negative effects of air pollution, raising the need to consider behavioural dimensions more thoroughly.

In terms of intersectionality, gender and caste interact for vulnerable groups, especially disadvantaging women in lower castes. Moreover, the transition to LPG is strongly correlated with income, while usage of cleaner sources is related to whether women are educated and to exposure to media. Indeed, low-income households often lack savings to pay for LPG cylinders, reducing their access to this cleaner energy source; affordability is also a greater concern in rural areas.

In terms of policy actions, researchers believe that there is a gap regarding policy dialogue (researchers meeting with policy actors), but also in terms of research, raising the need to provide more evidence (evaluation), and better communicate these results to policymakers. Much has been done from the EfD India centre to contribute to this aim: they have collaborated with the Centre for Policy Research (CPR), a leading government think tank, to inform on policy actions for mitigating air pollution burdens, and to recognize that implementation remains a serious challenge. Moreover, they have participated in policy days with stakeholders in India and have worked on several energy-gender-related research projects since 2019.

Despite the explicit inclusion of the energy-gender nexus in Indian government dialogues and the work of EfD researchers in the country, challenges impede the production of rigorous long-term evidence, especially regarding air pollution. There is a significant issue with the quality of administrative data, which constrains impact analysis to simulation tools and models as opposed to empirical analysis. Addressing this gap will not be easy but must be a priority to improve studies related to the energy sector in India.

#### *1.4.2.2.6 Vietnam*

The ongoing energy policy process in Vietnam is related to: (i) air pollution, especially in major cities and industrial provinces in Vietnam, arising from transportation, construction, and industrial production activities; (ii) heavy national reliance on imported fuels, and high demand for energy, increasing the levels of energy insecurity because of

the uncertainty regarding the availability of biomass from suppliers; (iii) carbon taxes and establishment of a carbon market; and (iv) the increasing number of hydropower plants which may create social and environmental problems, i.e., flooding, drought, deforestation, and migration. Researchers at the EfD-Vietnam centre indicated that there is a transition from fossil fuels to renewable energy, but that there is concern from policymakers regarding the high costs of this shift, which may stall or slow development. Nonetheless, the transition has included the use of hydro and solar plants, as well as renewables, aiming to lower dependence on coal, although efforts should also be made to reduce emissions related to transportation, specifically diesel fuel motorbikes (that use large amounts of fuel). More actions are needed to foster a transition to electric bikes and to reduce air pollution in cities and industrial sites (e.g., in the North of Vietnam, there are problems related to the industrial use of coal, but also to air pollution coming from China).

Researchers noted that people from rural areas are more vulnerable to these problems, especially those who live near power plants and industrial zones. In big cities, the poorest suffer more since they lack the resources to pay for clean technologies and access to clean air devices such as air filters. In urban areas, many people do not have cars, and therefore are exposed to high levels of roadside emissions when they walk or use motorbikes. Researchers indicated that most of these problems are not properly addressed in Vietnam, and there is a need for empirical studies of these problems.

In terms of gender, the team highlighted that, in South Asia, women are the main victims of air pollution since, as in many countries in the EfD network, they are the ones responsible for cooking and household activities. However, many women now use gas cookers, and are transitioning to electric cookers due to the increase in LPG prices. The researchers also indicated that women use motorbikes very often (more in rural areas), especially for household chores, and are a key constituency for promoting a transition to cleaner bikes. In general, studies of gender-related energy issues are rare in the country.

To tackle these problems, the EfD Vietnam centre has contributed to the revision of air quality laws (e.g., by providing input regarding economic and market-based instruments, and addressing environmental problems in general), monitoring air pollution in the country, and working along with the World Bank evaluating environmental performance. The overlaps with poverty and air pollution are key issues to be addressed.

#### *1.4.2.3 Upper and middle-income countries*

##### *1.4.2.3.1 South Africa*

The researchers at the EfD South Africa centre recognized that energy issues in their country are related to power outages and an energy-intensive coal-based economy, whose environmental costs are not fully internalized. This problem is accentuated by the lack of enforcement when municipalities do not pay their energy bills. Despite the fact that prices of coal-based energy in South Africa are not as high as in the developed world, they are increasing, posing a problem for the poorest groups of the country who rely more on this energy source, instead of modern options (which they typically lack). Moreover, researchers indicated that the energy matrix relies strongly on carbon. Big efforts are underway to enable a cleaner energy transition, but private firms producing green energy face difficulties with integration into the system (injecting the green energy into the grid). Additionally, energy storage infrastructure is deficient, impeding the saving of solar electricity and its addition to the energy matrix, and there is intermittency in the provision of the service, both in generation and distribution. The severe energy supply problems with outages in the country affect energy security. Hydropower electricity sources, imported from Mozambique and Lesotho, are vulnerable to drought.

In terms of gender, the researchers indicated that women living in rural areas are highly exposed to pollutants from wood burning for cooking. In addition, they use a large portion of their time to collect this energy source. This is a general problem in Africa, where more than 75% of households rely on biomass for cooking.

From an intersectionality perspective, researchers indicated that poor women and children from rural areas are the most vulnerable groups. However, there is evidence for poor urban areas too, especially in slums. This group of households have limited access to lighting, which has a detrimental effect on people's security. Moreover, they use paraffin for lighting and indoor wood burning for cooking; these fuels create health costs, especially for women and children.

For tackling these problems, gender is very well included in the South African policy agenda: they put the most vulnerable groups first in their activities to secure access to healthier energy sources. Researchers at the centre have contributed to this purpose, as discussants at a senior policy seminar organized by the African Economic Research Consultant, and by interacting with policymakers on issues related to sustainable development, climate change mitigation, and renewable energy.

#### 1.4.2.3.2 China

China is committed to achieving a goal of carbon peaking in 2030 and carbon neutrality in 2060. For this purpose, the country is working towards an energy transition away from fossil-based energy to clean and renewable sources, including wind, solar, and hydrogen energy. China is also making efforts to enhance sustainable management of forests, as it is recognized that these work as carbon sinks, absorbing more carbon from the atmosphere than they release, and helping to mitigate air pollution. The researchers from EfD China indicate that there are side benefits from reducing air pollution, and it is important to include such co-benefits in evaluations of different policies in the country, including those that affect incipient carbon markets. In China, most problems related to energy come from industry, and people living around polluting facilities are most affected by pollution. There are also local problems with forest management, especially because of the inconsistencies arising from decentralized management and centralized administration of resources (e.g., through carbon credits). This situation has led to unintended effects of policies in the form of pollution.

Researchers in the China centre recognize that air pollution in some rural areas continues to stem from the use of coal for cooking. Indeed, there is strong dependence on this energy source, and much employment remains in the coal industry, posing a challenge to policymakers seeking to foster a transition to affordable and clean energy sources. As such, the rural population and coal industry workers are part of the intersection group defined as vulnerable.

In terms of gender, China does not include this dimension in its energy policy. Overall, energy policy in the country is mainly focused on the industrial/production side, more than the household side. This gap pertains more generally to the country's environmental policy and extends to other vulnerable groups. This also matches with the reality of research, where most energy-related papers are dominated by a perspective from engineering and technology, while neglecting economics (and therefore, environmental economics) and social science views.

The EfD China centre is currently working with universities, centres, and government agencies (e.g., The Ministry of Ecology and Environment), through a task force aiming to help in the policy design of markets (e.g., through the design of auction/option mechanisms, which have been approved by the government). Moreover, during 2021 and in the context of the energy crisis in the country in response to the Russian-Ukrainian conflict, the centre submitted policy reports to the government and organized conferences to discuss these issues. It is important to note that during this crisis, the government interrupted power supply, mainly affecting the industrial sector. To promote energy security, researchers from EfD China proposed solutions to the government that relied on carbon taxations and markets.

#### 1.4.2.3.3. Colombia

The main energy problems described by researchers at EfD Colombia involve air pollution in major cities, given the high level of economic activity and transportation in such areas; promoting the security of energy supply and energy transition; and the need to increase electricity generation capacity. In terms of air quality, the centre has studied air pollution not only from the fuel/energy dimension, but also through traffic-reducing interventions with the potential of reducing exposure to particulate matter (PM). Regarding access to grid electricity, in addition to power plants, transmission lines are far from many residents. Because the absence of this key infrastructure, people in these areas cannot be connected to the grid, impeding energy access. Researchers explain that, in the Andes mountain system, there is a grid system that connects all the cities; outside this system, off-grid systems become relevant, especially because of high solar potential, even in places like the Chocó region, where the weather is rainy and cloudy. Regarding other technologies, such as wind and hydro, the country has the advantage of great offshore potential and access to many rivers.

Special attention has been given to cities, especially Bogotá. In a local study of ambient air pollution, the impacts of pollution were found to be heterogeneously distributed over space (Bonilla et al. 2021). Indeed, the study found that individuals living in southern Bogotá had poor levels of energy access, as well as lower access to services such as health/hospitals and poor quality of streets. This highlights the intersection between poverty and general lack of access to infrastructure. Moreover, there is high concern about the security of supply. In cities like Bogotá and Medellín, expressed willingness to pay for electricity services has been shown to be low, seemingly because households expect the state to provide low-cost access to reliable electricity. However, this is not the case for the Caribbean, where households and firms have their own diesel plants, which are expensive and inefficient. Researchers describe the existence of a culture of non-payment because of frustration over inefficient and unreliable service.

Researchers noted the need to improve energy efficiency in their energy matrix. They indicate that efficiency should also be directed to cooling systems, especially in high-temperature places such as Cartagena de Indias. Indeed, the demand

for cooling systems, especially air conditioning systems, is increasing every year given climate change and heat island effects in populous areas.

The problems of air pollution, energy security, and energy supply and access have differential effects across groups. For example, off-grid and non-interconnected areas are typically also high poverty zones; increasing coverage is thus an important issue for decreasing poverty. Colombia has a "strata system" that uses prices and subsidies for electricity and other public services to support energy access among different segments of the population. This system has shown a good performance while being socially accepted. However, increase in revenues to improve energy access from polluting sectors such as transport through similar schemes do not seem politically feasible. This is because air pollution control policies have mainly focused on promoting individuals' transitions to electric/hybrid cars (who are a smaller group than those that use fueled cars and public transport). This is an important issue to be addressed, since many people travel via motorbikes, generating substantial air pollution, especially given the lack of reliable public transportation systems.

Researchers indicate that the energy-gender nexus is not well understood, yet there is a growing interest in studying some of these linkages as part of their research agenda. Besides efforts to develop a research project on education-gender-energy aspects of off-grid systems (a very preliminary idea at this stage), there has been interaction with policymakers in the areas of energy and education to promote micro-investments in solar panels.

Researchers also indicate that there are different opinions on the conceptualization of gender (especially in Universidad de Los Andes), which is a sign of a move towards a more progressive and open conception of gender. This is also seen in the government, and will surely impact how gendered aspects of the energy transition are seen in the future.

Finally, the researchers at EfD Colombia highlighted two vulnerable intersectionalities: (i) poor women living in non-interconnected areas, who are often heads of households affected by violence (specifically sexual violence); and (ii) indigenous communities that have their own regulation and that also have high levels of wind potential (specifically in Alta Guajira, in the North Caribbean). The latter is a very interesting case, since having electricity is not a culturally embedded priority for people in these communities. Energy has been implicated in conflicts because indigenous people often defend their territories against the installations of energy companies.

#### *1.4.2.3.4 Central America*

The EfD centre of Central America is based in Costa Rica, and analyzes both national issues and those of neighboring countries. In terms of energy issues, the use of firewood for cooking in Costa Rica is not a problem, but it becomes relevant in other countries such as Panamá, Guatemala and El Salvador. In Costa Rica, most households rely on electricity for cooking, even in rural areas. The main energy issue in the country is decarbonization, especially as it relates to challenges in the transport sector in urban areas (also relevant in other countries of the region). Decarbonization is also related to the environmental program "Payment for Environmental Services", which is financed via fossil fuel taxes. However, this poses a future constraint on this program, since reducing the levels of fossil fuel consumption will lead to the loss of funding for this program, a topic that is highly debated in Costa Rica.

Other very important topics are hydropower electricity and energy production from biowaste. Researchers recognize that hydropower has had severe negative environmental effects, and given high reliance on it, the question now is how to secure energy supplies that for the future that are less damaging (i.e., a complex tradeoff between climate change, local environmental impacts, and energy security). On the latter, there is potential to use biowaste to produce energy in the country, which may lead to the reduction of pollution in the environment (i.e., waste to energy via biogas production).

In terms of gender, the centre recognizes that women in Central America generally cook with firewood as the energy source, and that roles between men and women on this purpose are very differentiated. Moreover, in terms of intersectionality, the researchers identify the following vulnerable groups: (i) low-income households in indigenous communities, especially in Guatemala and Honduras, with women having little decision-making power and low educational levels; and (ii) in Costa Rica, low-income immigrants from Nicaragua, Guatemala, Honduras, and El Salvador. In the words of Roger Madrigal (EfD Central America Director): "Not long ago I saw in person people walking here, not only from Central America, but also from South America. This creates pressure on various public services and does not seem to be an issue that has a solution. Immigrants have absolutely nothing, not even for one tortilla a day. That immediate need is there and sometimes the environmental issues seem to be secondary. Migration seems to be a very important factor."

In terms of policy actions, researchers indicated that gender issues have been strongly incorporated lately, but that the impacts and outcomes of such actions are not

clearly understood yet. There are now a large number of projects focused on women. For example, in the "Payment for Environmental Services" program, gender criteria are used to allocate credits. In this program, if women are single and belong to a rural sector, they get extra credits. This is important for a just energy transition policy, where equal rights apply to women, young people, and marginalized segments of society. Researchers recognize it is an obligation for them to include these issues in future policy engagement activities, especially because research in this topic is very scarce on the region.

Finally, in terms of the centre's interaction with policymakers, they recognize a lack of direct influence on policy issues on energy and gender. However, centre researchers do interact via some projects. For instance, they have worked on waste management and the potential to create energy, and they have discussed with policymakers the future impact of wind energy. Researchers also recognized the importance of conserving national areas, since in Costa Rica, national parks are untouchable.

*1.4.2.3.5 Chile*

In Chile, air pollution is a critical energy-related problem; more than 9 million inhabitants (48% of the population) are exposed to poor air quality. Indeed, around 3,600 people die each year from diseases associated with chronic exposure to air pollution, especially in central and southern Chile. Air pollution is mainly related to household burning of wood for heating in urban areas, which highlights the reality that household air pollution is not an issue that affects only lower-income countries. Its negative impact increases with poor dwelling insulation, low comfort, and energy poverty (as indicated by a large share of income spent on fuel), especially for households seeking to reduce spending on expensive clean fuels such as electricity and LPG. Other topics that are trending towards greater policy importance in Chile include: (i) solar generation of electricity, which will be strengthened in the new Energy Agenda of the government: (ii) generation of energy from green hydrogen (with impacts on the industrial sector); (iii) implementation of electromobility, which is a new topic with several gaps to be addressed; and (iv) inter-regional externalities imposed by the mining industry (lithium and copper production) on people's health and well-being.

Energy policy processes and consequences are very heterogenous across the country, with negative externalities related to industry in the north, while households are the primary air polluters in the central and southern zones. The high price of energy affects many households and has increased energy poverty throughout Chile; this dynamic plays an important role in the continued use of wood and other non-sustainable energy sources for heating. Nevertheless, researchers recognize that data and studies are lacking, particularly in rural areas.

Regarding intersectionality, researchers recognize the following groups of vulnerable individuals: women from low-income households, often living in rural areas (though this intersection needs to be explored), and migrants (given the high rates of migration during the last decade, and the precarious status of this group). Moreover, there could also be an intersection with indigenous populations and cultural aspects in the use of wood for heating. These intersections should be carefully studied and account for geographic diversity, and the lack of policy and research regarding the energy-gender nexus is a major gap in current work (there has only been one study on gender aspects of energy poverty in the Chile centre).

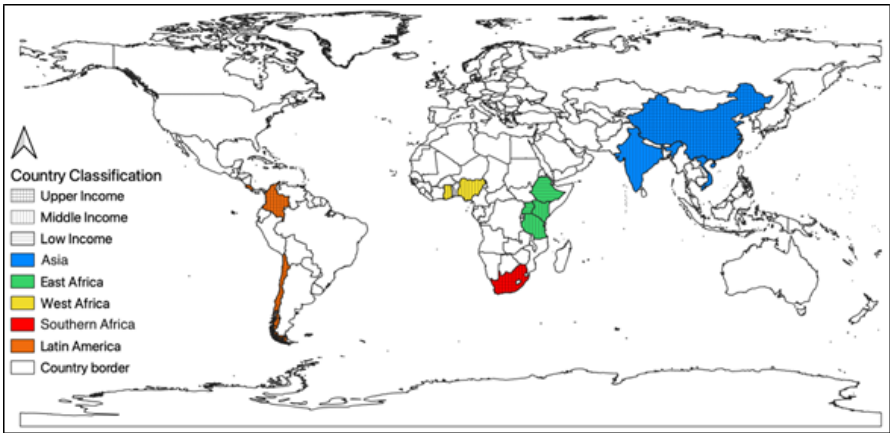
Regarding the state of research on energy in the Chilean context, the following issues can be recognized: (i) there is strong emphasis on the household level, while studies of industry need to be developed; (ii) there are studies related to decarbonization and its impacts in the labour sector; (iii) there are few studies on the supply of energy (the literature is highly concentrated on the demand side); (iv) there is a bidirectional relationship between poverty/inequality and environmental interventions and policies that needs to be addressed (e.g., how to consider inequality in the design of interventions, considering that cities are heterogenous, unequal, and socially segregated); and (v) there is a need to see how people perceive energy transition and how these perceptions influence behaviour.

In terms of contribution to public policy processes, the EfD Chile centre has contributed since its foundation to identifying relevant topics and interacting with policymakers, and shares the following insights: (i) interactions are key, as policymakers know what is most relevant for agenda-setting in the country; (ii) policymakers can facilitate access to information and data, and (iii) it is key to build students' capacity and experience interacting with policymakers. The interaction with policymakers has included integration into annual workshops, conducting policy days, production of short courses, and provision of spaces for sharing technical reports. Members of the centre have also contributed to the revision of the Atmospheric Decontamination Plan (PDA) in southern Chile and engaged in consultation activities that have led to research publications. An important goal that researchers recognize is that they have transitioned from a knowledge-transference model to an interaction model with

policy actors in order to address the energy policy issues in the country.

### 1.4.3 Concluding Remarks

The analysis of the information collected through the centres survey and the semi-structured interviews provides important insights for the identification and prioritization of research gaps. Some of these gaps arise from the local policy context, as shown in Figure 5. This figure highlights that policy and research in all countries agree on the importance of transitioning towards a low-carbon economy. However, the cost and reliability of cleaner sources create a risk of impeding this process. Air pollution arises as a major environmental problem in most countries, and fuel use has implications for forests.

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| | • **Ethiopia:**<br>• Energy transition problems in the domain of cooking in urban and rural areas.<br>• Lack of access to basic electricity services (e.g., lighting) in rural areas.<br>• Institutional challenges impeding private sector participation in the off-grid market. |
| | • **Uganda:**<br>• Poverty, forest depletion, and deforestation for cooking energy in Uganda.<br>• Motorbikes as major contributors to air pollution in urban areas.<br>• Cultural aspects and alternative cooking sources of biomass. |
| | • **Ghana:**<br>• Households heavily rely on charcoal for cooking, with low access to modern technology.<br>• Families suffer from high prices to modern fuels.<br>• Restrictions in the supply side for electricity. |
| | • **Nigeria:**<br>• Limited use of clean cooking energy sources. High cooking energy prices lead to the use of inefficient alternatives, leading to deforestation.<br>• High indoor and outdoor pollution from the incomplete combustion of energy sources, waste, and plastics pollution.<br>• Climate change: unclean energy sources being the highest source of GHG emissions in Nigeria. |
| | • **Kenya:**<br>• Air pollution in the country due to use of solid fuels for cooking and lighting.<br>• Forest degradation due to dependence on wood for fuel.<br>• Air pollution due to carbon emissions from industries and vehicles. |
| | • **Tanzania:**<br>• Deforestation associated with overreliance on biomass energy, mainly firewood and charcoal.<br>• Ambient air pollution due to increased use of biomass cooking energy.<br>• Air pollution in major cities due to obsolete technologies in many industries and the increasing use of fossil–fuel-dependent cars. |
| | • **India:**<br>• Energy generation from coal burning produces high levels of pollution and climate-harming emissions.<br>• Air pollution, particularly in Northern India, from households, coal-fired power plants, illegal crop burning, vehicles, etc. |
| | • **Vietnam:**<br>• Air pollution in major cities and industrial provinces due to transportation, construction, and industrial production.<br>• Energy insecurity due to high demand while the country heavily relies on imported fuels.<br>• Need to introduce carbon taxes and carbon market to minimize reliance on biomass.<br>• Increasing number of hydropower plants may create social and environmental problems, i.e., flooding, drought, deforestation, and migration. |
| | • **South Africa:**<br>• Frequent power outages.<br>• Lavish subsidies to coal-based power historically have led to very energy-intensive, coal-based economy. |

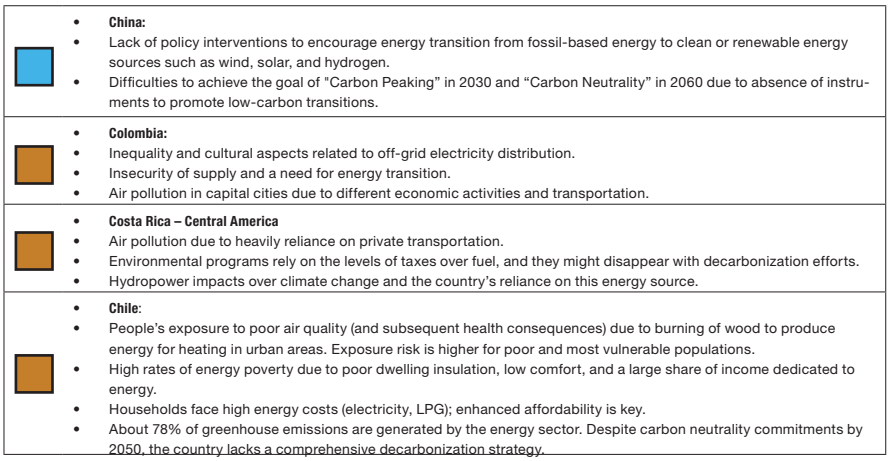


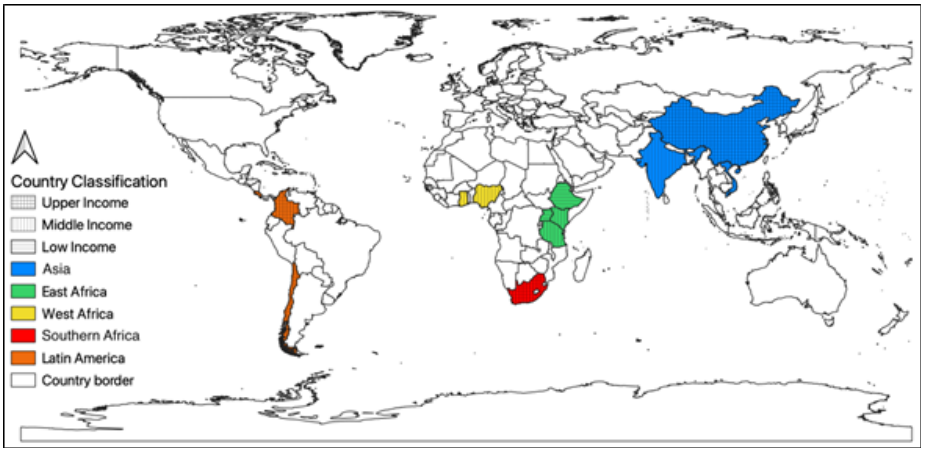

*Figure 5 Ongoing policy processes within the studied countries by development status.*
Note: own summary based on countries' responses.

Although air pollution exposure due to reliance on fossil fuels to produce energy arises as one of the major policy issues in our sample of countries, there is a great deal of heterogeneity when it comes to the factors determining this problem when the development status of countries is considered. In low-income countries, access to basic electricity services and to cleaner energy sources remains imperative. While some of these issues remain important for lower-middle-income countries, affordability and reliability issues arise as the main impediments to the adoption of low-carbon technologies. This is particularly important in the African region. Improvements in energy efficiency also appear imperative in some countries in Africa and Latin America. Enhanced energy efficiency is associated with lower energy costs and improved health outcomes and economic opportunities for individuals, contributing to sustainable development. Another important issue relates to pollution exposure due to local transportation, often produced with old technologies and low-cost but polluting energy sources. Finally, the most important policy issues in the studied upper-income countries relate to inequality in access to cleaner energy sources, affordability issues, and high rates of energy poverty, which accentuate the existing levels of inequity.

The challenges above and their impacts on local populations are borne differently by subgroups of individuals within the various countries. An analysis of intersectionality, displayed in Figure 6, indicates the groups of individuals who are at risk of being left behind when transitioning towards cleaner energy sources, or who are most likely to be negatively affected by reliance on traditional energy sources. Because gender is a key dimension of these distributional considerations of low-carbon transitions, centres were asked how they would define or conceptualize the role of gender for the purpose of policy design, and the extent to which this concept is incorporated into planning of environmental policy. In all cases, gender appears to be defined with a simple binary label (i.e., male, female); moreover, gender is not commonly considered in policy design. This emphasizes the importance of elevating this aspect in continuing discussions.

This analysis of intersectionality provides evidence that women and children, both in rural and urban (slums) settlements, and those in poverty conditions remain the most vulnerable groups of the population, regardless of the countries' development status. This finding highlights the importance of conducting policy-oriented research that sheds light on the interventions needed to promote access to clean energy, as well as affordability and reliability conditions for these vulnerable groups. In contrast, charcoal users as well as men and women participating in the agricultural sector exhibit higher vulnerability in low-income countries. As for lower-middle-income countries in Africa, intersectional aspects include fuel collectors, individuals inhabiting conflict areas, and those with low education and with disabilities. This contrasts with lower castes and users of motorbikes in South Asia. Finally, poor individuals, indigenous communities, those in non-grid-connected areas, and migrants arise as the

more vulnerable groups in the upper-income countries under study.




- **Ethiopia:**
- Energy transition problems in the domain of cooking in urban and rural areas.
- Lack of access to basic electricity services (e.g., lighting) in rural areas.
- Institutional challenges impeding private sector participation in the off-grid market.

- **Uganda:**
- Poverty, forest depletion, and deforestation for cooking energy in Uganda.
- Motorbikes as major contributors to air pollution in urban areas.
- Cultural aspects and alternative cooking sources of biomass.

- **Ghana:**
- Households heavily rely on charcoal for cooking, with low access to modern technology.
- Families suffer from high prices to modern fuels.
- Restrictions in the supply side for electricity.

- **Nigeria:**
- Limited use of clean cooking energy sources. High cooking energy prices lead to the use of inefficient alternatives, leading to deforestation.
- High indoor and outdoor pollution from the incomplete combustion of energy sources, waste, and plastics pollution.
- Climate change: unclean energy sources being the highest source of GHG emissions in Nigeria.

- **Kenya:**
- Air pollution in the country due to use of solid fuels for cooking and lighting.
- Forest degradation due to dependence on wood for fuel.
- Air pollution due to carbon emissions from industries and vehicles.

- **Tanzania:**
- Deforestation associated with overreliance on biomass energy, mainly firewood and charcoal.
- Ambient air pollution due to increased use of biomass cooking energy.
- Air pollution in major cities due to obsolete technologies in many industries and the increasing use of fossil–fuel-dependent cars.

- **India:**
- Energy generation from coal burning produces high levels of pollution and climate-harming emissions.
- Air pollution, particularly in Northern India, from households, coal-fired power plants, illegal crop burning, vehicles, etc.

- **Vietnam:**
- Air pollution in major cities and industrial provinces due to transportation, construction, and industrial production.
- Energy insecurity due to high demand while the country heavily relies on imported fuels.
- Need to introduce carbon taxes and carbon market to minimize reliance on biomass.
- Increasing number of hydropower plants may create social and environmental problems, i.e., flooding, drought, deforestation, and migration.

- **South Africa:**
- Frequent power outages.
- Lavish subsidies to coal-based power historically have led to very energy-intensive, coal-based economy.

- **China:**
- Lack of policy interventions to encourage energy transition from fossil-based energy to clean or renewable energy sources such as wind, solar, and hydrogen.
- Difficulties to achieve the goal of "Carbon Peaking" in 2030 and "Carbon Neutrality" in 2060 due to absence of instruments to promote low-carbon transitions.

- **Colombia:**
- Inequality and cultural aspects related to off-grid electricity distribution.
- Insecurity of supply and a need for energy transition.
- Air pollution in capital cities due to different economic activities and transportation.

| | |
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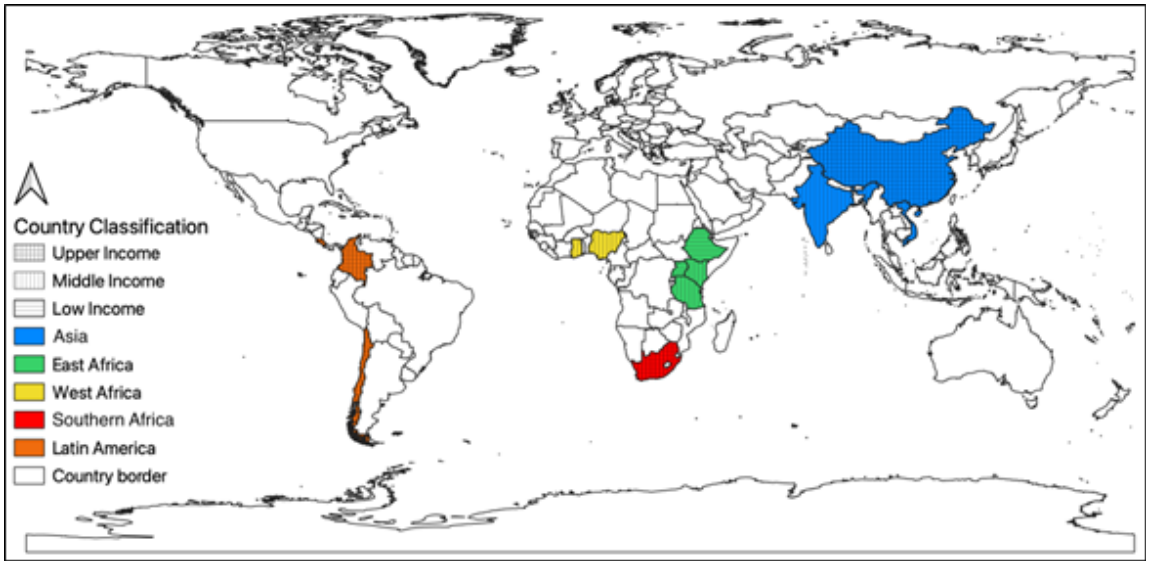
| | • **Costa Rica – Central America**<br>• Air pollution due to heavily reliance on private transportation.<br>• Environmental programs rely on the levels of taxes over fuel, and they might disappear with decarbonization efforts.<br>• Hydropower impacts over climate change and the country's reliance on this energy source. |
| | • **Chile**:<br>• People's exposure to poor air quality (and subsequent health consequences) due to burning of wood to produce energy for heating in urban areas. Exposure risk is higher for poor and most vulnerable populations.<br>• High rates of energy poverty due to poor dwelling insulation, low comfort, and a large share of income dedicated to energy.<br>• Households face high energy costs (electricity, LPG); enhanced affordability is key.<br>• About 78% of greenhouse emissions are generated by the energy sector. Despite carbon neutrality commitments by 2050, the country lacks a comprehensive decarbonization strategy. |

*Figure 6 Gendered aspects and intersectionality within the studied countries by development status*

Note: own summary based on countries' responses.

To conclude, based on the analysis of ongoing policy processes and intersectionality, Figures 7 and 8 summarize the main research gaps identified in the analysis, by country, development status, and frequency. While some of these gaps are in line with those identified by the literature, others indicate contextual factors specific to a given country as a result of its development status. This analysis provides us with important insights that are worth mentioning. First, cooking fuel stacking and the knowledge and understanding of barriers (and cultural aspects) impeding transitions to clean cooking in policy interventions arise as important research gaps in low- and middle-income countries in the African region. The analysis of policy options/instruments to increase electricity access, especially in rural areas, is an issue that also deserves attention in this group of countries. Second, because of its links with households' employment and income-generating alternatives, energy use among SMEs and in the agriculture and manufacturing sectors, especially from renewables, arises as an area where evidence is much needed, also in the African setting. Third, drivers of and barriers to transition to renewables, particularly the use of mini-grid and off-grid electricity, and adoption of off-grid renewables, are areas that could provide important insights for the design of macro policies promoting green growth and development. Fourth, understanding the role of prices of renewable energy, the effect of subsidies, and affordability of electricity become imperative in the lower-middle-income countries under study, especially in Africa and India. Fifth, the link between energy and urban transport appears as a cross-cutting issue in all regions. Understanding this link could generate important knowledge for the design of policies aimed at reducing air pollution exposure in urban areas in Africa, Asia, and Latin America.



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| | • **Uganda:**<br>• Poverty, forest depletion, and deforestation for cooking energy in Uganda.<br>• Motorbikes as major contributors to air pollution in urban areas.<br>• Cultural aspects and alternative cooking sources of biomass. |
| | • **Ghana:**<br>• Households heavily rely on charcoal for cooking, with low access to modern technology.<br>• Families suffer from high prices to modern fuels.<br>• Restrictions in the supply side for electricity. |
| | • **Nigeria:**<br>• Limited use of clean cooking energy sources. High cooking energy prices lead to the use of inefficient alternatives, leading to deforestation.<br>• High indoor and outdoor pollution from the incomplete combustion of energy sources, waste, and plastics pollution.<br>• Climate change: unclean energy sources being the highest source of GHG emissions in Nigeria. |
| | • **Kenya:**<br>• Air pollution in the country due to use of solid fuels for cooking and lighting.<br>• Forest degradation due to dependence on wood for fuel.<br>• Air pollution due to carbon emissions from industries and vehicles. |
| | • **Tanzania:**<br>• Deforestation associated with overreliance on biomass energy, mainly firewood and charcoal.<br>• Ambient air pollution due to increased use of biomass cooking energy.<br>• Air pollution in major cities due to obsolete technologies in many industries and the increasing use of fossil–fuel-dependent cars. |
| | • **India:**<br>• Energy generation from coal burning produces high levels of pollution and climate-harming emissions.<br>• Air pollution, particularly in Northern India, from households, coal-fired power plants, illegal crop burning, vehicles, etc. |
| | • **Vietnam:**<br>• Air pollution in major cities and industrial provinces due to transportation, construction, and industrial production.<br>• Energy insecurity due to high demand while the country heavily relies on imported fuels.<br>• Need to introduce carbon taxes and carbon market to minimize reliance on biomass.<br>• Increasing number of hydropower plants may create social and environmental problems, i.e., flooding, drought, deforestation, and migration. |
| | • **South Africa:**<br>• Frequent power outages.<br>• Lavish subsidies to coal-based power historically have led to very energy-intensive, coal-based economy. |
| | • **China:**<br>• Lack of policy interventions to encourage energy transition from fossil-based energy to clean or renewable energy sources such as wind, solar, and hydrogen.<br>• Difficulties to achieve the goal of "Carbon Peaking" in 2030 and "Carbon Neutrality" in 2060 due to absence of instruments to promote low-carbon transitions. |
| | • **Colombia:**<br>• Inequality and cultural aspects related to off-grid electricity distribution.<br>• Insecurity of supply and a need for energy transition.<br>• Air pollution in capital cities due to different economic activities and transportation. |
| | • **Costa Rica – Central America**<br>• Air pollution due to heavily reliance on private transportation.<br>• Environmental programs rely on the levels of taxes over fuel, and they might disappear with decarbonization efforts.<br>• Hydropower impacts over climate change and the country's reliance on this energy source. |
| | • **Chile**:<br>• People's exposure to poor air quality (and subsequent health consequences) due to burning of wood to produce energy for heating in urban areas. Exposure risk is higher for poor and most vulnerable populations.<br>• High rates of energy poverty due to poor dwelling insulation, low comfort, and a large share of income dedicated to energy.<br>• Households face high energy costs (electricity, LPG); enhanced affordability is key.<br>• About 78% of greenhouse emissions are generated by the energy sector. Despite carbon neutrality commitments by 2050, the country lacks a comprehensive decarbonization strategy. |

*Figure 7 Energy-related gaps in the studied countries by development status*
Note: own summary based on countries' responses.

Finally, in the group of lower-middle and upper-income countries, energy poverty and its gender distributional dimensions, power theft and its implications for energy tariffs, and energy efficiency are major issues where evidence is needed. Because of existing inequalities in access to energy services, off-grid electricity and new business models to reduce energy poverty arise as important gaps whose study could provide important insights to reach SDG 7 (access to clean energy) and SDG 10 (reduction of inequality). To this end, understanding peoples' reactions to energy-environment policy is crucial. These gaps should be considering when proposing short- and medium-term research agendas and

should be validated and prioritized by key stakeholders to guarantee a cost-effective allocation of funding with regional representativeness.

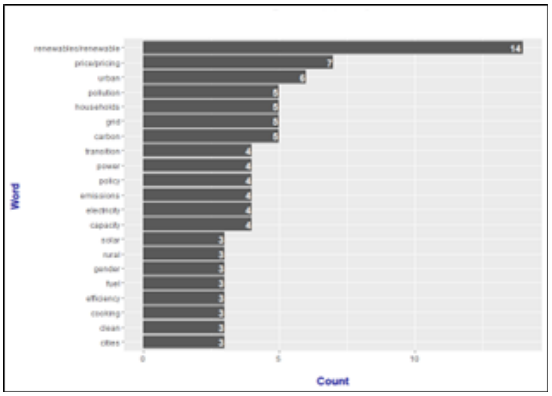


*Figure 8 Frequency of gaps as reported by EfD centres*
*Note: own summary based on countries' responses*

## 1.5 Proposal of an applied research agenda to plug key gaps

In this section, we draw on the syntheses presented above to emphasize a number of research gaps on which applied energy research should focus to support a more inclusive and sustainable energy transition that continues to also support economic development. The key questions are presented in Table 4 and described in further detail below. We also discuss the need for new and diverse methods to answer these questions and show how they relate to one another using visual schematics that are summarized by the visual shown in Figure 9.

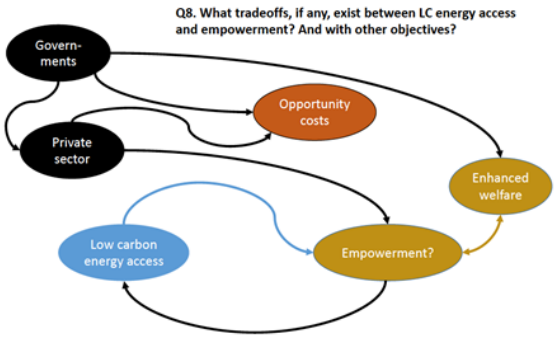


*Figure 9 Simple schematic depicting relationships emphasized in the proposed research questions*

**Table 4 Critical energy research questions related to an inclusive, sustainable, and development-enhancing LCT**

| # | Topic and research question description | Studies needed |
|---|---|---|
| 1 | How can the low-carbon energy transition create economic opportunities for marginalized groups (women, low-income, rural, minority, and other disenfranchised populations), and support their economic empowerment? | Theory development; mixed empirical methods (quantitative impact evaluations; qualitative analysis) |
| 2 | What are the broader benefits and social welfare implications of energy-related improvements in equity and inclusivity? Are there notable synergies with other development objectives, or across locations, and what mechanisms enable them? | Mixed empirical methods (quantitative impact evaluations; qualitative analysis) |
| 3 | Conversely, can improved equity or inclusivity help to stimulate and advance the progress of the low-carbon energy transition? Again, what are the specific mechanisms and pathways that explain these impacts? | Mixed empirical methods (quantitative impact evaluations; qualitative analysis) |
| 4 | How do private-sector actors involved in the low-carbon energy sector seek to incorporate equity into their general objectives, business models, and day-to-day operations? Are interventions needed to support more inclusivity in the private sector, and if so, which interventions? | Descriptive empirical methods (quantitative and qualitative analysis) |
| 5 | How can governments and private sector help to promote better access to productive resources (finance, sustainable energy, entrepreneurial capacity, business development services) to support women- and youth-owned and -led businesses? | Policy analysis; mixed empirical methods (quantitative impact evaluations; qualitative analysis) |
| 6 | What government and donor policies, incentives (subsidies, rewards, etc.), pathways, strategies and complementary initiatives (e.g., training programs, investment in infrastructure, or behaviour change campaigns) are both efficient and cost-effective in supporting economic opportunities for marginalized groups arising from the LCT and help to promote their involvement in policy- and decision-making discussions? What types of policies are counterproductive to these goals? | Policy analysis; mixed empirical methods (quantitative impact evaluations; qualitative analysis) |
| 7 | What gender and other disaggregated data are needed to design better policies for energy access and empowerment? How could the data best be made available? How can governments and private sector assist by providing disaggregated data? | Development of new metrics; descriptive empirical methods (quantitative and qualitative analysis) |
| 8 | What, if any, are the inherent tradeoffs in more inclusive approaches to low-carbon transition? Are there tradeoffs between energy access targets (e.g., due to differences in targeting, rates of penetration, or the longevity and stranding of assets)? How can such tradeoffs be characterized and managed? Similarly, are there tradeoffs with environmental objectives, or across measures of inclusivity (e.g., across groups, geographies, or other dimensions of marginalization)? | Policy analysis; descriptive empirical methods (quantitative and qualitative analysis, and impact evaluations) |

Note: own elaboration

### 1.5.1. Key questions and topics

1. *How can the low-carbon energy transition create economic opportunities for marginalized populations and support their economic empowerment? How can these groups benefit both as users of (renewable) electricity or clean cooking energy? Do marginalized groups or women own companies that are better in reaching those users, for example for energy access (EA) and adoption of clean cooking?*

The correlation between energy and economic opportunity or growth is well established in the literature (Jeuland et al. 2021), but unresolved questions remain about the extent to which energy access is the key driver that enables new economic opportunities, whether such opportunities are equivalent with grid-based and decentralized power provision, and under what conditions (Morrissey 2017, Lee et al. 2020). Research proposed under this question (Figure 10), besides having a strong gender and equity lens, must also articulate clearly how and why the new project will overcome the limitations of prior research on the linkage between EA and economic development. Connections to many sectors are potentially relevant, including, for example, agricultural productivity (via improved yields, higher quality crops, reduced post-harvest loss and risk of crop failure) (Burney et al. 2010); agricultural processing and value-added; reallocation of time saved from use of domestic labour-saving technology to income-generating activities (Ding et al. 2014, Jagoe et al. 2020); creation of new small businesses and employment opportunities (Dinkelman 2011); and health and human capital improvement.[15] With respect to employment, the relative persistence and quality of jobs generated in the renewable energy sector are of particular interest, given current scepticism that employment gains can be sustained beyond the initial phase of technology deployment (Böhringer et al. 2013). In each of these domains, the role of gender, class, ethnicity, rurality, and other dimensions of marginalization, as well as their intersectionality, and the relative share of gains flowing to different disenfranchised populations, is highly contextual and must be clarified (Standal and Winther 2016).

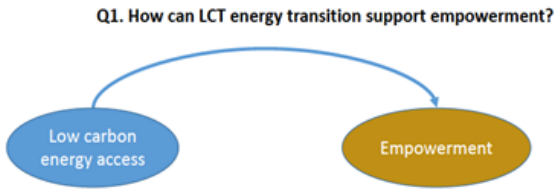


*Figure 10 Simple schematic depicting the focus of research question 1*

2. *What are the broader benefits and social welfare implications of the resulting energy-related improvements in equity and inclusivity? In particular, are there notable synergies with other development objectives, or across locations? What are the specific mechanisms and pathways that explain these broader impacts? Of particular interest are the implications for youth employment, entrepreneurship, and community resilience and adaptation to climate change, but other types of changes can also need investigation.*

A holistic understanding of the impacts of EA that goes beyond direct economic and financial impacts is especially warranted in the context of a low-carbon energy transition (Figure 11). This broader conception of welfare impacts encompasses enhanced rural community resilience in the face of weather and climate disruptions (Shammin and Enamul Haque 2022); upgraded public service provision; increased time use agency, empowerment, and psychological well-being (Gray et al. 2019); relatively intangible quality-of-life benefits (Jensen and Oster 2009); and improved health and human capital accumulation and investment (Wickramasinghe 2011). Some of these aspects emerge directly through energy use behaviour among those gaining access, but others arise from ameliorated community conditions from positive spillovers that are not limited to those users alone. Further research is especially needed to determine the varied pathways leading from impacts on welfare to women's and other groups' economic empowerment. Finally, long-term impacts are a critical knowledge gap, particularly as they transfer across generations (i.e., for girls living in households with clean technology).

15 This list is indicative, and proposals exploring additional areas are welcome as long as the theory of change is well explained, and the relevant prior empirical evidence well described.

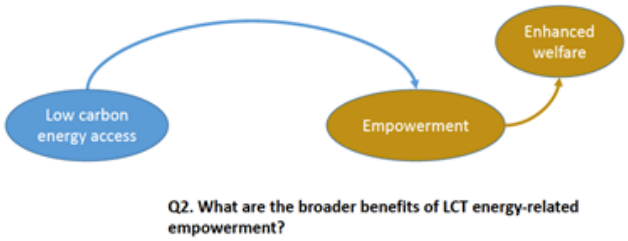


*Figure 11 Simple schematic depicting the focus of research question 2*

*3. Conversely, can empowerment and improved equity or inclusivity help to stimulate and advance the progress of the low-carbon energy transition? How can marginalized groups gain increased access and control over sustainable energy products and services? What are the specific mechanisms and pathways that explain these impacts?*

Considerable research relates proxies for economic empowerment, particularly of women, to enhanced adoption of improved cookstoves and clean fuels, noting that women's agency and decision-making power nonetheless typically remains limited and constrains willingness to pay for improved technology (Das et al. 2020) (Figure 12). Evidence for other energy technologies (such as Standal et al. (2020) in a developed world context) and sub-populations is much more limited. Still, women within households have been found to have lower say in how electricity is used and which appliances should be purchased (Winther et al. 2020), with potentially profound implications for welfare and the dynamics of energy transitions. In general, prior literature has focused much more on resources than on agency and process aspects of empowerment (Das et al. 2020).

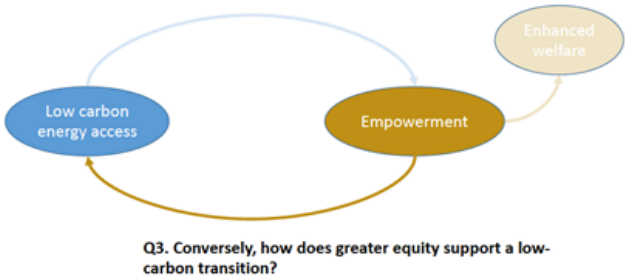


*Figure 12 Simple schematic depicting the focus of research question 3*

*4. How do private sector actors involved in the low-carbon energy sector seek to incorporate equity into their general objectives, business models, and day-to-day operations? How do such aspects vary across sub-sectors, and which private sub-sectors are most inclusive and why? Are interventions needed to support more inclusivity in the private sector, and if so, which interventions can do so effectively? Is there a role for financing to elevate such objectives?*

Limited existing work shows that women's engagement in the energy sector may result in increased technology adoption, but the gender balance in this sector remains highly inequitable (Figure 14). Other dimensions of diversity and inclusivity have scarcely been considered. Various barriers limit involvement by these disenfranchised groups, including social norms, limited networks and information, the care economy, glass ceilings, counterproductive workplace policies and practices, low availability of time, lack of education, and reduced access to finance and capital (Kabeer 2002). In this sense, there is a need for work on leveraging innovative sources of inclusive finance, and the potential role of public financing models that can be deployed to support the private sector. In addition, the potential of women's or other types of interest groups to aid dissemination of energy technology is worthy of researchers' attention (Cho et al. 2013).

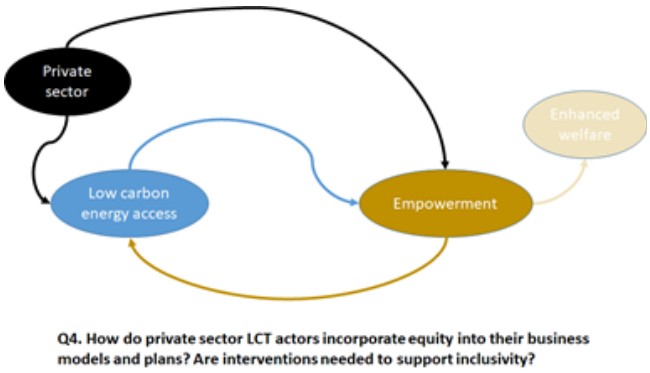


*Figure 13 Simple schematic depicting the focus of research question 4*

*5. How can governments and the private sector help to promote better access to productive resources (finance, sustainable energy, entrepreneurial capacity, business development services) to support businesses owned and led by women and marginalized groups within society?*

Existing research shows that constraints in access to, for example, financial services prevent many marginalized people from developing and growing enterprises, improving productivity, or entering into contracts without others in society (De Mel et al. 2009, McKenzie and Woodruff 2014, Bernhardt et al. 2019, Bardasi et al. 2021). A lack of independence and ownership over assets (collaterals) constrains these groups more than those who are economically

and socially favored. In this regard, it is important to ensure improved access to productive resources, such as finance, sustainable energy, and entrepreneurial capacity, and to explore how this is linked to a wider policy framework that contributes to empowerment and at the same time promotes the development of dynamics of energy transitions (Figure 14). In addition, advancement of this agenda would depend on improved capacity of governments to reformulate policies and programmes that enhance businesses owned and led by women and other disenfranchised groups by supporting participation and strengthening these groups' roles as rights holders and key actors in the development and expansion of markets and value chains.

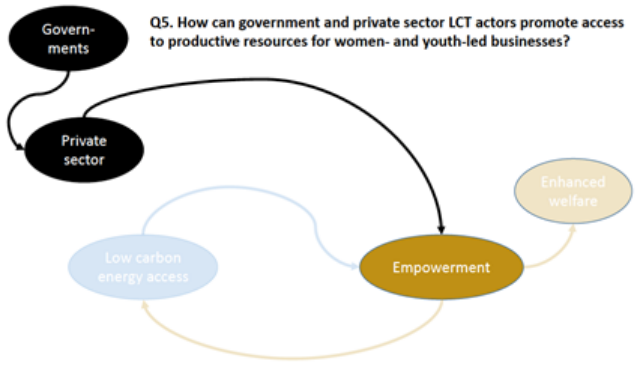


*Figure 14 Simple schematic depicting the focus of research question 5*

6. *What government and donor policies, incentives (subsidies, rewards, etc.), pathways, strategies, and complementary initiatives (e.g., training programs, investment in infrastructure, or behaviour change campaigns) are both efficient and cost-effective in supporting economic opportunities for marginalized people arising from the low-carbon energy transition and help to promote their involvement in policy- and decision-making discussions? What types of policies are, in contrast, counterproductive to these goals?*

Much research emphasizes the importance of awareness-raising, training, and capacity building as an aid to general economic development, as well as empowerment (McKenzie and Woodruff 2014). Though limited work has examined such interventions in the context of the gender-energy nexus (Shankar et al. 2015, Dutta 2020), there is a clear need for more such work, that would clarify, e.g., such aspects as technical, management and business skill and awareness of business opportunities; the capacity of women's organizations and other interest groups; specific energy end uses (e.g., irrigated farming) or enterprises (energy-intensive micro and medium enterprises) (Figure 15). The role of gender and other "mainstreaming" policies and efforts by national and local governments has also rarely been evaluated critically in existing work (Quintero 2006).

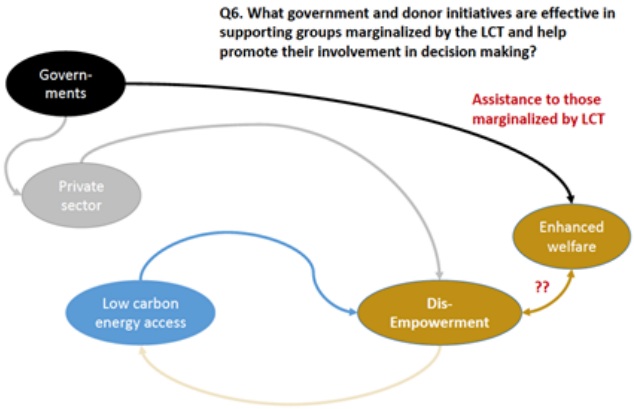


*Figure 15 Simple schematic depicting the focus of research question 6*

7. What disaggregated data are needed to design better *policies for energy access and empowerment? How could the data best be made available? Are there needs for particular compilation mechanisms and tools in order to provide data of adequate quality? How can governments and the private sector assist by providing disaggregated data of high quality?*

High quality, disaggregated data (by gender, ethnicity, rurality, class, etc.) are key to support policy formulation that is responsive to structural disadvantages and then monitoring and evaluation of the outcomes of such policies. It is therefore important to improve "mainstreaming" of private- and public-sector initiatives, projects, and policies. Indeed, sensors and smart monitoring technologies are being introduced, especially in the private sector, to provide alternative financing options (e.g., pay-as-you-go or use of energy technology as collateral in loans) and post-sale services (e.g. timely repair in case of malfunctions or fuel refills delivery) (Figure 16). These hold enormous potential as sources of data for research that is appropriate for analyses of various sub-populations of interest.

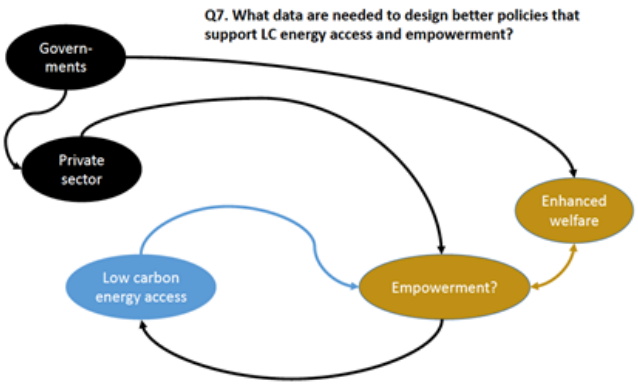


*Figure 16 Simple schematic depicting the focus of research question 7*

8. *What, if any, are the inherent tradeoffs in more inclusive approaches to low-carbon transition? In particular, are there tradeoffs between energy access targets (e.g., due to differences in targeting, rates of penetration, or the longevity and stranding of assets), and how can such tradeoffs be characterized, in the short and long term? Similarly, are there tradeoffs with environmental objectives, or across definitions of inclusivity (across groups, geographies, or other dimensions of marginalization)? Can these tradeoffs be managed, and if so, what are effective approaches to measure and manage them?*

Answering the questions above in a holistic manner is critical, because there will inevitably be tradeoffs across approaches that emphasize different aspects (Figure 17). For example, many economists speak of equity-efficiency tradeoffs, which might arise in the context of pro-poor or last-mile approaches. Government and donor funding and resources, meanwhile, have important opportunity costs, when these are devoted to energy access rather than allocated to meeting other sustainable development goals.

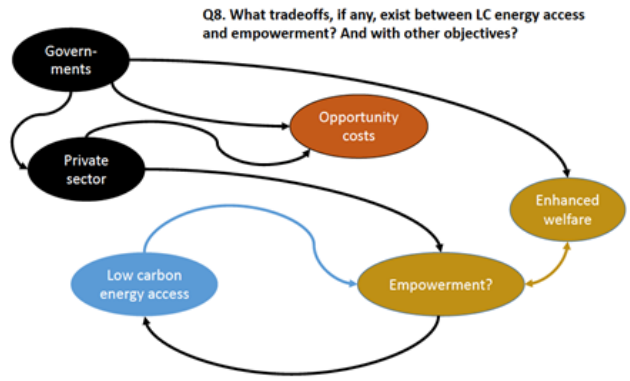


*Figure 17 Simple schematic depicting the focus of research question 8*

### 1.5.2. A need for new methods and a new research paradigm

In order to move forward in energy access research, including those issues on the empowerment-energy nexus, more attention should be given to the extent of use of energy services, rather than simple binary measures that indicate connections to electricity or ownership of improved or clean stoves. There is a need for validation and standardization of such measures across contexts to identify the most appropriate and informative metrics and facilitate their wider application. This is also true of the empirical literature that applies empowerment frameworks, methods, and metrics, where it is particularly important to understand how energy technologies are used and the role of intra-household bargaining in use (e.g., placement of lighting in the household). Indeed, measures suited to answering empowerment-energy nexus questions are particularly needed, that draw on the empowerment literature in other domains, and gender empowerment theory in particular, while exploring tailoring to the energy sector. For example, almost all relevant empirical literature in this domain focuses on the resources to which women have access, at the expense of examining richer theories and concepts of empowerment such as agency (Kabeer 1999), or considering other dimensions of marginalization. Moreover, very little existing work on this nexus engages critically with the dynamic nature of empowerment and energy transitions processes. Finally, in the gender empowerment literature, women are generally treated as a monolith, and there is a need to move beyond the binary definition of gender and for research to take intersectional approaches, considering also class, ethnicity, religion, and other social divisions.

Regarding methods, addressing topics as challenging as those at the intersection of energy and gender also requires methodological pluralism and transdisciplinarity. For example, randomized controlled trials (RCTs) and other types of experiments can be leveraged for testing specific mechanisms or for eliciting particular types of measures that are relevant to SDG 5 and SDG 7 connections, under controlled conditions, avoiding selection bias and other endogeneity problems, and abstracting from the messiness of real-world variation in implementation. There is nonetheless great need for more theoretically informed RCTs that carefully study the detailed linkages between empowerment and energy, rather than additional reduced-form work that does not really elucidate the precise mechanisms of change. Such studies would be helpful for examining both directions of the empowerment-energy access nexus, i.e., how empowerment facilitates energy technology adoption, and how energy

technology use advances empowerment processes.

Experiments alone will not suffice, however. Quasi-experimental and innovative data collection and processing methods including greater employment of mixed methods and high-frequency data should be employed to enrich understanding of these relationships under less artificial conditions. Researchers, practitioners, and policymakers often have a special interest in understanding the selection processes that lead to adoption, ongoing use, or dis-adoption of technologies, for example, to inform policies on targeting. Moreover, the long-term effects of energy products and services are often more practically studied using retrospective quasi-experimental methods, whereas experiments are most feasible and remain most valid for examining short-term processes. Methodological pluralism is also important to address internal versus external validity concerns, as RCTs typically address the former well while generalizability across settings can be limited (absent very careful cross-setting designs and ample resources for research). Finally, practitioners and policymakers need standard methods that they can relatively easily apply across contexts at reasonable cost, allowing them to coordinate multi-country or multi-setting analyses, thereby feeding into generalized learning about gendered theories of adoption and empowerment. It is only through adequately measuring the relationships between gender and energy that policymakers and practitioners can design interventions that support the synergies between SDG 5 and SDG 7 and mitigate the potential tradeoffs.

## 1.6 Conclusions

This paper was devoted to identifying knowledge gaps and controversies related to energy sector aspects of low-carbon transitions in LMICs. The analysis was grounded in two different yet complementary approaches. The first approach consisted of a review of the empirical literature, taking the knowledge gaps identified in Jeuland et al. (2021) as a starting point. The second approach included a data collection process (i.e., survey and semi-structured interviews) to analyze ongoing research and policy processes of a sample of 13 LMICs. These countries are devoted to studying the different dimensions of energy transitions through their involvement as research centres in the Environment for Development Initiative, and the Sustainable Energy Transitions Initiative (SETI). Analysis of observed differences and challenges impeding achievement of energy access goals across these countries, in combination with assessment of cultural and social differences, provides a richer understanding and appreciation of knowledge gaps that are not always apparent in the literature.

The combination of these approaches provides numerous insights that are worth mentioning. First, gender aspects of low-carbon transitions and their intersections are understudied in both empirical literature and ongoing research projects, and mostly excluded from the current policy processes of the sample of countries under study. Gender is mainly defined as a biological condition at birth, showing that important work is yet to be done for the acceptance of a more inclusive definition. This phenomenon is mainly explained by cultural and political issues. Second, there is a great deal of heterogeneity when it comes to intersectionality. While in some countries of Africa and Latin America, women, ethnic minorities, and rural populations are more vulnerable in terms of energy access, local communities within the same countries/regions also impede access to energy because of cultural considerations (e.g., being against instalment of hydro plants). In other countries of Africa, women and children are more exposed to both indoor and outdoor air pollution because they are responsible for the lion's share of household chores. Women and children who spend more time on fuelwood collection due to deforestation are also more exposed to violence (e.g., wild animals and third persons). In contrast, exposure is not an issue for men, as they devote most of their time to productive activities outside the house. In South Asia, the main intersectional factor is rurality, which is often correlated with poverty. Based on the aforementioned factors, an intersectional agenda should consider both an inter-country approach (prioritizing the tackling of common challenges) and intra-country approach (prioritizing particular country concerns). This distinction could help disentangle cultural and institutional issues impeding/favoring low-carbon transitions.

Third, while basic energy access problems continue to affect LICs, a broader energy poverty construct is at the core of challenges in both LoMICs and UMICs. Despite structural differences between these groups of countries, problems in all countries, regardless of development status, appear to be mediated by common intersectional factors. This suggests that universal access to energy that guarantees a minimum of energy services is compatible with economic empowerment and sustainable and equitable development. Transitioning off of a path that prioritizes basic access would leave certain subpopulations behind, forcing continued reliance on polluting technologies, exacerbating income poverty, and inhibiting empowerment. How to best allocate limited resources to this endeavor, and the extent to which addressing these problems contributes to economic empowerment are regarded as important points of the proposed research agenda.

Fourth, there are several prominent controversies in the literature, which highlight the heterogeneity of impacts of energy use across different contexts and the need for more thoughtful policymaker and researcher interaction. As discussed in the review of relevant literature, access to modern energy services does not always improve environmental and development outcomes. Technologies, implementation approaches, policies, and local contexts all matter. Too little is known about the specific mechanisms that explain divergent outcomes. A key problem emerges in the cooking energy domain, where barriers to adoption of clean technology are well understood, but effective interventions have proven difficult to support. Many studies on cooking services provide only marginal value relative to implementers' needs for evidence, adding to a body of evidence that is already robust (e.g., showing that traditional stove use harms air quality and health, or documenting household-level barriers to adoption of improved stoves). Such studies do little to show how to effectively overcome serious supply chain, information, and behavioural obstacles that inhibit improved stove use and impacts. Effective ways to enhance affordability and complementary conditions (robust supply chains, market connectivity, access to financing) warrant particular attention. Similarly, though electricity access in general appears strongly linked to increased income and productivity and negative environmental consequences, a closer look at this evidence reveals that causal evidence does not extend consistently to all regions, technologies, and solutions. Whether off-grid solar can boost incomes is a particularly critical question to tackle, oriented around analyses that identify which specific appliances help produce the greatest improvements in development and well-being outcomes.

Fifth, very little is known regarding issues of governance and cost recovery of electric utilities, and their role in energy transitions in developing countries. Missing markets and/or regulatory policy uncertainty prevent investment in modern renewables and decentralized solutions while public investment becomes untenable when end-use energy prices are distorted. This problem is exacerbated by low willingness to pay for electricity access and use. Although some studies have focused on these problems (see, e.g., Fowlie et al. (2021), Blimpo et al. (2017)), they mainly focus on access, while the transition part is largely missing. Finally, another issue that deserves attention relates to the extent to which infrastructure complementarities can accelerate energy transition. For instance, digitalization can facilitate penetration of modern flexible generation technologies and reduce technical and commercial losses, but it requires reliable internet access. Likewise, lack of market access will likely deter investment in modern technologies due to low economic returns (to justify public investment) and financial incentives (to justify investment by the private sector).

We conclude this paper with an important reflection. The issues of conflicts and fragility are gaining more traction in light of numerous recent events culminating in the Russian-Ukrainian war. Rising food and energy input prices are likely to severely hamper energy transition progress, as are direct effects of conflicts such as destruction of critical infrastructures and human capital, and policy uncertainty preventing post-conflict investment. This arises as a promised yet relevant knowledge gap affecting low-carbon transitions. Finally, to develop a comprehensive and impactful research agenda, identified knowledge gaps need to be validated and prioritized based on a number of criteria (e.g., low- and middle-income countries versus lower-income countries, region-specific versus nonspecific). Therefore, validation workshops and definition of key actors both in the academic and policy arenas arise as important venues of work to provide an accurate prioritization of the need to fill specific knowledge gaps to support the process of transitioning towards a low-carbon economy in LMICs.

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