ENVIRONMENTAL RESEARCH
LETTERS

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To cite this article: William F Lamb *et al* 2020 *Environ. Res. Lett.* **15** 113006

Environmental Research Letters

CrossMark

OPEN ACCESS

RECEIVED
21 December 2018

REVISED
18 August 2020

ACCEPTED FOR PUBLICATION
14 October 2020

PUBLISHED
23 November 2020

TOPICAL REVIEW

What are the social outcomes of climate policies? A systematic map and review of the ex-post literature

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Keywords: climate policy, energy policy, social outcomes, distributional outcomes, just transitions, systematic review, equity

Supplementary material for this article is available online

Abstract

It is critical to ensure climate and energy policies are just, equitable and beneficial for communities, both to sustain public support for decarbonisation and address multifaceted societal challenges. Our objective in this article is to examine the diverse social outcomes that have resulted from climate policies, in varying contexts worldwide, over the past few decades. We review 203 ex-post climate policy assessments that analyse social outcomes in the literature. We systematically and comprehensively map out this work, identifying articles on carbon, energy and transport taxes, feed-in-tariffs, subsidies, direct procurement policies, large renewable deployment projects, and other regulatory and market-based interventions. We code each article in terms of their studied social outcomes and effects, with a focus on electricity access, energy affordability, community cohesion, employment, distributional and equity issues, livelihoods and poverty, procedural justice, subjective well-being and drudgery. Our analysis finds that climate and energy policies often fall short of delivering positive social outcomes. Nonetheless, across country contexts and policy types there are manifold examples of climate policymaking that does deliver on both social and climate goals. This requires attending to distributive and procedural justice in policy design, and making use of appropriate mechanisms to ensure that policy costs and benefits are fairly shared. We emphasize the need to further advance ex-post policy assessments and learn about what policies work for a just transition.

1. Introduction

Climate change mitigation policies are urgently needed worldwide to avoid exceeding the Paris Agreement goals of 1.5 °C and 2 °C warming. Such policies will induce wide-ranging changes to society and everyday life, penalising some technologies and behaviours, such as private car use or coal powered electricity, while supporting others, such as active travel or better quality thermal insulation. The social effects of these policy shifts—ranging across issues such as poverty alleviation, inequality, social cohesion and employment—are the subject of this review.

The climate mitigation literature is increasingly preoccupied with the social outcomes of climate policies (Barbier 2014, Bendlin 2014, von Stechow *et al* 2016, Klinsky *et al* 2016, Rao *et al* 2017, Lamb and Steinberger 2017, Carley *et al* 2018, Klinsky and Winkler 2018, Sovacool *et al* 2020). Many measures are now being implemented worldwide, from climate-relevant policies such as transport fuel taxes, to targeted interventions such as renewable energy subsidies, feed-in-tariffs and carbon prices. Avoiding negative social impacts has thus become a critical issue: if these policies are perceived as unfair or socially harmful, they no doubt stand a greater chance of being attacked, repealed and revoked. This remains a deep concern in developed and developing contexts alike—including major emitting countries such as the United States, Brazil, India, France, and others—where pre-existing issues such as structural inequality and the emergence of right-wing populism have primed the political landscape against climate policy action (Lockwood 2018, Rodríguez-Pose 2018). Poorly designed policies that exacerbate social problems are a gift to fossil fuel interests, who will actively exploit such opportunities to roll-back regulations and limit their compliance costs.

On the other hand, with sound design and governance, climate policies can undoubtedly bring positive social benefits. They could eliminate the enormous health burden of fossil fuel combustion in cities (Kwan and Hashim 2016, Burney 2020) and address persistent fuel poverty among poor communities (Bouzarovski and Petrova 2015, Galvin 2019). They are an opportunity to initiate wide-ranging fiscal reforms, shifting funds from fossil subsidies towards directly addressing the needs of disadvantaged populations (UNEP 2018). Above all, action taken to reduce emissions now will reduce catastrophic climate impacts in the future, which will predominantly affect the global marginalised and poor (Allen *et al* 2018, Watts *et al* 2019). 'Just transition' proposals that forefront social benefits in climate policy design are now emerging in several countries (e.g. in 'Green New Deal' proposals) (Newell and Mulvaney 2013, Heffron and Mccauley 2018). Indeed, recent analyses find that climate policies with an emphasis on fairness, equity and social benefits garner more public support than those that exempt industries, or place undue burdens on the poor (Andor *et al* 2018, Maestre-Andrés *et al* 2019, Svenningsen 2019, Douenne and Fabre 2020, Bergquist *et al* 2020).

In this article we pose a simple question: *what are the social outcomes of climate policies?* Answering this question is not so straightforward, however, as this is a large subject area, with many competing frameworks and definitions regarding the 'social' side of climate policies (Smith and Haigler 2008, Mayrhofer and Gupta 2016). There is no shortage of reviews on climate policy 'co-benefits' (Ürge-Vorsatz *et al* 2014, Watts *et al* 2019), sustainable development linkages (von Stechow *et al* 2015), and equity considerations (Markkanen and Anger-Kraavi 2019). Indeed the topic of sustainable development and equity is addressed in specific chapters from the IPCC 5th Assessment Report (Fleurbaey *et al* 2014) and the Special Report on 1.5 °C (Roy *et al* 2018).

Our article differs from these literatures in one crucial respect: we set out to investigate only the *ex-post* climate policy literature. This means we examine and review the social outcomes of climate policies in their *real implementation context*, rather than in ex-ante modelled scenarios or theoretical experiments. While there is an important role for the latter types of studies, policy making is beset by complexities of design and implementation. It takes place within an institutional and social setting—a political economy—that will no doubt influence the type and direction of social outcomes that manifest in each case. Ex-post studies that capture these details have been identified as a key gap in the climate policy literature, alongside formal evidence synthesis studies such as systematic reviews that aggregate their findings (Aldy 2014, Somanthan *et al* 2014, Minx *et al* 2017). In this sense we build upon a much smaller number of systematic reviews on climate mitigation interventions, which have to date largely focused on the health and livelihood impacts of clean cook stove and renewable energy access (Policies and Operations Evaluation Department (IOB) 2013, Pope *et al* 2017), and housing or energy efficiency measures (Maidment *et al* 2014, Camprubí *et al* 2016, Thomson *et al* 2017).

We have three broad aims in this article. First, we aim to identify the ex-post policy literature on climate change mitigation that examines social outcomes. This is not a trivial task, since such studies are by far outweighed by ex-ante modelling and scenario studies. Nonetheless, we are able to make use of innovations in machine learning, as well as extensive hand screening, to filter tens of thousands of articles and reach a high level of comprehensiveness in this task. Second, we aim to extract a variety of evidence from each study. This includes the location and type of policy; their scale and scope; and the documented climate outcomes. Most importantly for this systematic review, we extract the social outcomes from each study, including affected populations, and the type and valence of each outcome. This summarised information for all articles is available in a supplementary data file to this article (available online at https://stacks.iop.org/ERL/15/113006/mmedia). Finally, we aim to synthesize from the ex-post policy literature, to inform and guide future policy. We examine the different types of social outcomes that resulted under varying policies and contexts, and we identify key cases where positive outcomes were achieved by design—or negative outcomes were avoided. In doing so we hope to engender a new cumulative literature that learns from the ongoing implementation of climate policies.

2. Materials and methods

In this article we cut across several types of review. First, we apply a systematic mapping methodology,

Table 1. Scope of systematic review and inclusion/exclusion criteria.

Criteria	Inclusion	Exclusion
Climate policy intervention	Measures that: • Penalize fossil fuel use • Reduce energy demand • Support renewable energy expansion This includes grid-level low-carbon energy projects (nuclear, hydro, wind, solar, biomass), which require planning, consent and support of policy makers	• Land-use sector policies (agriculture, forestry, biofuels, also migration) • Adaptation & climate impacts • Measures directed at local air pollution (e.g. NOx, SOx only) • Social policies with climate outcomes (e.g. social housing) • Energy price fluctuations with no policy intervention • Fuel switching (e.g. biomass to LPG)
Policy scope	Policies initiated by political institutions: • National • Regional • Urban/local • International (World Bank, Asia Development Bank, UNDP)	• Policies led by private institutions, NGOs, companies • Voluntary and community initiatives, no policy involvement • Pilot studies, experiments and research-led initiatives
Social outcome	• Poverty and livelihoods • Access & affordability of electricity services • Inequality and distributional impacts (income, spatial, gender) • Jobs and unemployment • Social and procedural justice • Community cohesion and conflict • Relevant assessed populations include individuals, households, social groups (gendered, classed)	• Health, air quality • Nutrition and hunger • Infrastructure access (water, sanitation) • Mobility • Housing and shelter • Acceptability of policy/energy project • GDP, 'Social cost of carbon' (aggregate economic measures without distributional analysis) • Social outcomes that relate to industries, sectors and companies alone
Focus of study	• Studies on actual implemented policies, with no method restrictions	• Studies on policies not yet implemented • Simulations of possible policies • Ex-ante analysis of implemented policies

which is suited to the collation and analysis of large literatures on broad research questions (Bates *et al* 2007, James *et al* 2016, Haddaway *et al* 2016). Using this approach to systematically identify and code the literature, we examine the overall content and direction of research in terms of studied policies, outcomes, effects and populations. This mapping of the literature is then followed by an in-depth narrative synthesis of social outcomes as they have been assessed under different policies.

To maximise the transparency and reproducibility of our review, we outline our method in the five typical stages of a systematic evidence synthesis project (James *et al* 2016, Haddaway *et al* 2018).[9] These include the initial scoping of a review (1), evidence searching (2), evidence screening (3), information extraction (4) and synthesis (5). We describe these stages in more detail here, with additional information available in the supplementary material (SM) to this article.

[9]An optional 6th stage, a critical appraisal of the evidence, is not conducted in this review.

2.1. Scope of review

Four aspects of scope determine the type of studies we review in this article: (1) the specific climate policy interventions to be investigated; (2) the scope of these policies and their targeted populations; (3) the social outcomes they induce; and (4) aspects of study and document type in each case. These respective choices are summarised in table 1.

2.1.1. Climate policy interventions

Our review of policy interventions focuses on those that either penalize fossil fuel use, reduce energy demand, or support renewable energy expansion. One can distinguish here between policies designed explicitly for climate protection, and those that have other primary objectives, such as energy security, revenue generation, or strategic industrial support. We include both types of policy in this review, using the term 'climate policy' as shorthand for all policies with the effect of mitigation. Examples of the former include carbon taxes, emissions trading schemes and coal moratoria. The latter includes taxes or levies on energy and fuels; feed-in-tariffs and subsidies for renewable or low-carbon energy technologies; fossil subsidy reform; appliance standards; retrofit or renewable energy procurement obligations; and public procurement of renewable or low-carbon technologies and infrastructures. Definitions of these are documented in the SM (section 4; SM Table 4).

In our scoping of the literature we found many articles documenting large-scale renewable energy deployment projects, in particular for hydro and wind power. Since many of these projects rely upon government support, planning, and occasionally investment (Castro *et al* 2016), we included them so long as they refer to grid-scale (not community energy) projects.

Certain pragmatic exceptions to the list of 'climate policies' should be noted here. Since our review is primarily focused on energy use policies and associated sectors (e.g. electricity and industry), we do not investigate land-use policies addressing agriculture, biofuels and forestry. For tractability, we also exclude policies for climate adaptation and those that deal only with local environmental effects (e.g. local air pollution). Importantly, we exclude policies where mitigation is the indirect outcome of a social intervention—for instance, when investment in social housing or public transportation improves access to low-energy services, resulting in lower energy demand. These social policies would have added many more categories to our review and arguably deserve their own treatment. This contrasts with our *inclusion* of policies where social outcomes result from a mitigation intervention—as when a home energy retrofit subsidy reduces energy demand, thus lowering fuel expenditures and increasing affordability.

Finally, we do not include fuel switching policies (e.g. coal to gas, biomass to LPG) unless they are part of an explicit climate policy package. This excludes a suite of clean cook stove interventions that undoubtedly have positive climate effects and social outcomes (Cameron *et al* 2016). Nonetheless, we find such measures have already been extensively reviewed in the development and health literature (Pope *et al* 2017).

2.1.2. Policy scope

The policies we assess are implemented by national, regional or local institutions. Importantly, they must be politically mandated interventions, not the private initiatives of NGOs and companies or other subnational actors (although these organisations and networks may be contracted to carry out a policy). This choice facilitates comparability been the diverse national contexts we study, but means we reject various NGO-led renewable technology support programs in the global South; some of which are very impressive in scope, such as the Grameen Shakti solar home system program in Bangladesh (Sovacool and Drupady 2011). It also means we exclude voluntary and community-led initiatives, on which there is a large literature, particularly in the United Kingdom (Seyfang *et al* 2013). Nonetheless, we still find that there remains a significant policy literature in the global South. For consistency, we *include* projects run by international political institutions such as the World Bank, Asian Development Bank and United Nations agencies. Finally, we found many articles on pilot projects and short-term policy experiments; since these typically result in smaller scale and more temporary outcomes, they are excluded from our scope.

2.1.3. Social outcomes

We assess six interrelated social outcomes in this review: (1) poverty and livelihood impacts; (2) access to and affordability of electricity services; (3) the distributional impacts of policies by income, gender and geography; (4) impacts on jobs and unemployment; (5) aspects of social and procedural justice; and (6) impacts on community cohesion and conflict. These social outcomes are leading concerns under the Sustainable Development Goals (United Nations General Assembly 2015). They have a strong theoretical foundation in eudaimonic concepts of well-being and are of the highest relevance in carrying out just climate and energy transitions (Brand-Correa and Steinberger 2017, Lamb and Steinberger 2017, O'Neill *et al* 2018). Definitions of these social outcomes are documented in the SM (section 4; SM Table 5).

However, several aspects of human well-being are missing from our review: health outcomes, nutrition and hunger, mobility, housing and shelter, and infrastructure access (e.g. sanitation, water). The first of these is most consequential—health being a critical component of human flourishing in most formulations of well-being (Alkire 2002). Nonetheless, we exclude it for pragmatic reasons, due to the enormous expansion of potential literature and health related search terms to screen. This would be a key area for future reviews. Systematic reviews have already been conducted on the health effects of housing improvements and energy efficiency measures (Maidment *et al* 2014, Camprubí *et al* 2016, Thomson *et al* 2017). And while we are aware of a growing body of literature linking climate policies to social outcomes in areas such as mobility (Mattioli 2016) and infrastructure access (Jakob *et al* 2016), we exclude these on the expectation that there are few existing policies and hence few studies to review.

Finally, we do not include studies assessing aggregate measures of welfare, GDP loss and the 'social cost of carbon'. These are important criteria for policy assessment, but are less relevant for our review of social outcomes. We follow much scholarship on the limitations of aggregate welfare measures (Stiglitz *et al* 2009, Costanza *et al* 2014) and focus our attention instead on specific social outcomes along individual, non-substitutable dimensions (Gough 2015).

To be clear, this still includes studies that disaggregate income or welfare losses by income bracket or social class, as these meet the criteria of distributional analysis—the third social outcome in our review.

2.1.4. Focus of study

In this review we only include ex-post policy evaluation studies. All types of methods and approaches are acceptable. In most cases this restriction is clear, as articles often clearly indicate whether they evaluate an implemented versus a potential policy measure. A very large volume of ex-ante studies on the distributional incidence of carbon taxes is excluded by this criteria (see Ohlendorf *et al* 2018 for a meta-analysis). In some cases, authors will conduct an ex-ante analysis of policies soon to be implemented; these are also excluded from our review.

2.2. Evidence search

To identify articles we conducted a keyword search in the Web of Science (all collections) and SCOPUS databases. The supplementary materials documents the search string we use (SM section 2.1; SM table 2). It broadly consists of four combinations of keywords linked with logical AND operations:

1. (1) Synonyms for 'climate change', 'energy', 'fuels', 'renewables' etc.
2. AND (2) Synonyms for 'policies', 'measures', 'taxes', 'subsidies', etc.
3. AND (3) Synonyms for social outcomes, such as 'livelihoods', 'inequality', 'well-being', etc.
4. AND (4) Synonyms for intervention effects, such as 'outcomes', 'incidence', 'improvement', etc.

This search (conducted in August 2019) yielded 62 425 articles. We reduced it to 45 025 articles using a set of generic exclusion criteria, removing all articles that are: not in English; written before 1990; listed under non-relevant journal subject categories; or that contain adaptation and land use synonyms in their titles (refer to the protocol for a detailed list of these exclusions).

In addition to this search, we manually identified further articles based on author knowledge and from references identified while reading documents in the later stages of our review. We also searched the institutional websites of seven well-known development and aid organisations for grey literature. These are listed in the SI.

2.3. Evidence screening

We examined each title and abstract yielded by our search for relevance, either including or excluding each based on the criteria set out in the scoping stage (section 2.1; table 1). In practice, the number of articles we yield would have rendered this procedure enormously time consuming.[10] Therefore, instead of compromising on our broad search query, we made use of new innovations in machine learning to speed up this stage of the review.

Our screening procedure was as follows. First, we selected a *random sample* of 100 documents and independently screened it for relevance among four members of the review team. We then discussed the results and reached agreement on the appropriate scope of the review and application of the inclusion/exclusion criteria. Two further samples of 100 documents were screened by four authors in this manner, and a final 200 by the lead author alone.

Second, based on this initial set of 500 screened articles (of which 15 were relevant ex-post studies), we applied a machine learning algorithm to predict the relevance of all remaining documents. We use the Python scikit-learn package's neural network classifier to perform the machine learning (Pedregosa *et al* 2011). This algorithm analyses the frequency of single words (unigrams) and pairs of words (bigrams) within abstracts and titles, learning from the training set (the 500 screened articles) to predict the relevance of all remaining documents. Such machine learning tools are increasingly applied in systematic reviews to reduce the time burden, and increase the accuracy, of manually screening articles (O'Mara-Eves *et al* 2015).

Third, we *re-ordered* the remaining documents yielded by our search from highest to lowest predicted relevance. The lead author then proceeded to screen a sample of the 100 most relevant articles. On completing these, the machine learning was performed again on the non-reviewed documents, using the new, expanded training set (now 600 articles). The documents were re-ordered, and a further set of articles screened. We repeated this procedure until no further relevant articles were yielded in a sample of 100. This procedure is in line with other computer-assisted reviewing protocols in the literature (Przybyła *et al* 2018). To ensure that certain document types or content are not systematically excluded from the (progressively expanding) training set, we generated random samples of 50 documents in each iteration to screen parallel to the machine learned sample. Overall a total of 4650 documents were screened (out of 45 025 in total), yielding 381 potentially relevant articles.

2.4. Evidence coding

In the evidence coding stage the review team read the full texts of all 381 articles identified in the screening stage. Of these, 202 turned out to not fulfil our inclusion criteria upon closer inspection. This left us with 179 relevant articles, supplemented with a further 24

[10] At an optimistic estimate of 30 s per abstract, screening ~40 000 articles would take a researcher over two months of full time work.

articles identified from reference lists and prior knowledge. A set of standardised coding categories was developed to extract the relevant information from each article. This includes generic study information (location, method) and a description of the policy (e.g. the type of policy, its scope, and associated legislation and implementation date). Where possible, we extracted information on the climate outcome, such as the volume of emissions avoided or number of households treated with energy efficiency measures. Finally, we coded the social outcome, including the category of outcome (e.g. affordability, equality, employment), the affected population (e.g. everyone, or specific groups) and the direction of the outcome (positive, negative, mixed or insignificant). We do not capture the magnitude of outcomes, due to the large variety in underlying reporting styles (e.g. 1000 jobs created, 2 million households retrofitted, increase in aggregate inequality), unless the author of a paper explicitly refers to an effect as trivial. In these cases we report 'insignificant'. We present our codebook and discuss the coding in more detail in the supplementary materials.

Article reading and coding was performed by all co-authors. To facilitate consistency between coders, we double coded 10% of the articles before conducting the full review. Additional double coding was performed in cases flagged as problematic. Where we were unable to code a paper, due to missing or incomplete information on the policy or social outcomes, we tended to reject it.

2.5. Synthesis

We conduct a two-part synthesis of the ex-post climate policy literature. First, we analyse basic information about the types of studies identified and their breakdown of assessed policies and social outcomes. In doing so we make an overall assessment of what literature exists, on which topics, using what methods (thus analysing knowledge gaps and clusters). In the second part of our synthesis, we group the literature by six overarching policy types and document their investigated social outcomes. Our review tends towards a narrative review in these sections, albeit with systematic elements. We begin each section with an overview of the literature, in particular the countries and social outcomes studied, as well as any climate outcomes recorded. We then divide the review into major subcategories, such as the different technologies under a feed-in tariff (FIT) scheme, or different types of taxes; within these we focus on clusters of outcome effects and identify deviating cases. Finally, in each policy category we discuss specific policy examples that alleviated negative social outcomes. Since the literature tends to focus on particular social outcomes within each policy category, the type of outcomes discussed varies between policy sections.

3. Results

In this section, we present our synthetic results, focusing first on a general overview of the entire sample of literature, before moving into a discussion of six classes of policy: taxes, subsidies, FITs, direct procurement, renewable planning and deployment, and other. When placing studies in these categories, our coding was inclusive, rather than mutually exclusive, meaning a single policy or study could be coded in multiple places (e.g. where outcomes were investigated for legislation combining both a subsidy and procurement obligation).

3.1. An overview of the literature

Our comprehensive search and screening identifies 203 ex-post studies on the social outcomes of climate policies. Separating out the individual policies and social outcomes within these studies, we find a total of 457 effects, or policy-outcome combinations.

The literature is dominated by one journal, *Energy Policy*, rather than more climate focused journals such as *Climate Policy* or *Climatic Change* (figure 11). Although studies utilized a mix of qualitative and quantitative methods, statistical methods, interviews and the use of secondary sources were the most frequently employed research designs. Methods also tended to be split by research topic and social outcome: distributional analysis and employment were largely treated with statistical approaches, whereas livelihoods and justice concerns were examined with mostly qualitative approaches. The number of articles per year has been growing, especially since 2010, but only 13 articles were published in the last complete year in our search (2018), down from a peak of 24 articles during the IPCC 5th Assessment Report cycle (2016/2017).

In terms of their geographic coverage, many studies are concentrated in Germany, the US, and the UK (figure 2). Of these, FITs and subsidies are well-researched. Nonetheless, there is global coverage in the literature, with examples of each policy category found in every region. In particular, the 'renewable deployment' category—which captures the social outcomes from grid-level solar, wind and hydropower projects—accounts for many local case studies in the global South. A large number of tax studies have also been conducted across Europe, the United States and several developing countries. Major gaps in the sample persist in Russia, Latin America, Central Asia and North Africa.

The literature is further divided in the type of social outcomes investigated in each policy category (figure 3). Economic effects such as distributional outcomes (income), fuel/electricity affordability and employment are the focus of studies on taxes, FITs and subsidies. Livelihoods and poverty, procedural justice and community cohesion are rather the focus

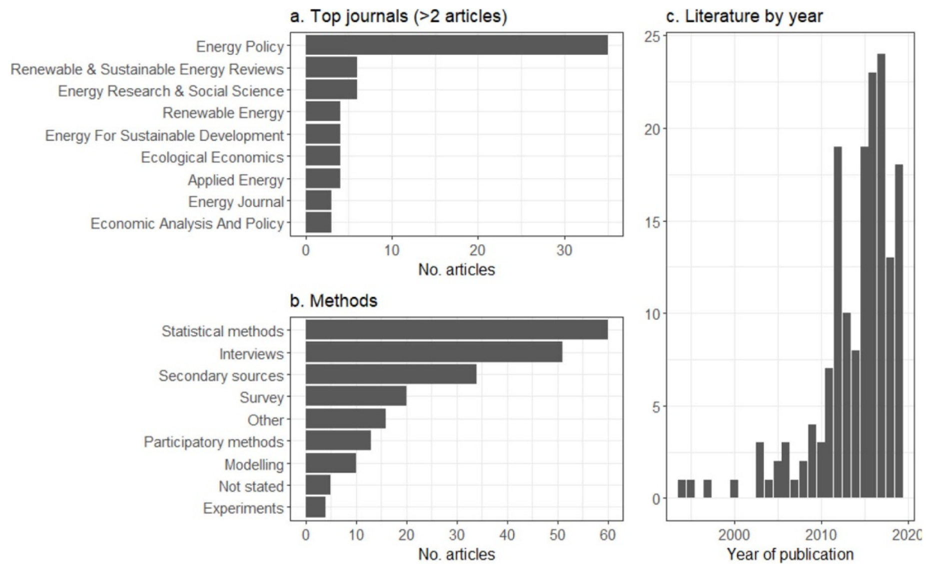

Figure 1. Journals, methods and literature trends.

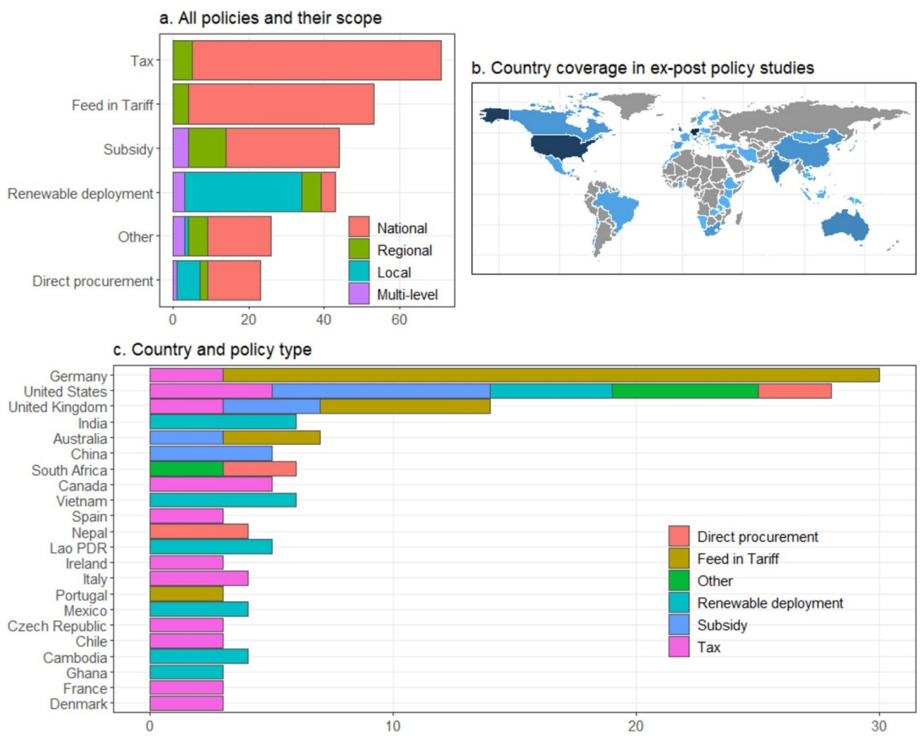

Figure 2. Climate policy scope, coverage and type. Note that a study can cover several policies and/or countries. Only countries with more than two studies are shown in panel c. We distinguish FITs from subsidies, the former comprising guaranteed revenue associated with renewable energy generation, drawn directly from consumer electricity bills; the latter comprising a broad range of financial support measures for installations (e.g. rebates, tax credits). Renewable deployment refers to individual, grid-scale renewable projects, which are typically linked to government planning and investment.

of renewable deployment studies. Substantively, there is a rather negative overall assessment for renewable deployment and FITs, with the literature reporting failures of these policies to avoid livelihood impacts or address distributional concerns. Reported taxes have tended towards either positive or insignificant effects. There is a general positive trend of social outcomes reported for direct procurement, and both positive and negative outcomes linked to subsidies. As we discuss later in this review, there are many exceptions in each case.

The literature spans a wide range of policy scales, from national policies with comprehensive coverage (e.g. fuel and energy taxes), to smaller regional or local scale initiatives, such as renewable deployment projects or community retrofit programmes.

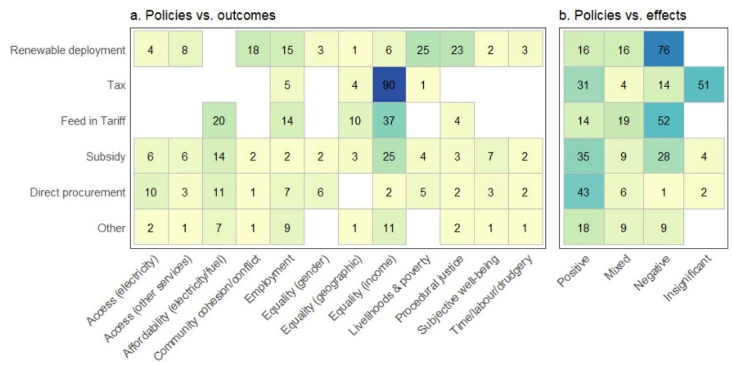

Figure 3. Climate policies and social outcomes. The heatmap scale increases with the number of effects recorded, highlighting clusters of evidence (e.g. income equality outcomes for taxes) and the typical direction of effects for different policies (e.g. negative for renewable deployment).

Table 2. A sample of large-scale policies with reported climate outcomes in the literature.

Jurisdiction	Policy	Policy category	Description of scale or scope (at time of publication)	References
United States of America	U.S. Weatherization Assistance Program	Direct procurement	5 million households served with energy retrofit measures	(Schweitzer and Tonn 2003, Tonn *et al* 2003)
United Kingdom	Warm Front Home Energy Efficiency Program	Subsidy (energy efficiency retrofits)	2.4 million households served with energy retrofit measures	(Sovacool 2015, Chawla and Pollitt 2013, Gilbertson *et al* 2012)
Germany	Energiewende (Renewable Energy Act)	Feed-in Tariff, overarching legislation	Increase in national share of renewables, from 7% in 2000%–33% in 2017	(Sopher 2015, Többen 2017, Morton and Müller 2016, Winter and Schlesewsky 2019, Gawel *et al* 2015, Pegels and Lütkenhorst 2014)
Canada	British Colombia Carbon Tax	Carbon Tax	Estimated 5%–15% reduction in greenhouse gas emissions	(Murray and Rivers 2015, Beck *et al* 2016, Yip 2018, Yamazaki 2017)
Australia	Feed-in Tariff	Feed-in Tariff	1.5 million solar PV systems installed	(Poruschi and Ambrey 2019, Chapman *et al* 2016, Nelson *et al* 2011)
Mexico	Wind farms on the Isthmus of Tehuantepec	Renewable Deployment	2854 MW of installed wind power capacity	(Huesca-Pérez *et al* 2016, Zárate-Toledo *et al* 2019, Avila-Calero 2017)
Vietnam	Son La hydropower dam	Renewable Deployment	2400 MW hydropower dam	(Bui *et al* 2013, Hang Bui and Schreinemachers 2018)
Portugal	Feed-in Tariff	Feed-in Tariff	Increase in national share of renewables, from 30% in 2000%–50% in 2010	(Behrens *et al* 2016)
South Africa	Renewable Energy Independent Power Producers Procurement Programme	Renewable energy procurement obligation	1417 MW renewable energy capacity	(Walwyn and Brent 2015, Pahle *et al* 2016)
Bulgaria	Renewables Law (2007)	Feed-in Tariff	1000 MW of installed solar capacity; 660 MW of installed wind power capacity	Andreas *et al* 2018

Some of the larger-scale policies reported in the literature include the Renewable Energy Act in Germany (estimated increase in national share of renewables from 7% in 2000%–33% in 2017), the Warm Front Home Energy Efficiency Program in the UK (2.4 million households served with energy retrofit measures), the U.S. Weatherization Assistance Program (5 million households served with energy retrofit measures), as well as renewable energy programs and projects in Mexico, Vietnam and South Africa, each with installed capacities of over 1000 MW (table 2).

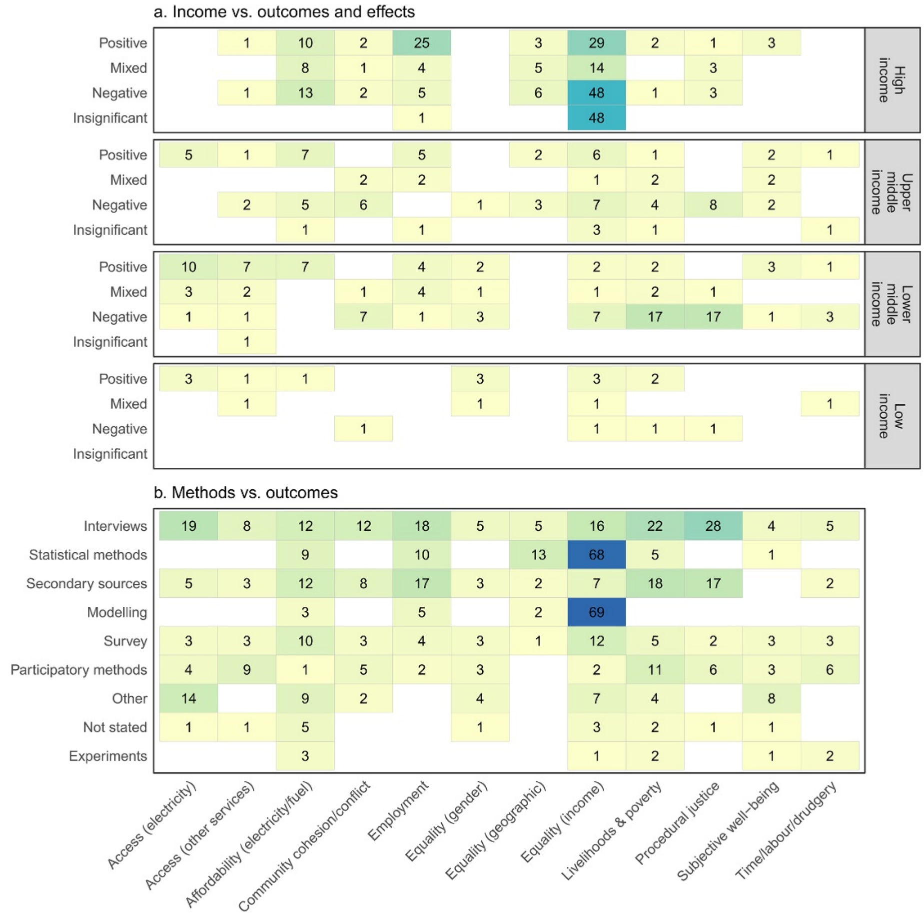

Figure 4. Evaluated effects of policies by country category (income) and outcome type (panel a); and evaluation methods by outcome type (panel b). The heatmap scale increases with the number of effects recorded, highlighting clusters of evidence (e.g. studies with statistical methods investigating income equality) and the typical direction of outcome effects (e.g. negative income equality outcomes in high income countries).

In the following policy-focused sections, our review of social outcome effects should be strongly caveated. With the literature at an early stage—less than 200 articles *across all policy types*—many outcomes will be unreported. Additionally, we observe a high concentration of studies and study types around particular topics and contexts, such as negative distributional effects linked to subsidies and FITs in wealthier countries, or negative livelihood and procedural justice impacts linked to renewable deployments in low middle income countries (figure 4(a)). This initial survey of the literature lacks a full accounting of policies in less developed regions, is based on an incomplete methodological coverage of the relevant outcomes (figure 5(b)), and does not report on the magnitude of effects. Finally, we do not conduct a critical appraisal of the articles in our review, and thus assume that they adequately demonstrate causality or association between the studied policies and outcomes. Our reporting of the social outcomes of climate policies should therefore be treated as preliminary, exploratory, and conditional upon much further critical reflection and development of the literature.

3.2. Climate policies and their social outcomes

3.2.1. Taxes

3.2.1.1. Overview

Ex-post evaluations of the social outcomes of tax policies cover most high-income countries, with additional cases in China, Kenya, Ethiopia, Costa Rica, and Turkey (figure 5). Of the 22 studies assessed, nine analyse the effects of carbon taxes, 14 analyse transport taxes on gasoline and diesel, and three a broad array of energy taxes (several studies examine more than one). The large majority of studies deal with taxes that are imposed on the national level, with the exception of three papers on British Columbia, which introduced a carbon tax on a sub-national level. The earliest indicated start date for any of these policies is 1993, even though it seems safe to assume that taxes for transport fuels have been in place for much longer.

In most cases, these studies do not explicitly account for the climate effects of the policies under scrutiny. Indeed, many authors introduce energy and transport taxes as government measures purposed to mitigate local air pollution, congestion and raise

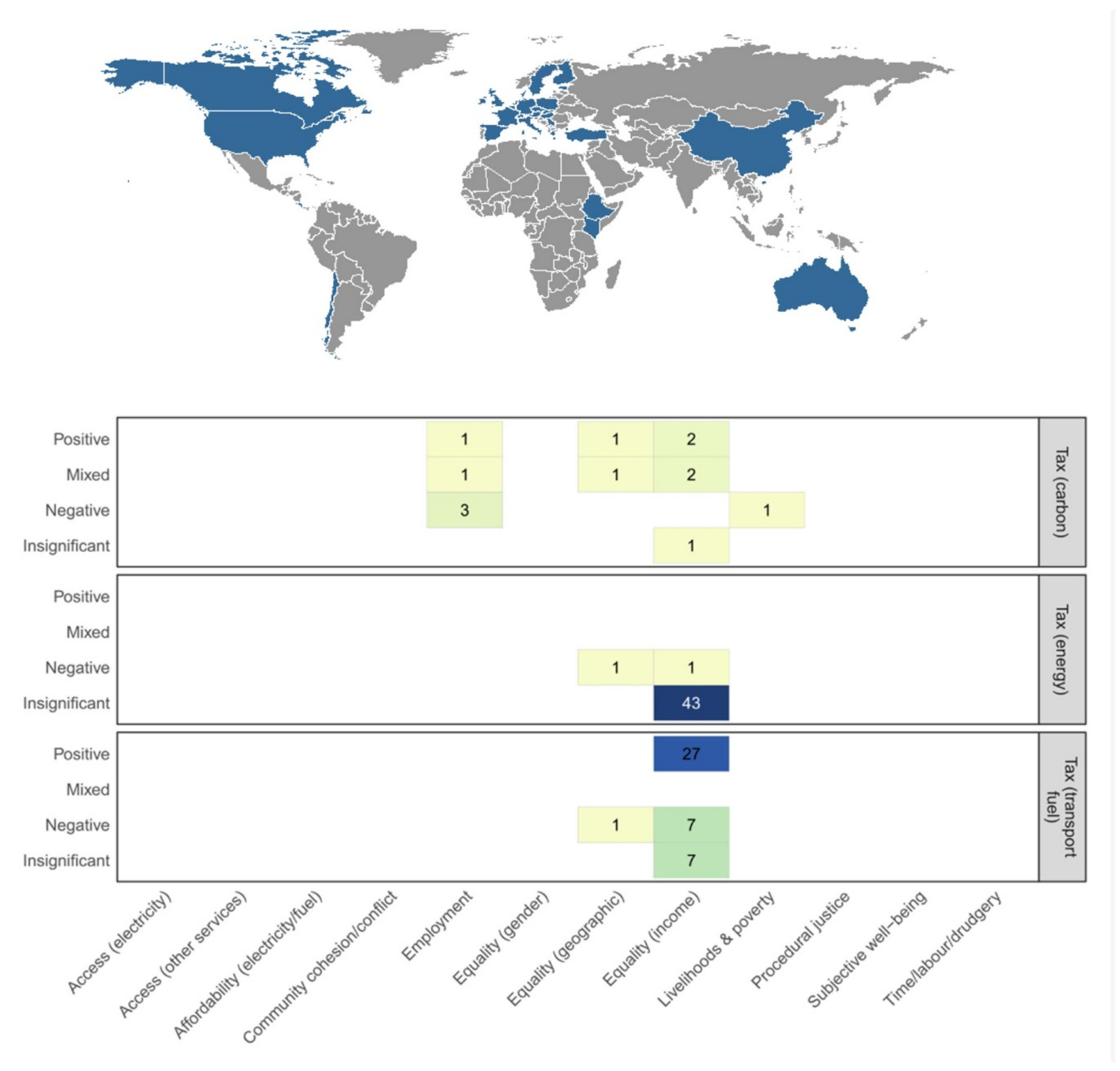

Figure 5. Country coverage and social outcomes of taxes. The heatmap scale increases with the number of effects recorded, highlighting clusters (and absence) of evidence and the common direction of effects.

revenues, rather than address greenhouse gas emissions (Blackman *et al* 2012, Cao 2012, Yusef and Resosudarmo 2012, Mekonnen *et al* 2012, Mutua *et al* 2012). Two studies on the British Columbia carbon tax do present quantitative estimates of implied emission reductions (Murray and Rivers 2015, Beck *et al* 2015), while multiple studies argue that the analysed fuel taxes would reduce emissions, but do not provide a quantitative assessments (e.g. Tiezzi 2005, Sterner 2012).

In terms of social outcomes, the large majority of studies (21) focus on the distributional outcomes of environmental taxes, coded in figure 5 as 'Equality (income)'. Three examine employment effects, and one analyses livelihoods and poverty. Statistical approaches predominate in these assessments (13 studies), in particular using household expenditure data in the evaluation of distributional effects. Other methods include modelling (6), as well as secondary sources and surveys (1 each).

3.2.1.2. Social outcomes of transport fuel taxes
In total, the assessed studies provide 13 estimates for the social outcomes of carbon pricing, 45 for energy taxes, and 42 for transport fuel taxes. The largest share of these effects stem from a comprehensive analysis comparing the distributional implications of taxes on transport fuels, heating fuels and electricity across 21 OECD countries (Flues and Thomas 2015). Using micro-simulations based on household data, this study provides 63 distinct effects (21*3, i.e. 21 countries and three fuel types). For taxes on electricity and heating fuels (recorded here as energy taxes), it finds predominantly regressive distributional effects, which, however, are modest in absolute terms (i.e. typically less than 1% of household expenditure in the lowest income bracket). For this reason, we decided to code them as 'insignificant' in our analysis. With regard to transport fuels, the authors find proportional to progressive distributional effects for the majority of countries when expenditure is used as

an income measure (as a proxy of lifetime income instead of available actual income). Using current income instead produces a more heterogeneous picture, in which some countries show progressive effects and others slightly regressive ones. Independent of the income measure, countries with lower GDP per capita are more likely to exhibit progressive distributional effects of taxes on transport fuels.

The finding that taxes on transport fuel taxes tend to become slightly regressive in wealthier countries is duplicated across a number of case studies (Wiese *et al* 1995, Chernick and Reschovsky 1997, Sterner 2012, Scasny 2012). Sterner (2012) compare the incidence of gasoline and diesel taxes for seven European countries (France, Germany, Italy, Serbia, Sweden, Spain and the UK). The results indicate that on average, these taxes are slightly regressive, but that the effect is so small that they can be considered to be roughly neutral, i.e. impose a similar burden on poor and rich households relative to their income. Considering expenditures as a measure of income yields neutral outcomes (weakly progressive in some countries, and weakly regressive in others). A similar small, but regressive outcome, is shown for the Czech Republic (Scasny 2012). For the case of the US gasoline tax, Chernick and Reschovsky (1997) show that regressive distributional outcomes not only occur on a current income basis, but also when household income is tracked over a longer time-horizon, which provides a more appropriate picture of lifetime income. Based on a general equilibrium analysis that considers revenue recycling, one study (Wiese *et al* 1995) finds that redirecting tax receipts from road construction to general funds in the 1980s has turned the US gasoline tax regressive. Contrasting evidence from Chile suggests that its gasoline tax is progressive, whether assessed by income or expenditure, due to the low share of car ownership among the poorer parts of the population (Agostini and Jiménez 2015). Jacobsen *et al* (2003) also find a progressive effect attributable to Denmark's transport fuel tax.

The distributional incidence of transport fuel taxes in less wealthy countries is generally found to be progressive. This is the case for Costa Rica (Blackman *et al* 2012), China (Cao 2012), Ethiopia (Mekonnen *et al* 2012), Kenya (Mutua *et al* 2012) and Chile (Agostini and Jiménez 2015). The main intuition is that wealthier households in these countries tend to own and use vehicles, and are therefore more exposed to fuel taxes, while poorer households use alternative modes such as public transportation. In the study on Costa Rica, an analytical distinction is made between gasoline and diesel taxes, with the latter being regressive (Blackman *et al* 2012). This is because diesel fuel constitutes a large share of bus transportation running costs in Costa Rica, which is heavily used by poorer households. Indeed, the inclusion of indirect costs for public transportation tends to decrease the progressivity of fuel taxes (Cao 2012, Mekonnen *et al* 2012, Mutua *et al* 2012). Generous subsidies for public transportation are therefore suggested as an effective measure to shield poorer households from upstream fuel taxes (Cao 2012, Blackman *et al* 2012).

3.2.1.3. Social outcomes of energy and carbon taxes

Broad based energy and environmental taxation has been investigated in the United States and Denmark (Casler and Rafiqui 1993, Bull *et al* 1994, Jacobsen *et al* 2003, Wier *et al* 2005). Bull *et al* (1994) use household data to analyse broad-based energy taxes in the United States, concluding that these taxes are regressive when only direct effects are taken into account and outcomes are assessed relative to current income. The effects are roughly neutral when assessed against expenditures and accounting for indirect effects (i.e. through price changes for goods and services that use energy as an input to production). Two studies analysing the effects of a broad basket of environmental taxes (including transport fuels and CO_2) on household income in Denmark (Jacobsen *et al* 2003, Wier *et al* 2005) find overall regressive effects (again, using expenditures instead of disposable income results in less regressive effects) and a higher cost burden for rural than for urban households.

All three studies examining the distributional effects of the British Columbia carbon tax find progressive distributional effects, which is attributed to the recycling of revenues by means of overall tax reductions and transfers to particularly affected households (Beck *et al* 2015, 2016, Murray and Rivers 2015). Even though further scaling up of the tax in later years without increasing support for low-income households may have resulted in regressive outcomes, the overall effect is assumed to be small (Murray and Rivers 2015). Furthermore, without compensatory measures, this carbon tax would have had the most severe adverse impacts for the rural population. With revenue recycling, however, it conveys a welfare gain to rural households, even though to a lesser extent than for urban dwellers (Beck *et al* 2016).

Only a few studies examine social outcomes not pertaining to distributional effects. These include a pair of studies on the effects of carbon pricing on employment in British Columbia (Yamazaki 2017, Yip 2018). Each takes a different methodological approach and finds contradictory results. Using a partial equilibrium model and an empirical demand function for labor based on industry-level employment data, Yamazaki (2017) finds positive overall labor market effects, in spite of negative effects for emission-intensive and trade-exposed sectors. By contrast, Yip (2018) carries out an analysis based on individual-level data on unemployment, labor force participation, and the characteristics of layoffs and new hires. His results indicate that the carbon tax has reduced employment, in particular for medium- and low-educated males. Finally, Ge (2014) examines the effect of Australia's carbon tax on housing affordability, finding that especially low-income households were adversely affected, mainly by higher gas and electricity prices.

In summary, the literature on social outcomes of carbon and energy taxes largely focuses on distributional outcomes, for which it finds mixed results. Taxes on transport fuels appear to be more likely to be progressive than energy or carbon taxes, particularly in less wealthy countries. In addition, studies assessing tax burdens relative to expenditures (as a proxy of life-time income) instead of actual income more frequently find progressive impacts. These differences can be attributed to country-specific differences (especially to differences in energy use patterns, which are closely linked to income), the type of policy under study (carbon vs. fuel vs. energy taxes) as well as the measure of income used (actual income vs. expenditures). Moreover, revenue recycling, which is only considered for the studies for the British Columbia carbon tax, is a key determinant of distributional consequences. Hence, a tax design that is appropriate for the specific country context, in particular regarding the use of tax revenues, can likely prevent adverse implications for other important social outcomes, such as the distribution of income.

3.2.2. Subsidies

3.2.2.1. Overview

We divide ex-post evaluations of subsidy schemes into four categories: those that support energy efficiency retrofits, solar installations, wind power installations, and other clean energy investments in general. Overall, we find 37 studies reporting on 76 social outcomes of subsidy schemes. The time coverage of subsidy schemes analysed in the literature starts as early as 1975, but is mainly clustered around the 2000s.

Geographically, we find cases across all continents covering a total of 22 countries (figure 6). While the vast majority of cases are focussed at the national level, there are also 8 sub-national subsidy schemes investigated in Europe, the United States, South Africa and China. A suite of different methods are used to analyse social outcomes of subsidy schemes: statistical methods (16), interviews (8) surveys (5). Other methods are much less frequently applied, such as experiments, participatory methods and CGE modelling.

In case studies from high-income countries, reporting also tends to include climate outcomes. For instance, studies on the Photovoltaic Rebate Programme in Australia (2000–2010) suggest it triggered a total of about 110 000 PV installations (128 MW) at an estimated cost of about 1.1 billion Australian dollars, albeit at a relatively low level of cost effectiveness (AU$238 and AU$282 per tonne GHG abated) (Macintosh and Wilkinson 2011, Granqvist and Grover 2016).

Across the different policy instruments the literature on subsidy schemes covers the broadest range of social outcomes. While analyses of social outcomes most frequently focus on distributional effects by income (25), there are also clusters of studies examining electricity affordability impacts (14), access to electricity and services (12), as well as subjective well-being (7). The balance of evidence on outcome effects is mixed: we find 35 positive outcomes reported and 28 negative ones, while other studies show mixed (9) or insignificant (4) effects. Our following discussion focuses specifically on reported outcomes for solar installations and energy efficiency retrofit subsidies. This leaves out a very heterogeneous, albeit interesting, group of papers on wind subsidies and other schemes (van Groenendaal and Gehua 2010, Sovacool and Drupady 2012a, 2012b, Karki and Tao 2016, Borenstein and Davis 2016, Brannstrom *et al* 2017, Barman *et al* 2017, Bhattarai *et al* 2018, Barrington-Leigh *et al* 2019).

3.2.2.2. Social outcomes of solar subsidies

16 studies analyse the social outcomes of solar PV subsidy schemes, covering both low-income (such as Bangladesh, Nepal or Indonesia) and high-income countries (Australia, Germany, and the United States). In the former, studies find exclusively positive effects linked to these policies, typically in terms of energy affordability and access, while the picture is very mixed for developed countries, where equity issues are more prominently analysed.

Among the evidence on low-income and middle-income countries, there are prominent examples of subsidies focused on rural, decentralised energy access, for instance via solar home systems (Kabir *et al* 2010, Sovacool and Drupady 2012c, 2012d, Bhattarai *et al* 2018). The documented outcomes of these policies include the improved affordability of energy services compared to fossil-fuel based alternatives such as kerosene or diesel. Electricity access and its manifold benefits for lighting, refrigeration, communications, and income generating activities (thus poverty reduction) are also prominent. A fundamental question, however, is whether these schemes reach poor households. Only one study addresses this question, finding that a Nepalese scheme for solar home systems is indeed accessible to the poor (Bhattarai *et al* 2018). Of the 27% of eligible households that participated in the scheme, 25% were below the poverty line compared to a poverty rate of 19% in the country. Still, across the sample, poorer households are 18 percentage points less likely to adopt solar home systems than richer households.

In studies of high-income countries, many authors pose the inverse question: do wealthier households disproportionally benefit from solar subsidies? This is indeed the general case, with evidence of negative (income and geographic) equality effects from the Australian photovoltaic rebate policy

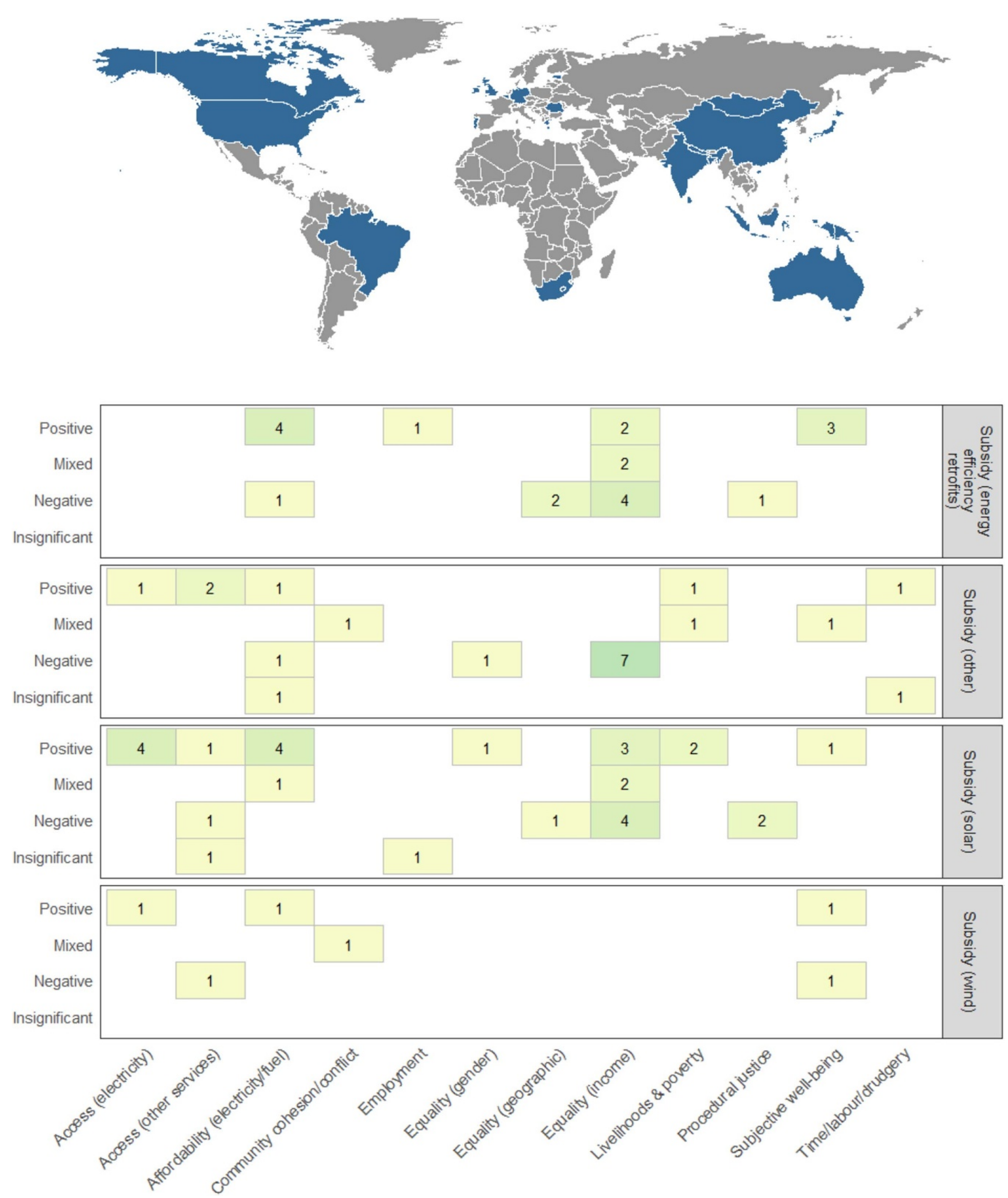

Figure 6. Country coverage and social outcomes of subsidies. The heatmap scale increases with the number of effects recorded, highlighting clusters (and absence) of evidence and the common direction of effects.

(Macintosh and Wilkinson 2011), federal subsidies in the US (Vaishnav *et al* 2017), the Hawaii solar tax credit program (Coffman *et al* 2016), and schemes in Belgium and Portugal (Bartiaux *et al* 2016). Since wealthier households can front the investment needed to install PV systems and gain a subsidy or rebate, they are often the beneficiaries of such policies. Nevertheless, authors argue that Australian and federal US programs decreased in regressivity over time (Macintosh and Wilkinson 2011, Vaishnav *et al* 2017), while the former succeeded on other fairness criteria such as proportional payments and protection of lowest welfare levels (Granqvist and Grover 2016). It is also significant that one programme specifically aimed at increasing solar penetration in low-income communities in the US was successful in doing so, reducing targeted low-income household energy expenses by about $350–500 per year, and thus contributing to poverty reduction and income equality (Nichols and Greschner 2013).

3.2.2.3. Social outcomes of energy efficiency retrofit subsidies

We find 15 ex-post evaluations of energy efficiency retrofit subsidies. Cases are focused on high-income countries in Europe and North America, except for two in Brazil and China. Overall, we find rather positive outcomes reported in studies assessing affordability and subjective well-being, but rather mixed outcomes in terms of distributional (geographic and income) effects.

There are six studies assessing electricity and fuel affordability outcomes, four of them reporting positive results. Among these are two assessments of the UK Warm Front program, which provided insulation and heating improvement subsidies to 2.3 million fuel-poor English homes (Gilbertson *et al* 2012, Sovacool 2015). In a review of secondary sources, Sovacool (2015) highlights the success of this program in saving annual energy costs (about £600 per home) and carbon (about 1.5 tons of CO_2 per home), while Gilbertson *et al*'s (2012) quasi-experimental study showed it led to increased energy affordability for grant recipients. Similar positive effects are reported by Bao *et al* (2012) for another large retrofit scheme in China targeting a total of 150 million m^2 floorspace and avoiding 3.2 million tons of CO_2 per year. Since these policies mostly or fully cover retrofit costs with comprehensive grants, there are few downsides for recipients and significant affordability benefits to be gained. On the negative side, an econometric study by Weber and Wolff (2018) reports a decline in affordability borne by renters under Germany's retrofit subsidy scheme, as landlords were able to pass on a significant share of the retrofit costs through annual rents—ultimately outweighing the benefits gained in terms of lower energy bills.

Nine outcomes in our sample are reported on distributional issues triggered by energy efficiency retrofit subsidies—both geographic and income. Similar to studies on solar PV subsidies in wealthy countries, the guiding question here is whether these policies reached low as well as high-income households. Indeed, in cases from Estonia (Lihtmaa *et al* 2018), Romania (Turcu 2017), Canada (Rivers and Shiell 2016) and the United States (Xu and Chen 2019), public subsidies for building and household retrofits were typically regressive in terms of income and geographic distribution, with grant recipients mainly located in middle and high income areas. Again, this was principally because low-income households lacked the upfront capital and support required to invest and participate in these schemes. The 'Saving in-house' program in Greece overcame this problem with a combination of interest-free loans and energy retrofit subsidies that progressively increased for lower-income households (Drivas *et al* 2019). It ultimately reached 50 000 participants (2011–2015), the vast majority of which were in low-income brackets.

In summary, subsidies for solar and energy efficiency installations are attractive for recipients, with reported benefits for affordability, access and poverty reduction. Yet without mechanisms to explicitly target or support low-income households, they may exacerbate pre-existing inequalities.

3.2.3. Feed-in tariffs

3.2.3.1. Overview

We identified a similarly large sample, 32 studies, on the social outcomes of FIT systems. The majority of studies investigate policies for solar energy (30), with a further 13 covering FITs for wind, and eight on other renewable technologies. Some studies cover FITs designed for a package of renewable energy technologies, sometimes also in combination with other policy instruments like subsidies, grid-level renewable deployment schemes or renewable energy procurement obligations.

The social outcomes of FIT policies have mainly been explored in high-income countries (figure 7). Most studies focus on Germany (14), the UK (5), and Australia (4). Only a handful investigate FIT systems in countries of the Global South: India (Yenneti and Day 2015, Yenneti *et al* 2016) and Malaysia (Muhammad-Sukki *et al* 2014). While the majority of the investigated FITs are national policies, five papers cover regional policies. The earliest FIT evaluated in one of the surveyed studies dates back to 1998 in Spain (Sáenz de Miera *et al* 2008), but most of the policies were established in the 2000s. The reported climate outcomes range from a few megawatts of installed renewable energy capacity, to dozens of gigawatts, or more than a million individually installed roof-top PV systems (Poruschi and Ambrey 2019). Overall, the ex-post literature suggests FIT systems have been very successful in expanding renewable energy in many countries.

The majority of studies used statistical methods to assess social outcomes (17), although many also used secondary sources (8). Some used mainly qualitative techniques like interviews (4) and surveys, and two applied computational modelling.

3.2.3.2. Social outcomes of FITs

Most research on the social outcomes of FITs has evaluated distributional aspects, especially effects on disposable income. A majority of studies on solar FITs record negative outcomes, especially on income equality (18) and electricity affordability (6). The main mechanism underlying these regressive outcomes is the electricity surcharge from which FITs are financed, which typically constitutes a constant share of retail electricity prices. Since energy costs have a higher share in the budgets of poor households, they bear a proportionally greater burden from the FIT surcharge (Frondel *et al* 2008, 2010, 2015, Behrens *et al* 2016, Verde and Pazienza 2016, Többen 2017, Andreas *et al* 2018, Winter and Schlesewsky 2019).

To make things worse, evidence from Australia, Germany, and the UK suggest that while all residential users share the costs of renewables through the surcharge, the benefits go disproportionately to rich households, especially in the case of subsidies to rooftop solar (Torres *et al* 2010, Andor *et al* 2015, Grover and Daniels 2017, Winter and

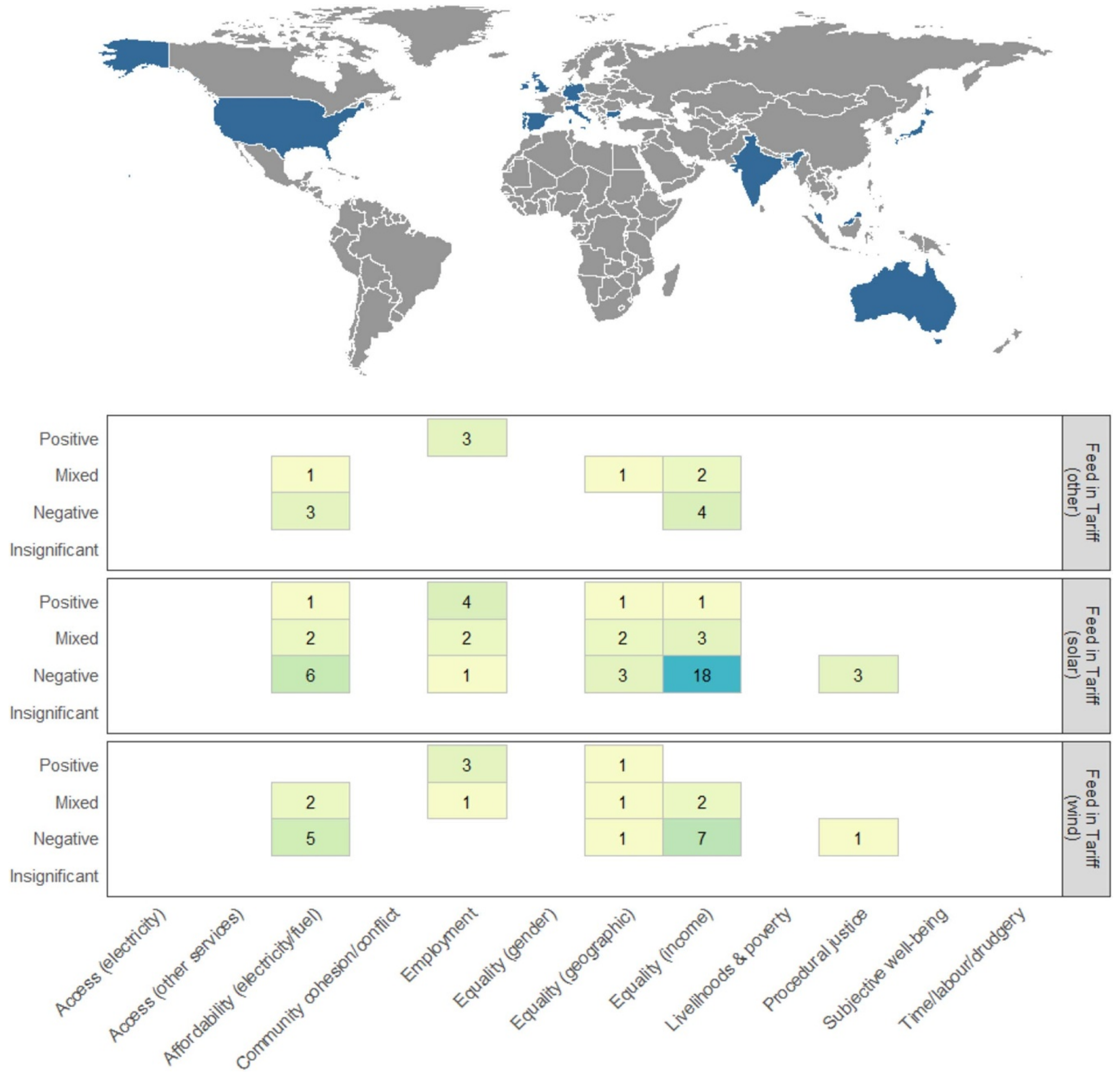

Figure 7. Country coverage and social outcomes of feed-in-tariffs. The heatmap scale increases with the number of effects recorded, highlighting clusters (and absence) of evidence and the common direction of effects.

Schlesewsky 2019). In addition, a large uptake of solar PV systems induces costs for expanding and modernising electricity grids, exacerbating income inequality where lower population densities correlate with lower incomes and thus higher grid expansion costs (Schlesewsky and Winter 2018). PV integration also increases grid costs directly by reducing the total traded electricity, since PV owners consume their own power, thereby shrinking the base over which these total grid costs are shared (Strielkowski *et al* 2017). In the specific case of Germany, these regressive effects are further increased by extensive FIT surcharge exemptions for energy-intensive industries (Neuhoff *et al* 2013).

However, the increased share of renewables can also lead to decreasing wholesale prices of electricity due to the merit-order effect, which made the FIT in Germany less regressive (Cludius *et al* 2014b). Furthermore, Gawel *et al* (2015) warn that it is impossible to make general statements about the distributional effects of the transition in Germany driven by the FIT based on a mere assessment of surcharge payments and subsidies. Other costs and benefits, including externalities, have to be considered, and the baseline for any comparison has to be clarified because no alternative would be neutral from a distributional perspective.

There are four studies from other countries that find positive or mixed effects on equality and affordability at different levels. California's FIT was explicitly designed to support low- and very low-income households, with 10% of the program budget set aside for this purpose via low-interest loans and fully subsidized systems (Granqvist and Grover 2016). The program did not, however, ensure that low-income households were exempted from overall FIT costs. Saunders *et al* (2012) report on community energy organisations that assisted low-income households in applying and paying for FIT generating systems, showing these are indeed one institutional mechanism to alleviate distributional impacts. Other studies have shown broad benefits of FITS, for example in local Japanese communities, indicators of social equity improved with the siting of FIT supported mega-solar plants (Chapman and Fraser 2019), while in Spain consumer savings due to the merit-order effect outweighed the overall costs of a wind energy FIT (Sáenz de Miera *et al* 2008).

In terms of geographical equality, results are mixed. In Germany, the largest cost burdens fall on relatively rich city states (Többen 2017), but solar subsidies also go to the relatively rich South (Winter and Schlesewsky 2019). In Australia, PV installations are sparser in denser urban environments, suggesting that renters profit much less (Poruschi and Ambrey 2019). And while PV installations in the UK are more concentrated in high-income areas, wind projects are mainly realized in medium-income areas (Leicester *et al* 2011). Two cases highlight procedural injustice as a problem with FIT policies. In the first, a FIT supported mega-solar project in rural India lacked appropriate information exchange and community consultation in project planning; this was partially attributed to the low procedural requirements for gaining access to the FIT program (Yenneti and Day 2015, Yenneti *et al* 2016). In the second case, under the Bulgarian FIT, government decisions for energy projects lacked transparency and public consultations, furthering opportunities for corruption between politicians and investors (Andreas *et al* 2018).

The only social outcome of FITs that was mainly positively evaluated is the effect on employment: The policies in Malaysia and Portugal led to net job creation (Muhammad-Sukki *et al* 2014, Behrens *et al* 2016). For Germany, one study found positive impacts (Sopher 2015), especially for Eastern federal states where unemployment is higher (Pegels and Lütkenhorst 2014), two studies found mixed evidence (Frondel *et al* 2010, Pahle *et al* 2016) and one reported negative outcomes (Frondel *et al* 2008).

In summary, FITs have two specific distributional effects, on which the literature mostly agrees: first, the costs of increasing renewables in the power system is shared based on electricity consumption, which makes it regressive. Second, the financial benefits of FITs for residential PV systems go to homeowners who can afford these investments. But there are remedies: exemptions for low-income households or smaller reductions for energy-intensive industries can make the levy less regressive. Furthermore, local energy communities and targeted financial programs can facilitate access to renewable energy systems such that low-income households can also profit from FITs.

3.2.4. Direct procurement

3.2.4.1. Overview

We identified 23 ex-post evaluations of the social outcomes of direct procurement policies covering 18 different policies world-wide. 15 studies focus on the provision of distributed renewably energy installations, including small scale hydropower units in Nepal (Mahat 2006, 2011, Sovacool 2016), solar water heaters in South Africa (Curry *et al* 2017), hybrid solar-diesel mini-grids in Namibia (Azimoh *et al* 2017), biogas units in India (Raha *et al* 2014), solar-battery systems in Thailand (Green 2004) and micro-hydro and solar panels in Cuba (Cherni and Hill 2009). The other 6 policies studied were energy retrofit programs including the Weatherization Assistance Program in the US (Riggert *et al* 2000, Schweitzer and Tonn 2003, Tonn *et al* 2003), two retrofit programs in the UK (Shortt and Rugkåsa 2007, Grey *et al* 2017), and one each in Switzerland (Yushchenko and Patel 2016), Australia (Watson *et al* 2015) and South Africa (Thobejane *et al* 2019).

Geographically there is a discernible divide with all renewable energy policies located within low and middle-income countries, whereas five of six energy retrofit programs were located in high-income countries (figure 8). Moreover, the renewable energy programs were predominantly national in scale, with the exception of Azimoh *et al*'s (2017) study of the installation of a hybrid mini-grid in Twumkwe Village in Namibia and a study of a local bio-digester provisioning program in Arusha, Tanzania (Laramee and Davis 2013). Conversely the energy retrofit policies studied were more varied with the U.S. Weatherization Assistance Program retaining a national focus whereas the other four policies studied were more locally or/regionally focused. Apart from the Weatherization Assistance Program, which was started in 1976, the other policies studied were generally initiated around the early 2000's, ranging from the Renewable Energy Development Program in Nepal, initiated in 1996, to the Get Smart Bill in Tasmania, Australia in 2013.

Thirteen of the 16 identified studies reported climate outcomes, most in terms of renewable energy installations. These ranged from 51 900 installed solar heater systems in Thailand (Green 2004, p 749), to 6 MW of micro-hydro systems in Nepal (Sovacool 2016), and the construction of 200 hydroelectric plants in Cuba (Cherni and Hill 2009). The studies on efficiency retrofits described policies that covered 54 household retrofits in Northern Ireland (Shortt and Rugkåsa 2007) to 5 million through the Weatherization program in the US (Schweitzer and Tonn 2003, Tonn *et al* 2003). Energy efficiency improvements were also reported, amounting to 7.7GWh/y from solar water heater installations in South Africa (Curry *et al* 2017) and a 0.1% reduction in the total amount of energy consumed in the Geneva canton (Yushchenko and Patel 2016).

3.2.4.2. Social outcomes of direct procurement

Direct procurement studies report mainly positive social outcomes, with only a single negative finding (there were however six mixed findings and one

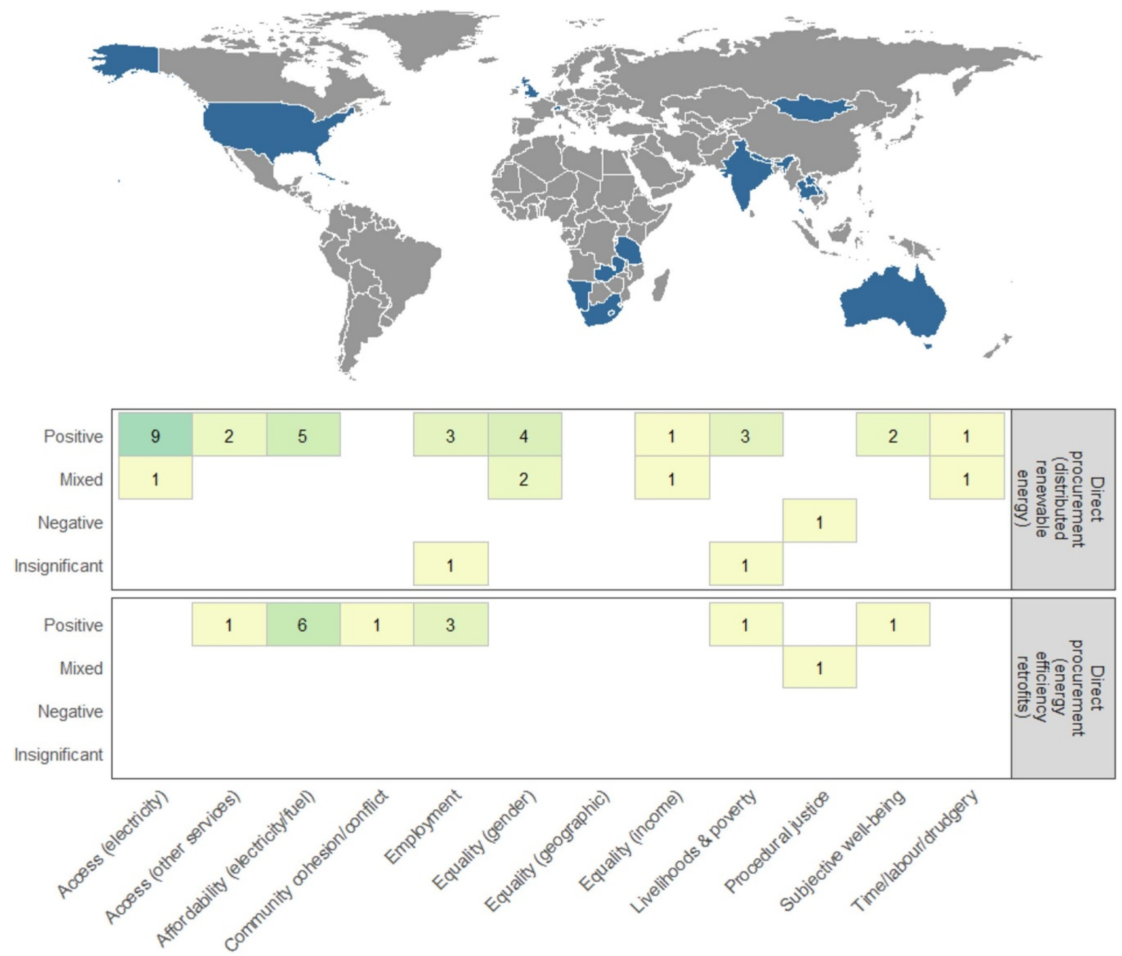

Figure 8. Country coverage and social outcomes of direct procurement. The heatmap scale increases with the number of effects recorded, highlighting clusters (and absence) of evidence and the common direction of effects.

insignificant). Electricity affordability is highlighted as a key benefit of these programs, with renewable energy or energy efficiency procurements providing beneficiaries with cheaper on-site energy production and substitution or demand-reduction possibilities away from expensive fossil fuels (Schweitzer and Tonn 2003, Tonn *et al* 2003, Shortt and Rugkåsa 2007, Raha *et al* 2014, Curry *et al* 2017, Grey *et al* 2017).

Studies covering renewable energy deployment also report electricity access (Green 2004, Mahat 2006, Sovacool 2016, Azimoh *et al* 2017) and poverty reduction (Green 2004, Cherni and Hill 2009, Sovacool 2016) as significant and recurring positive outcomes. These outcomes are especially pertinent in low-income countries. Since electricity access is closely tied to human development—providing energy services such as lighting, refrigeration and communication—further outcomes in terms of education, health, and human capability expansion (which we do not assess here) are also likely to result (Alstone *et al* 2015).

Studies of energy efficiency retrofit programs in high-income countries reported the employment opportunities created by each policy as a significant social outcome (Riggert *et al* 2000, Schweitzer and Tonn 2003, Yushchenko and Patel 2016, Curry *et al* 2017). This is in part due to the high labour demands of retrofitting households with energy efficiency technologies. For instance, one retrofit procurement program reported higher employment generation compared to standard public expenditure in Switzerland (8.19 vs. 7.94 full time equivalent job per 1 million CHF, respectively) (Yushchenko and Patel 2016). Poverty reduction was also cited as a positive outcome of the Weatherization Program in the US (Schweitzer and Tonn 2003), and though not explicitly reported as such, increased employment combined with cheaper energy bills are also likely to alleviate poverty levels.

Further identified positive outcomes include income equality (Riggert *et al* 2000), subjective well-being (Azimoh *et al* 2017, Grey *et al* 2017), community cohesion (Riggert *et al* 2000), gender equality (Sovacool and Linnér 2016), time/labour/drudgery (Curry *et al* 2017), procedural justice (Grey *et al* 2017), and access to non-energy services (Grey *et al* 2017). Mixed outcomes include gender equality (Mahat 2011), procedural justice (Watson *et al* 2015), employment (Cherni and Hill 2009), time/labour/drudgery (Mahat 2006), income equality

(Sovacool 2016), and procedural justice (Grey *et al* 2017). One study noted procedural justice as a negative outcome (Mahat 2006).

Qualifying these mixed outcomes, both Sovacool (2016) and Mahat (2006) find that the Rural Energy Deployment Program in Nepal, while generally positive for receiving communities, did tend to exacerbate pre-existing gender and income inequalities—men generally retained ownership over installed renewable energy systems, and established caste systems led to non-uniform pricing and access to renewable energy. Some studies identified further mediators of positive outcomes, arguing for example that poverty alleviation would be better served by efforts to increase income than to deploy houses with energy efficiency retrofits (Shortt and Rugkåsa 2007). Additional issues include poor quality installations and a lack of maintenance (Raha *et al* 2014, Curry *et al* 2017, Thobejane *et al* 2019), as well as the need to integrate community goals and develop additional policies alongside procurement to support development and energy access (Cherni and Hill 2009, Azimoh *et al* 2017, Grey *et al* 2017).

In conclusion, direct procurement seems to be a climate policy with significant positive social outcomes. Depending on the context of the policies, a range of social outcomes has been reported, with affordability of, and access to, electricity/energy as well as employment and poverty reduction standing out as primary positives. These studies, however, tend not to analyze how policy costs are allocated, and thus whether there are any adverse distributional implications at a macro level.

3.2.5. Renewable planning and deployment

3.2.5.1. Overview

Renewable planning and deployment is the largest category of literature assessed, with 38 studies set across 16 countries. These studies can be distinguished from other policy categories in several ways.

First, they specifically focus on centralised renewable energy projects designed for feed in to the electricity grid, in contrast to more decentralised projects that deliver electricity mainly for own or local use (several of the latter are reported in the direct provisioning and subsidy categories). Second, these studies tend to have a highly localised focus, using mainly qualitative case study designs (e.g. interviews, surveys) to trace the social impacts of large and small renewable energy projects in their immediate vicinity. Third, there is a high coverage of low-income countries, particularly in South Asia (India, Vietnam, Laos, and Cambodia) (figure 9). This is due to the burgeoning literature on large hydropower dam projects, many of which are situated in this region and have been extensively studied. Indeed, hydropower dam projects account for over half of the assessed literature here (24 studies), followed by wind farm projects (10) and large-scale solar (4).[11] And finally, this literature tends to focus on livelihoods and poverty, procedural justice, community cohesion, and employment as social outcomes, in contrast to the distributional issues that are more prominent in other policy categories.

The climate outcomes of renewable planning and deployment studies range from smaller projects with less than 100 MW of installed capacity, to megaprojects of over 1000 MW, such as the Son La (2400 MW; Vietnam), Bakun (2400 MW; Malaysia) and Nam Theun 2 (1070 MW; Laos) hydropower dams (Cooke *et al* 2017, Manorom *et al* 2017, Hang Bui and Schreinemachers 2018). Some wind power projects also sit towards the higher end of this scale, such as the aggregate installed wind capacity of the Isthmus of Tehuantepec, Mexico (2317 MW), or the large wind farm at Lake Turkana, Kenya (310 MW) (Huesca-Pérez *et al* 2016, Cormack and Kurewa 2018).

Despite the individual, often privately financed nature of these projects, they all bear the fingerprint of policymaking. Large renewable energy installations often feature in wider national or regional strategic development plans. For instance, the Bakun dam is a component of the Sarawak Corridor of Renewable Energy, a complex regional investment and development plan for the island of Borneo (Sovacool and Bulan 2012). Similarly, the Nam Theun 2 dam, which exports electricity to Thailand, is one of the primary foreign exchange and revenue sources for the Laos government (Baird *et al* 2015, Manorom *et al* 2017). Multiple projects are also reported to be financed by international institutions, including the Asian Development Bank, the African Development Bank and the World Bank (Baird *et al* 2015, Blake and Barney 2018, Cormack and Kurewa 2018). In the case of smaller projects, many are dependent on national policies (e.g. wind or solar subsidies), or on the Clean Development Mechanism (Huesca-Pérez *et al* 2016, Jumani *et al* 2017, Lakhanpal 2019). An assessment of the localised effects of grid-level renewable deployment therefore complements and overlaps with several other of the reviewed policy categories.

3.2.5.2. Social outcomes of renewable deployment

Overall, the literature tends towards a negative assessment of social outcomes resulting from these projects. Of the 38 articles reviewed, a total of 22 negative effects on livelihoods and poverty were reported, as well as a further 3 mixed (positive and negative) effects. This highly negative assessment arises primarily from extensive research into involuntary resettlement policies linked to hydropower dam

[11] A reminder: in the scope of this review, we excluded studies that investigate the public acceptance of policies and projects. As a result, the large literature situated in northern Europe on public perceptions of wind power is not covered here.

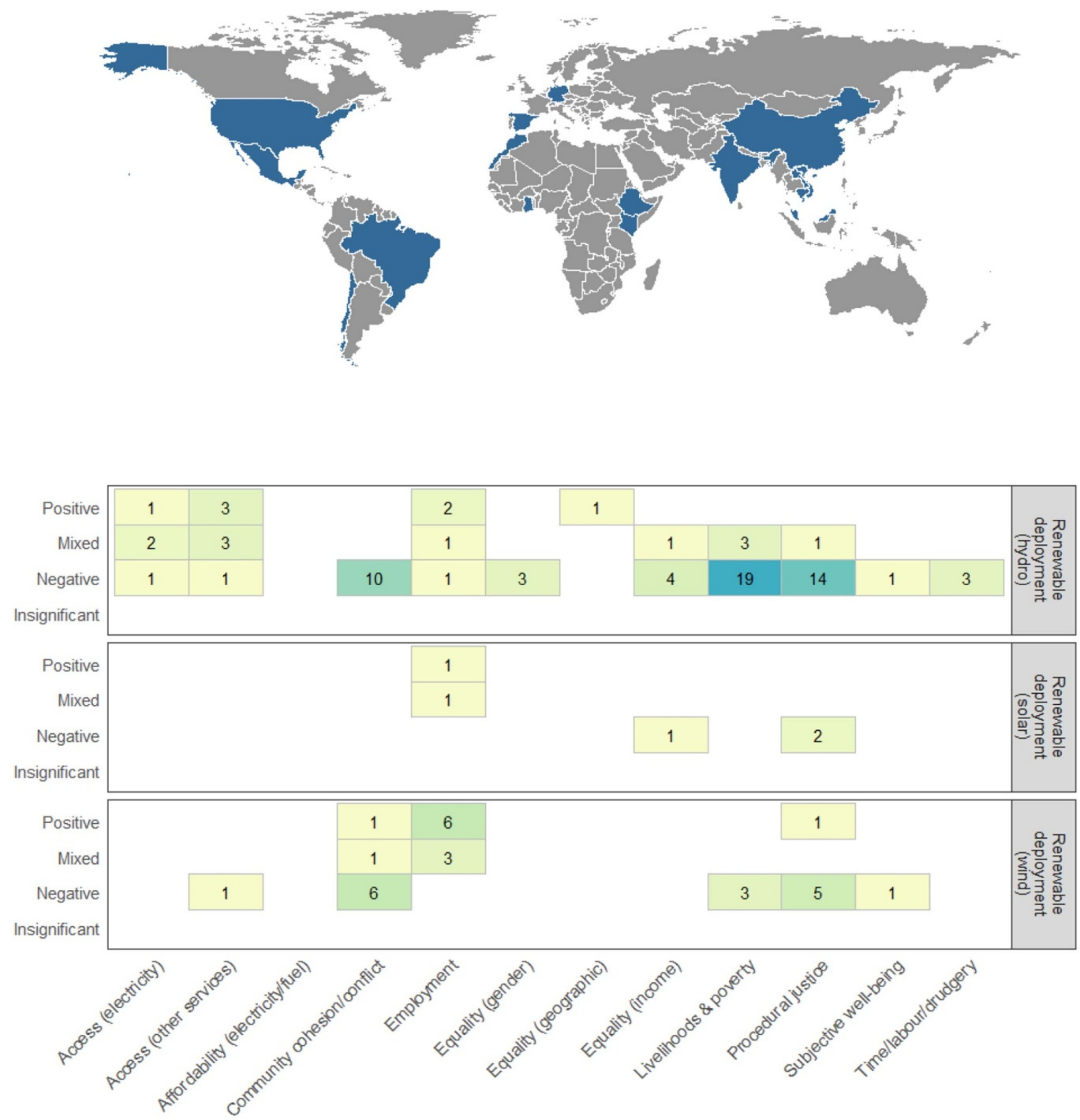

Figure 9. Country coverage and social outcomes of renewable planning and deployment. The heatmap scale increases with the number of effects recorded, highlighting clusters (and absence) of evidence and the common direction of effects.

reservoir flooding. In such cases, compensation packages for resettled communities often fall significantly short of promises made prior to resettlement, with financial support being too meagre, or compensated landholdings being of inferior quality and location (Sovacool and Bulan 2012, Ty *et al* 2013, Bui *et al* 2013, Singer and Watanabe 2014, Urban *et al* 2015, Baird *et al* 2015, Buechler *et al* 2016, Rousseau *et al* 2017, Hang Bui and Schreinemachers 2018, Yankson *et al* 2018, Annys *et al* 2019). Compounding this, traditional subsistence and income-generating practices using communal forests, rivers and land often becomes infeasible in the new landscapes rendered by dam construction, resulting in further uncompensated losses and costs for local communities (Ty *et al* 2013, Urban *et al* 2015, Siciliano *et al* 2015, Baird *et al* 2015, Obour *et al* 2016, Pheakdey 2017, Blake and Barney 2018, Yankson *et al* 2018).

Interestingly, and worryingly, new literatures have reported similar land related concerns arising from large wind and solar energy projects. In multiple case studies from the Isthmus of Tehuantepec (Mexico), Lake Turkana (Kenya), the Western Ghats (India), the Ceará state (Brazil), and Charanka (India), it is claimed that wind and solar energy investors took advantage of weak regulatory contexts to minimise compliance costs, or inadequately compensate rural and vulnerable communities for their land (Yenneti and Day 2015, Huesca-Pérez *et al* 2016, Yenneti *et al* 2016, Avila-Calero 2017, Brannstrom *et al* 2017, Cormack and Kurewa 2018, Lakhanpal 2019).

The siting of renewable energy infrastructures in such rural, poor and indigenous areas has been linked to contemporary forms of enclosure—the privatisation of land previously held in communal ownership (Yenneti and Day 2015, Obour *et al* 2016, Yenneti *et al* 2016, Avila-Calero 2017, Cooke *et al* 2017, Cormack and Kurewa 2018). These land enclosures can initiate new social conflicts as beneficiaries, and losers, emerge from the changing ownership and legal status of land resources, often superimposed upon, and exacerbating, pre-existing social fractures such as income inequality, ethnic conflicts, or gender divides. Hence we also see additional negative effects reported—such as community cohesion (16), income inequality (5) and gender inequality (3)—as local societies adjust to significant disruption in their social, economic and geographic circumstances following these projects.

Many of the reviewed projects failed to achieve procedural justice (21 negative effects reported). Typically, this outcome was linked to inadequate consultation by authorities and private companies regarding energy installations and their expected impacts (Ty *et al* 2013, Yenneti and Day 2015, Baird *et al* 2015, Buechler *et al* 2016, Avila-Calero 2017, Jumani *et al* 2017, Rousseau *et al* 2017, Huesca-Pérez *et al* 2018, Cormack and Kurewa 2018). In two instance, locals only found out about major renewable energy projects when the machines arrived (Yenneti and Day 2015, Buechler *et al* 2016). Yet beyond mere consultation, communities desire to take part in the governance and design of a project, to draw benefits from it, or at minimum, to have reciprocal channels for lodging complaints and concerns (Blake and Barney 2018). In many cases these options were absent and serious violations of procedural justice took place. The severe power imbalances between large renewable energy investors and local communities are key to understanding this outcome, particularly where regulatory contexts are weak and corrupt (Singer and Watanabe 2014, Buechler *et al* 2016), or where autocratic governance regimes simply offer no recourse for democratic decision making (Baird *et al* 2015, Rousseau *et al* 2017, Blake and Barney 2018).

On the positive side, several studies have reported improvements in employment opportunities (9 effects), particularly during the construction phase of large projects. Renewable energy projects are also an opportunity to provision electricity access in rural locations, as well as revitalise local infrastructures such as roads, schools and hospitals. Indeed such effects have been reported (Diduck *et al* 2013, Singer and Watanabe 2014, Pheakdey 2017, Sivongxay *et al* 2017, Cooke *et al* 2017). Equally, however, some studies report instances where villages are still waiting for electricity access, or have lost access to key services such as clean water (Urban *et al* 2015, Baird *et al* 2015, Jumani *et al* 2017, Annys *et al* 2019).

Overall, the poor social performance of grid-level renewable projects serves as a warning for the future development of large energy infrastructures, particularly in the global South where the vast majority of these effects have been documented.

3.2.6. Other

3.2.6.1. Overview

This final category is the most general, being comprised of 26 studies covering renewable energy procurement obligations (9), policy mixes (4), fossil subsidy removal (3), energy efficiency retrofit obligations (2), public awareness campaigns (2), coal phase-out policies (2), appliance standards (1), and emissions trading schemes (1). The geographical coverage was large too, including countries from North America, Europe, Africa and Asia, albeit with substantial gaps (figure 10).

3.2.6.2. Social outcomes of other policies

Of these varied policies, renewable energy procurement obligations stand out as having either positive or mixed outcomes. At least some of these effects were due to the purposeful design of energy policies to capture social benefits. For instance, in South Africa (Walwyn and Brent 2015, Pahle *et al* 2016), a renewable energy procurement obligation was tied to local job provisioning conditions, hence leading to a boost in employment. A similar effect has been observed from energy procurement obligations in the United States, albeit without the local job requirement (Yi 2013, Lee 2017). Of course, one question is who pays for these policies. In Australia, the Renewable Energy Target in Australia placed downward pressure on wholesale electricity prices via the merit-order effect (similar to FITs), but since companies passed compliance costs on to consumers, uneven and regressive outcomes were reported (Cludius *et al* 2014a). A similar finding was shown by Farrell and Lyons (2015) in the case of Ireland's Public Service Obligation levies.

A second category of policies comprises clean-energy legislation in general, or 'policy mixes', such as the combined effects of the Carbon Emission Reduction Target, Community Energy Saving Programme and Warm Front Scheme in the UK (Chawla and Pollitt 2013), or the multiple measures under Germany's Energiewende program (Schlesewsky and Winter 2018). When taking into account the allocation of policy costs, both of these studies reported negative distributional effects. But on the positive side, such large-scale programs can stimulate structural change and generate new employment opportunities, as shown for clean-energy legislation in Spain (Faulin *et al* 2006) and the Czech Republic (Dvořák *et al* 2017).

Other regulatory instruments such as energy efficiency retrofit obligations, product standards, and government mandated investments reported a variety of positive and negative outcomes. In the UK based Community Energy Savings Scheme, which placed an obligation on energy companies to deliver energy retrofits to low-income households, positive effects on energy affordability were noted by participants (Elsharkawy and Rutherford 2018). More

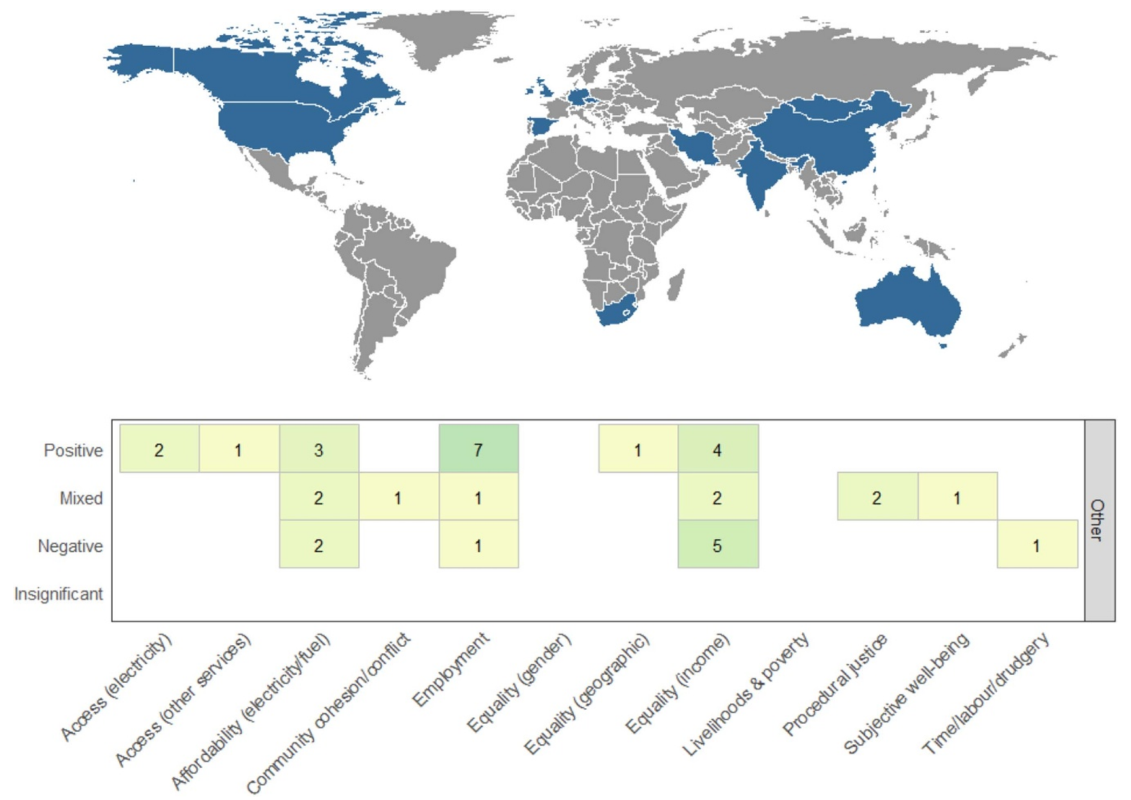

Figure 10. Country coverage and social outcomes of other policies. The heatmap scale increases with the number of effects recorded, highlighting clusters (and absence) of evidence and the common direction of effects.

mixed outcomes were shown in the case of building energy codes in California, which improved the energy efficiency of low-income household homes, but also tended to reduce floor space and property values (Bruegge *et al* 2019). Complex private sector responses to regulations were also found in a smart-grid investment program in the United States, where racial and socio-economic disparities tended to correlate with receiving local utilities (Zhou and Noonan 2019). Finally, generally negative distributional outcomes resulted from appliance standards in the United States, which eliminated comparatively cheaper options favoured by low-income consumers from the market (Serret and Johnstone 2006).

For coal phase-out policies, social outcomes were both negative. This was the case in Beijing, due to the inability of some households to switch to other energy sources (Barrington-Leigh *et al* 2019), and in Germany, where the phase out of coal mining engendered community conflicts among those who either supported or opposed a transition (Morton and Müller 2016). Fossil subsidy reforms, however, were generally successful at addressing distributional (income) impacts in Iran and Indonesia, largely because existing transport fuel subsidies favoured high-income groups (Yusef and Resosudarmo 2012, Salehi-Isfahani *et al* 2015, Kafaie and Garshasbi 2016). In the case of Iran's reform, subsidies were replaced with direct cash transfers, shielding low-income households in particular (Salehi-Isfahani *et al* 2015, Kafaie and Garshasbi 2016).

In summary, these ex-post studies emphasise that social outcomes still arise from more varied energy policies and programs. Where applicable, local job requirements, poverty tariffs or revenue recycling offer opportunities to mitigate adverse effects.

4. Discussion and conclusion

It is critical that climate policies result in strong positive social outcomes, whether in terms of poverty alleviation, equity, employment, or justice. In this review we examine policies that have been implemented and subsequently documented in the ex-post literature, finding extensive evidence that they influence social outcomes in a variety of ways. Before reflecting on these issues, we acknowledge a series of challenges in synthesising this diverse literature.

First, while we perceive a growing appreciation for the importance of social outcomes of climate policies by practitioners, the limited sample of 203 studies we identified suggests that there is much we have yet to learn about implemented climate policies worldwide. In particular, we were struck by the small number of studies meeting our key selection criteria: a focus on social outcomes within ex-post assessments. In screening the search results, we found hundreds of articles that either perform ex-ante policy assessments, or focus on pure economic criteria (e.g. policy costs). Our small literature sample thus brings the risk of systematic biases in reported outcome effects, with researchers tending towards the study of particular topics, outcomes or controversial policies. More literature is required to better understand and explain mixed results in key outcomes such as income equality, employment and energy affordability. Recent developments such as the yellow vest protests in France highlight the urgency for rapid learning and an expansion of the available literature on these issues.

It is also striking that, with a few exceptions (such as studies looking at hydropower or off-grid solar), the majority of ex-post policy research remains focuses on WEIRD countries, case studies, and populations: oriented to Western, Educated, Industrialized, Rich, and Democratic locations (Henrich *et al* 2010). This narrow focus excludes a rich mosaic of non-Western cultures that shape the beliefs and lives of more than half the world's population, while also oversampling 'typical' populations—white, middleclass, middle age men or women, for example—but not 'atypical' types such as the disabled, ethnic minorities, the poor, the old, or the young. Of course, this bias is likely exacerbated by our exclusion of non-English publications.

We further note that few studies go beyond analysing the social impacts of individual climate policies, towards groups of policies, or policy mixes. This is crucial, as climate policies are often packaged into bundles of legislation; indeed they may be embedded in milieu of other social, financial and other non-climate policies. The German Energiewende is a prominent example, with FITs, subsidies, and network charges all coalescing to drive particular distributional outcomes. Understanding the aggregate social outcomes of these policy mixes, in addition to their individual underlying effects, is necessary for sound design and should be a key area of future research.

Other promising avenues of future research that emerge from our systematic review and map would be exploring an even wider range of policy options. We only included those policy interventions that could be easily classified or commonly used, when in fact other studies have noted a full array of more 100 different possible policy options in the domain of energy and climate change (Brown and Sovacool 2011, Valentine *et al* 2019), and an almost infinite number of permutations between them. Exploring these, as well as the mixed impacts they may have, would be fruitful. There are also very new policy mechanisms emerging, including property assessments for energy efficiency, phase-outs and exnovation, subsidy reform, green finance and new forms of insurance and liability—to name a few—that are not yet well established enough in the academic literature, but could become the policy regimes of the future.

Finally, it is important to acknowledge several limitations in our own study design, implementation, and scope. For pragmatic reasons our assessment of social outcomes overlooks several critical dimensions, particularly health and the mitigation of local air pollution. Positive outcomes in these dimensions may go some way towards offsetting negative effects reported for some measures—as documented, for instance, in the case of the Beijing coal phase-out policy (Barrington-Leigh *et al* 2019). It may also render some policies even more attractive, such as retrofit subsidies or procurement policies that improve thermal comfort. Further, our focus on climate policies with direct mitigation outcomes excludes important categories of social policy, namely public investment in transportation infrastructures and social housing. These also have indirect emissions outcomes and may be particularly salient for developing and middle-income countries. Follow-up research exploring the question '*what are the climate outcomes of social policies?*' would be a useful complement to this study. And while this paper's merits lie in its broad scope and novel application of systematic review methods (the first to our knowledge in this area of research), such an overview of the literature limits the detail and depth of analysis required to assess each policy outcome. We see here an important role for more focused and policy-driven reviews, making use of a broad variety of quantitative and qualitative synthesis methods that are well suited to this topic, but have seen limited application so far in the social sciences of energy and climate change (Kastner *et al* 2016, Minx *et al* 2017).

Despite these caveats and complexities, however, we find there is much to learn on how policies can be designed to capture positive social outcomes, or at least avoid potential harms. Fundamentally, many of the negative outcomes in our review can be linked to a failure of policy-makers to attend to basic issues of equity and procedural justice—core elements of the 'just transition' (Newell and Mulvaney 2013).

On the equity side, we find three common mechanisms by which policies exacerbate inequalities. First, policy financing may be passed on to households in an untargeted manner, for instance, via increases in electricity prices under FITs and renewable procurement obligations. Second, the costs of policy compliance may fall on baskets of subsistence consumption that poorer households are particularly exposed to. This is often the case for taxes on fuels, or appliance and building standards. Third, policy benefits may accrue to wealthier households in particular, who can afford the capital investments required to gain access to a support measure, such as subsidies for solar PV systems. In most cases it was unclear whether policy makers were aware of, or had attempted to mitigate these outcomes. They are, however, not a foregone conclusion when appropriately addressed through lump-sum transfers, means-testing, or other design options. Indeed we find multiple cases where negative equity outcomes are deliberately and successfully avoided via policy design (Salehi-Isfahani *et al* 2015, Beck *et al* 2016, Drivas *et al* 2019). It is further important to note that taxes on certain consumption categories are often progressive (e.g. transport fuels), that overall policy effects can be positive (e.g. FITs pushing down electricity prices), and that some policies are simply popular (e.g. the Energiewende).

Regarding procedural aspects of 'just transitions', many of the negative social outcomes we observe revolve around a lack of scope for citizen, community or public participation in decision-making. These have long been acknowledged as key reasons underpinning public opposition to certain forms of climate policy intervention, especially renewable energy deployment (Zoellner *et al* 2008), although a similar lack of public participation is not uncommon for other large infrastructure projects. As a result, many authors have argued that greater and more meaningful participation—beyond mere 'box-ticking' exercises—can lead to more publicly acceptable projects (Hall *et al* 2013). Indeed, publics involved in several of the reviewed policies noted that while participation options were available, these fell far short of expectations and were ultimately ineffective in addressing community concerns (Avila-Calero 2017, Blake and Barney 2018). Shifting public participation even further 'upstream', to deliberation over broader questions on the purpose and direction of policy, and shaping public values, will be necessary to advance even more ambitious measures that avoid rejection in their final implementation (Wilsdon and Willis 2004, Demski *et al* 2015).

In summary, there is ample evidence that climate policies and efforts influence a wide range of social outcomes. In the ex-post literature, these outcomes tend towards negative (renewable deployment projects, feed-in-tariffs), positive (carbon and fuel taxes, direct procurement) and inconclusive effects (subsidies). Nevertheless, across all policy types, at a variety of scales and configurations, we find that it is possible to meet climate mitigation goals alongside improvements in livelihoods, affordability, equality, the provision of employment, and community cohesion. This requires integrated policies that directly address equity and procedural justice, supported by well-functioning institutions and financial alignment towards affordable low-carbon energy services. Although this finding may seem obvious to some, it does offer robust empirical support for those trying to craft or justify low-carbon policy in hostile regimes, or in making sure that broader publics better understand the benefits that may accrue to them from climate action. While the range and scope of these connections is not always strong or straightforward, it does nonetheless imply that low-carbon goals can be inherently compatible with more equitable, cohesive, fairer societies and cultures.

Acknowledgments

This work was supported by the Bundesministerium für Bildung und Forschung IPCC-AR6-III-2 (Grant No. 01LG1910A) and ARIADNE (Grant No. 03SFK5J0) projects; the Lendület grant (No. 95245) of the Hungarian Academy of Sciences; the Leverhulme Trust's Research Leadership Award 'Living Well Within Limits' (RL2016–048) project awarded to J. Steinberger; the European Union's Horizon 2020 research and innovation programme (Grant No. 730403 'Innovation pathways, strategies and policies for the Low-Carbon Transition in Europe (INNOPATHS)'). The content of this deliverable does not reflect the official opinion of the European Union. Responsibility for the information and views expressed herein lies entirely with the author(s). We thank Christian Flachsland for feedback at an early stage of the project.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary information files).

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