ENERGY JUSTICE IN THE ERA OF GREEN TRANSITIONS

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ENERGY JUSTICE IN THE ERA OF GREEN TRANSITIONS

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EDITORIAL
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Editorial: Energy Justice in the Era of Green Transitions

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Editorial on the Research Topic

Energy Justice in the Era of Green Transitions

The need to rapidly decarbonize our energy systems to address the challenge of climate breakdown is now widely accepted. It is also increasingly recognized that processes of decarbonization ought to be undertaken in a manner that considers issues of justice and equity (Martiskainen et al., 2020; Calver et al., 2022; Knox et al., 2022). Over the past decade, the concept of "energy justice" has highlighted the multitude of ways that the operation of energy systems—and the ways that they change and evolve—can impact different places and sections of society in decidedly unequal and potentially unjust ways, but that there are also opportunities for energy systems to evolve to be more just and inclusive (McCauley et al., 2013; Sovacool et al., 2014; Sovacool and Dworkin, 2015; Jenkins et al., 2016; Bouzarovski et al., 2017).

This type of Research Topic is perhaps more pertinent than ever. The COVID-19 pandemic has highlighted, and arguably intensified, the centrality of energy services to our everyday lives and the functioning of societies (e.g., Carvalho et al., 2021; García et al., 2021; Rouleau and Gosselin, 2021). This Research Topic—*Energy Justice in the Era of Green Transitions*—seeks to contribute to ongoing research and debates regarding how current "green," or "climate neutral," energy transitions and policies might be causing, or avoiding, injustices, and the potential role such transitions might play in creating a more just society in the future.

In curating this Research Topic of 12 papers, we aimed to include a diverse range of contributions to enable a wide set of voices. While still largely Europe and North America focused, the Research Topic spans the Global North and South as well as the Eastern and Western hemispheres. This highlights the breadth and depth of research into energy justice across all corners of the globe but also, as the collection points out, shows that the experiences of energy injustice remain woefully common across many geographic and social contexts. The contributions come from a mix of established scholars as well as from emerging researchers publishing from their doctoral research, or their first publications. They also come from a range of disciplinary backgrounds, from architecture, environmental studies, geography, political sciences, psychology, and public and urban affairs to name a few. This diversity of disciplinary, geographic, and experiential backgrounds is reflected in the varied yet complementary approaches this Research Topic of papers took to addressing the broad topic.

The papers expose a range of energy (in)justice issues, covering the three established tenets of distributional, procedural, and recognition justice. Beginning with *distributional* justice, a key theme in several papers is the unequal ability of different sectors of society to engage with, and benefit from, sustainable energy innovations and policies. Focusing on a case study of Ontario in Canada, Wyse et al. highlight that, without policy and regulatory intervention, low-carbon innovations bring most benefit to private businesses and more privileged groups, whilst the more

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marginalized continue to be left behind. Reames shows that ethnic and racial disparities in domestic solar photovoltaic adoption in the USA cannot be explained solely by differences in resource potential. Rather, such disparities appear to be caused by deeply entrenched socio-economic and racial inequities experienced by communities of color. Through a case study of Mexico, Molar-Cruz et al. criticize "one-size-fits-all" energy policies and low-carbon subsidies, arguing that these often have regressive outcomes by most benefitting more affluent sectors of society.

Some of these inequitable outcomes may be long lasting, especially when concerning our built environment. Gower argues that shortcomings in housing regulation can embed unsustainable design, which in turn increases the energy vulnerability of residents over the long-term, ultimately entrenching socio-economic and tenure disparities long into the future. Cevheribucak discusses how, in Turkey, competing ideologies concerning energy transitions create unintended impacts on domestic energy poverty, and argues that any regressive outcomes from energy transition policies should be mitigated to prevent exacerbation of existing socio-economic inequalities. Finally, with a more conceptual take, Grossmann and Trubina liken the uneven experiences of energy poverty to violations of human dignity.

Several papers in this Research Topic also discuss concerns around *procedural* injustice, in terms of unfair or undemocratic policymaking processes. Reed et al. are highly critical of present climate change and energy transition policymaking in Canada. They show that the voices of Indigenous Peoples are not fully included in the design of two major climate change and net-zero strategies, violating the core procedural justice principles of self-determination and informed consent. Si and Stephens similarly show that low-income households have limited political power and restricted ability to participate in the design of solar energy policies in Massachusetts in the USA, a situation they argue may lead to low-income households failing to benefit from solar technology. This echoes Bal et al.'s call for the importance of full engagement with social housing residents as part of low-carbon building renovation, if a just and sustainable urban energy transition is to be achieved.

Finally, some papers highlight concerns around *recognition* justice. This is perhaps most evident in the piece by Feenstra et al., who argue that the experiences of vulnerable energy consumers are often "invisible" in national policymaking. Similarly, Haarbosch et al. demonstrate a mismatch between the "narratives" and visions of energy transition policymakers versus those expressed by everyday citizens, with the perspectives of more marginalized citizens barely recognized within dominant policy narratives.

As well as highlighting current and potential injustices, however, what all the papers also make clear is that such inequities are not an inevitable consequence of green energy transitions, but rather can be avoided and/or mitigated by progressive policies and governance choices. Feenstra et al. argue that, if energy poverty mitigation is fully integrated into energy transitions policy, there is significant potential for both emissions reductions and greater social equity. In short, with political will, energy transitions can be a tool for greater energy justice. Equally, the paper by Pellegrini-Masini et al. indicates that citizens of more egalitarian societies show more favorable attitudes toward sustainable energy policies—greater justice, in turn, helps facilitate energy transitions.

As scholars, we must endeavor to delve deeper into the details, both qualitatively and quantitatively, to ensure that different sections of our societies—be they social, economic, cultural, locational, or otherwise—are able to enjoy the same opportunities to partake in and benefit from continuing green transitions.

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EL wrote the first draft. NS and MM edited and revised subsequent drafts. All authors contributed to the article and approved the submitted version.

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ORIGINAL RESEARCH
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How the Concept of Dignity Is Relevant to the Study of Energy Poverty and Energy Justice

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Since the concept of energy poverty first emerged, studies have combined normative orientations, analytical approaches and policy review to engage with energy deprivation as a problematic feature of contemporary societies. Over the past decade, this scholarship has aimed to conceptualize the normative grounds for critique, empirical work and policy design when engaging with the interplay of social life and energy systems. Scholars now include dynamic and complex concepts such as energy vulnerability and energy deprivation and are shifting toward the incorporation of social-philosophical justice concepts. However, in most of these writings on energy equality or energy justice, material aspects like access to (clean) energy, affordable energy costs, and material deprivation are in the foreground. This resonates with the energy poverty literature's emphasis on energy poverty as a material deprivation (Longhurst and Hargreaves, 2019). The way that energy poverty can result in financial stress, cold homes, poor health and the need to cut other basic expenditures is well-explored, but the less tangible, non-material deprivations stemming from energy poverty are less well-captured. We instead find it beneficial to also focus on the less tangible, non-material deprivations which have not yet been captured conceptually, and argue that the concept of dignity can be a pathway to investigate them. We aim to demonstrate how "dignity" can add to the normative orientations of energy poverty and energy justice research, and complement existing frames. With an empirical position in Europe we will draw from own empirical data and existing literature to illustrate how households living in energy poverty, or being cut off from energy provision, experience dignity violations.

Keywords: dignity, normativity, energy justice, energy poverty, respect, disconnections

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INTRODUCTION

Since the concept of energy poverty first emerged, studies have used normative orientations to inform their analytical approaches when investigating energy-related deprivations. Over the past decade, this scholarship has aimed to conceptualize the normative grounds for critique, empirical work, and policy review and design when engaging with the interplay of social life and energy systems. When it comes to the social dimensions of energy distribution, the normative orientations in energy research have evolved from their rather static view of poverty as a social problem. Scholars now include dynamic and complex concepts such as energy vulnerability and energy deprivation (Bouzarovski, 2013; Middlemiss and Gillard, 2015), and are shifting toward the incorporation of social-philosophical justice concepts. Scholars increasingly make ethical or normative statements, that is the ones expressing certain values and proclaiming a certain condition desirable or critical.

In exploring how this literature can be instructive for the transition to a fair, socially and ecologically just future, the energy justice literature stresses three dimensions: distributional justice or equity; recognition or attention to social difference; and procedural justice or democracy (Walker, 2009; Jenkins et al., 2016). These three tenets are sometimes augmented with the idea of restorative justice (Heffron and McCauley, 2018). Further, the concept of capabilities is used to explore the basic needs for a decent life, leaning on Nussbaum's idea that a necessary set of principles must be fulfilled across contexts to achieve a life that can be called livable (Day et al., 2016). Pellegrini-Masini et al. (2020) emphasizes energy equality as a core concept for energy justice and the benchmark by which the achievement of energy justice can be measured. However, in most of these writings, material aspects like access to (clean) energy, affordable energy costs, and material deprivation are in the foreground. This resonates with the energy poverty literature's emphasis on energy poverty as a material deprivation (Longhurst and Hargreaves, 2019). The way that energy poverty can result in financial stress, cold homes, poor health and the need to cut other basic expenditures is well-explored, but the less tangible, non-material deprivations stemming from energy poverty are less well-captured.

Our aim here is to aid in filling this gap by applying a dignity perspective to the lived experiences of energy-poor households. A review of both scholarly writings and policy documents reveals that, while material aspects are in the foreground, dignity as a goal and value only enters the picture indirectly. For example, in their October 14th 2020 recommendation, the European Commission called for "decent housing," defined by adequate access to energy and energy efficiency in order to avoid high energy usage and costs. After defining energy poverty as "a situation in which households are unable to access essential energy services" (European Commission, 2020), the document recognizes the scope of the problem: "With nearly 34 million Europeans unable to afford to keep their homes adequately warm in 2018, energy poverty is a major challenge for the EU." In a second point, the document defines "a decent standard of living and health" by noting that "adequate warmth, cooling, lighting, and energy to power appliances are essential services" (European Commission, 2020). This shows a common pattern in how dignity is conceived: it's achieved when a basic or material standard is met. As we will show, an in-depth consideration of dignity would bring rather different aspects into play.

Non-material deprivations present in the literature comprise quantitative studies showing how energy poverty correlates with mental illness and lower levels of subjective well-being (Biermann, 2016; Thomson et al., 2017). More recently, Longhurst and Hargreaves (2019) presented a pioneering study on emotional engagements with energy poverty. This study is part of a recent rise in interest in the lived experience of energy-poor households (e.g., Middlemiss and Gillard, 2015; Butler and Sherriff, 2017; Middlemiss et al., 2018; Willand and Horne, 2018; Yoon and Saurí, 2019). In most of this literature on the lived experience of energy-poor households, the actual material deprivation, and the situations of the household members as well as their coping strategies are again the focus. But from these writings, we also learn about the subjective perceptions, mental states, and how energy poverty impacts social relations. The "cold home," a situation where a household cannot heat the house or the flat sufficiently (Boardman, 1991), is not just a state of material deprivation causing illness. Qualitative studies show how a cold home causes loneliness and exclusion when people cannot - or feel ashamed to - invite friends and family, and in consequence reduce social contacts at large (Brunner et al., 2017; Middlemiss et al., 2019).

Our premise is that non-material deprivations need more attention to reach a broader picture of the meaning of energy poverty for societies. Scholars justifiably connect energy poverty with well-being (Biermann, 2016; Thomson et al., 2017). However, the ways in which energy-poor households are affected by and cope with the challenges of not being able to afford the necessary level of energy—a widely accepted definition of energy poverty (e.g., Bouzarovski and Petrova, 2015)—should be seen beyond money flows, energy prices and efficiency questions largely addressed in the literature. We believe these struggles must also be seen in light of emotions and affect, stigma, and prejudice. We aim to employ the conceptual framework of dignity and dignity violation in order to understand the non-material deprivation that energy-poor households experience. Fukuyama (2018) for instance, argues that much of what is commonly seen as material deprivation – and thus the economic motivation for resentment, unrest, or protest – would be more accurately described as the violation of dignity, here largely defined as recognition and respect. Hochschild (2016), Gest (2016), and Illouz (2020) demonstrate how dignity violations, such as feelings of neglect or of being left behind, indifferent attitudes from "elites," feelings of inferiority, and the fear of future loss of status within the respective society, induce resentment and voting for politicians who follow nationalist, discriminating policies. Although the exact composition and typology of such non-material deprivations remain to be explored, recent writings have integrated the idea that dignity-violations are among the causes for such changes in societies, even claiming that dignity-violations are of higher relevance than material deprivation.

The concept of dignity may be an entry point for a normatively-framed engagement with non-material deprivations resulting from energy poverty. Dignity has been debated extensively in philosophical writings, where it has enjoyed attention similar to concepts of justice. In other disciplines, it has also been widely used to discuss normative orientations, for example in biology and genetics when reflecting upon the ethical dimension of research on the human embryo. Interestingly, in the wider literature on sustainability transitions, the concept has not yet entered the debate.

We aim to demonstrate how "dignity" can add to the normative orientations of energy research, and can provide a different perspective or complement existing frames. With an empirical position in Europe (and also being aware of the differences among the European and the global debates on energy poverty, see Bouzarovski and Petrova, 2015), we will draw from own empirical data and existing literature to illustrate how

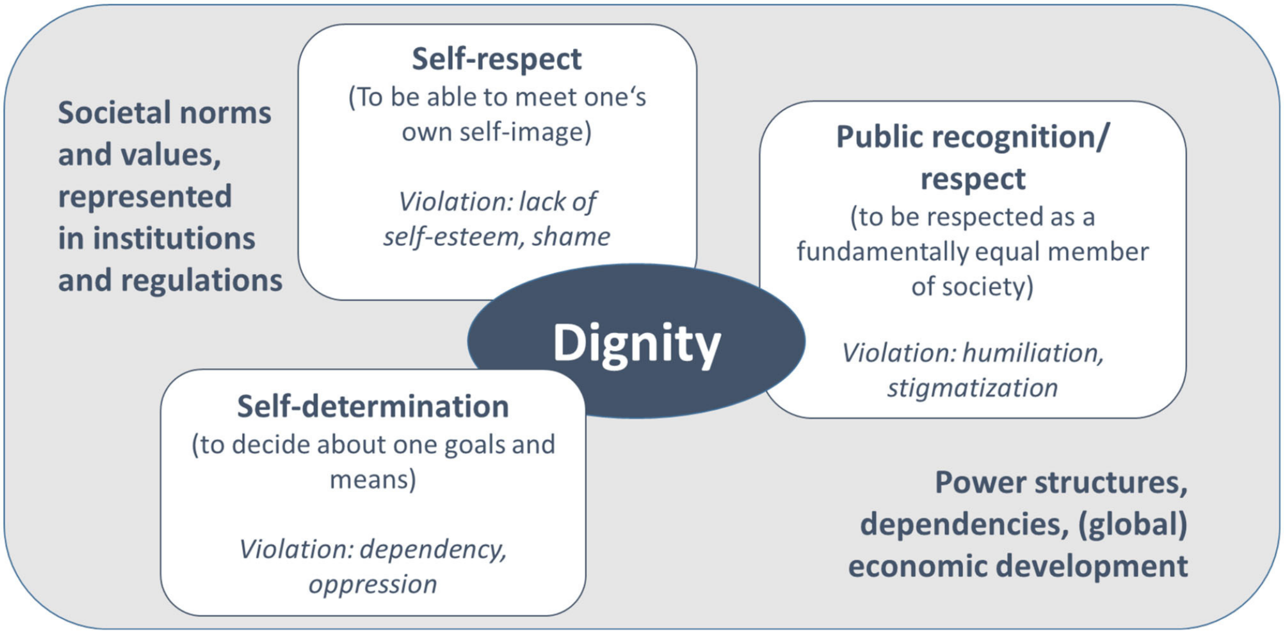

FIGURE 1 | Conceptual aspects of dignity and dignity violations, authors work.

households living in energy poverty, or being cut off from energy provision, experience dignity violations. The qualitative data was gathered in various research projects over the past 6 years and underwent a secondary analysis for the purposes of this paper. Altogether, 27 interviews from a pool of 45 were included in the analysis based on their relevance to the topic. Transcripts of these interviews were coded deductively, using the aspects of dignity and dignity violation introduced below, and the relevant passages were interpreted to find patterns of dignity violations. We also included published articles on the lived experience of energy-poor households in this endeavor, including unofficial publications like a master's thesis by Franke (2019). In the interpretation, we apply careful consideration to the contexts of energy poverty experiences. Our judgement and positionality is a European perspective, non-material energy deprivation may differ largely from this in other countries.

This paper is structured as follows: we first provide a brief account of our understanding of dignity, then touch upon notions of dignity in energy poverty and energy justice scholarship before presenting the ways that dignity and dignity violations are reflected in the experiences of households. In the discussion, we establish how a "dignity lens" can stimulate a more nuanced understanding of the non-material aspects of energy justice.

DIGNITY: THEORETICAL CONSIDERATIONS

Stemming from the Latin "dignitas" (worthiness), dignity is most often defined as the moral status of a person (Forst, 2011). While equity and distributional justice often focus on the socio-economic status of a person, the concept of dignity we employ addresses how a person is given value and respect in a society. The term "dignity" is widely used in politics and everyday life, and its individual significance and political salience also complicate the ways in which the concept is experienced and understood. What provides the common foundation for all these differences and complexities is the notion of the universal worth of all people without exception, of a universal value which everyone is entitled to and which is strongly linked with autonomy and liberty. Habermas (2010: 466) demonstrates that human dignity "Is the moral "source" from which all of the basic rights derive their meaning." However, the notion of dignity as a universal value is rather new. Dignity was historically seen as something to be achieved, a status that marks a respected position in society (Debes, 2017). Today, the status-derived form of dignity still lingers in expressions like "the men of honor," but it has lost significance. The concept of dignity today implies that members of society respect each other as fundamentally equal, which is a first defining aspect of dignity as derived from philosophical literature, see **Figure 1**.

In academic literature, to be respected by others is then seen as the basis for achieving self-respect. For the purposes of this article, it is important to emphasize that dignity and its "negations" (indignity and humiliation) are considered to be subjectively experienced and thus have an impact on the self-respect of a person. One has dignity when one believes in one's worth, when one is proud of oneself, and when one leads a meaningful life which is worthy of the respect of others. Weber-Guskar (2017) pronounce that self-respect is found when a person is able to meet their own self-image—and it's hard to find when one fails to achieve that very image (Brandhorst and Weber-Guskar, 2017). Thus, humans perpetually struggle to reach self-determined norms. Bloch's famous metaphor of the "upright gait" (der aufrechte Gang) illustrates the outlined meaning of dignity as moral status captured in the balanced interrelation of respect and self-respect (Bloch, 1986: 174).

A third defining aspect in the philosophical literature on dignity is self-determination. Von der Pfordten, a contemporary German philosopher, defines self-determination as the grand human dignity which is an "inner, necessary and unchangeable characteristic of humanity" (Von der Pfordten, 2016: 9f.). Beyond the control over your own body, he suggests to define this grand human dignity as the self-determination of one's own interests. In contrast, the idea of status dignity that elevates individuals above the rest is seen here as the small dignity, and the idea of equality as a medium dignity (Von der Pfordten, 2016). Most convincingly, in our view, Forst (2011: 968) points to the political implication of seeing dignity as self-determination: "the general concept of human dignity is … inextricably bound up with that of self-determination in a creative and simultaneously moral sense that already involves a political component. … At stake is one's status of not being subject to external forces that have not been legitimized to exercise rule – in other words, it is a matter of being respected in one's autonomy as an independent being."

The three aspects of respect, self-respect, and self-determination are interrelated and together provide a way of operationalizing the concept for applied research on dignity and its violations. This can also be discerned in Forst's statement that "to act with dignity means being able to justify oneself to others; to be treated in accordance with this dignity means being respected as such an equal member; to renounce one's dignity means no longer regarding oneself as such a member but as inferior; and to treat others in ways that violate their dignity means regarding them as lacking any justification authority." (2011: 968f.).

Dignity violations are commonly described as humiliations (Statman, 2000). The violations and deprivations of dignity are morally reproachable and normatively problematic. Brandhorst and Weber-Guskar (2017) defines humiliation as the experience of being forced into a negative view of yourself in a situation of powerlessness. An external image is forced upon a person that is different from their self-image; people feel ashamed, degraded, inferior (Weber-Guskar, 2017: 222–224). Moral philosopher Margalit (1996: 51) broadens the notion of humiliation to the level of societies when he argues that "violation of moral integrity is sufficient for branding a society as humiliating … A decent society is one whose institutions do not violate the dignity of the person in its orbit," a claim which raises questions about the moral condition of today's societies, economies and political systems in general. Margalit makes the concept of humiliation the focus of his book on decent society, thus exhibiting a strong commitment to both the normative reasoning ("What is a decent society?") and the realistic rendering of today's world ("Why is there so much humiliation?"). Important for our further arguments, he shows that ensuring people get what they deserve is not necessarily all that matters, since the distribution of social benefits and the imposition of their preconditions may very well be conducted in a way that is also humiliating (Margalit, 1996: 122).

As signs of the violation of one's self-respect, stigma and shame seem most important. Shame is a primary affect and a powerful emotion (Tomkins, 1963). It can be produced by a number of cultural, economic, political and social factors (Sayer, 2005). Shame can be induced by experiences of poverty, racism, struggles during adolescence, homophobia, and the like. In contrast to guilt, which is mostly experienced internally, shame is relational: there is almost always an individual, group or institution which inflicts shame. Interiorization of repeated experiences of shame results in individuals shaming themselves – the presence of others is not necessary for this emotional process (Tomkins, 1963; Kaufman, 1993).

So, the challenge here is to analytically combine the arguments on structural inequality (because, again, it is societal shame which falls on poor individuals) with our increasing knowledge of the behaviors of neoliberal governments. These governments impose the burden of providing for basic needs onto households themselves, only to then inflict shame on those incapable of doing so due to poverty. "Blaming the poor" is a prominent phrase depicting this ideology and reasoning (Dorey, 2010; Greenbaum, 2015).

Figure 1 also highlights the contingent and relational nature of the concept of human dignity emphasized by most contemporary authors (e.g., Brandhorst and Weber-Guskar, 2017; Clark-Miller, 2017; Zylberman, 2018). The values and norms, economic structures, institutions, and the power relations of a given societal context are significant to the experience of dignity (or the lack thereof) meaning that the same circumstances can be dignifying in one context and humiliating in another (Forst, 2011: 967). On the micro-level, a relational perspective emphasizes that dignity does not exist as a personal property, but rather emerges in interpersonal relations. Dignity—as well as dignity violations—come to the fore in "dignity encounters," which are often shaped by asymmetrical structures within society, that is, "when one actor has more power, authority, knowledge, wealth, or strength than the other" (Jacobson et al., 2009: 3). What exacerbates asymmetries is that states have withdrawn from the provision of social benefits and reduced their social policy. They now outsource a great deal of these services to private agencies. Yet states remain involved as the main regulators that require "outcomes" and "impact."

To achieve dignity, what is needed is not cultures of dependency and paternalistically treated citizens but, as Forst (2011: 967) argues, an active conception of dignity. The active conception of dignity here is introduced to problematize a more conventional, "passive" understanding of dignity where dignity only concerns satisfying basic needs equally across the world by way of social improvements. We agree with Forst that more effort needs to be taken to resist the wide-spread tendency of subjecting citizens to being neglected, abandoned, and turned into waste by those who rule for the sake of their legitimacy. On issues concerning human dignity, therefore, the relative deprivation forced by others is decisive: "Thus the central phenomenon of the violation of dignity is not the lack of the necessary means to live a "life fit for a human being," but the conscious violation of the moral status of being a person who is owed justifications for existing relations or specific actions." Dignity, in this understanding, is not to think of needs, ends or conditions, "but of social relations, of processes, interactions and structures between persons, and of the status of individuals within them." (Forst, 2011). Forst exemplifies this claim by referring to forms of poverty relief through charity or social welfare payment. While such poverty relief payments may satisfy material needs, they may "treat the "needy" in a condescending manner" and thus be "no less degrading than poverty itself." (Forst, 2011).

Drawing from such contributions, this paper explores the three defining aspects of dignity highlighted above as well as their violations: (1) public respect and recognition (rather than humiliation and disrespect); (2) self-respect (rather than shame and loss of self-worth); (3) self-determination (rather than dependence and helplessness). We aim to demonstrate how these can be relevant points of attention for energy justice research and thinking.

NOTIONS OF DIGNITY IN ENERGY POVERTY AND ENERGY JUSTICE SCHOLARSHIP

To explore how dignity is related to energy poverty, we start by summarizing how dignity appears in writings on the subject. While—to the best of our knowledge—dignity has never been addressed as a concept in research on energy poverty, various, most often implicit, notions of dignity do presently exist.

First, dignity is listed among other goods human beings are entitled to, but often deprived of in reality, whether this is a warm house or a good education. The word is mentioned incidentally by authors specializing in the technical and/or regulatory constraints of energy delivery: "Energy is fundamental to economic and social development; to reduce poverty and continue to grow. It supports people as they seek a whole range of development benefits: cleaner and safer homes, lives of greater dignity and less drudgery, to better livelihoods and better quality education and health services" (Bilgiç, 2017: 1). Consequently, dignity offences figure among other negative tendencies marking today's urban social life. For instance, Balachandra (2012: 165) posits with regard to unequal access to modern energy sources: "The implications are typically in the form of income poverty, primitive lifestyles, loss of dignity, physical hardship, health hazards, lack of employment and polluted environment." By the same token, Chakravarty and Tavoni (2013: 67) claim that "Modern sources of energy like electricity and clean cooking fuels are the prerequisite of a life with a minimal standard of comfort and dignity. There is a tremendous imbalance in the access to and consumption of these energy sources today: the poorest 3 billion people suffer from debilitating energy poverty while the richest 1 billion consume an overwhelming fraction. Sub-Saharan Africa, South Asia and South East Asia are home to most of the world's energy poor."

Second, dignity-related notions are also present in claims for "decent housing" in reports that feature people ashamed of the dark and cold homes that result from severe energy poverty. Here, "decent" and "dignifying" are used as adverbs to describe the standard that should be achieved. Ever since the pioneering work of Boardman (1991, 2010), the problems of cold homes, substandard dwellings unable to provide some level of comfort, and income poverty preventing households from heating their homes to an acceptable level have been core concerns of energy poverty writings. Thermal comfort has been at the heart of policies in the UK and Ireland, with the introduction of the Decent Homes Standard in 2000 in England, for example. A decent home is defined here "against four specified criteria: a minimum statutory standard, disrepair, modernization, and thermal comfort" (Hulme, 2012: 98). All social housing had to meet these "standards of decency" by 2010 (Hulme, 2012).

Leaving Europe for a moment, the words "dignified housing" and "dignified living" appear particularly often in work on the non-Western countries where "decent" is often reduced to "fit for survival" or to achieving minimum standards for material well-being. A case in point is the Decent Living Energy Project, aimed to define a "universal, irreducible and essential set of material conditions for achieving basic human well-being" (Rao and Min, 2018). In a similarly universalist, basic approach to a decent living, other scholars acknowledge that a minimum provision of energy cannot be applied without reference to a specific context. When discussing indicators for the measurement of energy poverty, Pachauri and Spreng (2011: 7501) argue that a minimum for cooking and lighting cannot be the benchmark for developed nations. Similarly, Bulkeley et al. (2014: 32) see dignified housing as an improvement within a given context. Looking at Cape Town and São Paulo, they stress "a decent standard housing that moves away from the cheaply built housing in which key costs such as thermal efficiency are transferred from the state to households."

Third, dignity features in writings—and actions—that employ a human rights-oriented approach to energy poverty. "The detrimental developmental impacts related to energy poverty in Africa constitute a challenge to the full realization of human rights. Furthermore, access to energy should be seen as an economic and/or social right which is indispensable to the notion of human dignity" (Barnard and Scholtz, 2013: 60, see also Sing-hang Ngai, 2012). It is hardly surprising that dignity is part of calls within social movements for combatting energy poverty, as in Bulkeley et al. (2014): "The raising of the quality of housing infrastructures, via low carbon interventions, rationalities and financing, may provide a potential platform for social justice campaigners to coalesce around and further articulate the demand for dignified lives through housing quality as well as quantity." Within the emerging social movement that advocates for a right to energy, the Right to Energy Coalition claims on their website that "Energy is a basic human right: no one should ever have to choose between eating, lighting or warming one's home. An end to energy poverty is vital for social justice and fighting the climate crisis. Access to energy can be a matter of life and death and it is a condition for living a dignified life."[1] While dignity is taken up prominently and explicitly, it is not used conceptually. The main claim made here is that dignity

[1] righttoenergy.org

is the moral source upon which the claim for a right to energy as part of human rights is based. Here, we see a more conceptual understanding of dignity as a valuable contribution to this debate.

Fourth, and finally, dignity appears in the energy justice literature under the tenet of "recognition." While—at least in our view—the meaning of the other two tenets (distributional and procedural justice) are much more clear, recognition seems to be the least elaborated one. In some definitions, recognition points to the requirement to understand different social groups and their needs, a use that resembles the reading of justice tenets in the "just city" - literature, where Fainstein (2010) argues prominently for equity, democracy and diversity. For Fainstein, recognition requires apprehending the social diversity of society and the different needs to be acknowledged when designing urban development. McCauley et al. (2019: 917) for instance define recognition justice in low carbon transitions as a call to recognize those who are overlooked, the "neglected sections of society," and to instead "reflect upon [the question] "who exactly should we focus on when we think of energy victims?" This process is referred to as post-distributional, or recognition-based justice. In their review article on energy justice concepts, Pellegrini-Masini et al. (2020) agree with the three tenets of energy justice and locates the importance of dignity in the third tenet, recognition, as "the need to recognize the dignity and rights of all individuals and the need for them to be included and therefore avoid the conditions of deprivation, such as that of fuel poverty."[2] Here again, dignity appears to be something that is achieved through overcoming material deprivation. Jenkins et al. (2018) offer a slightly different account of justice as recognition, which to them "represents a concern for processes of disrespect, stigmatization and othering—questioning who is, or who is not, included [in the transition to low carbon systems]." The emphasis of this article, however, is on more material issues. Elsewhere, Jenkins et al. (2016) provide the most elaborate understanding of recognition justice when they combine a call to recognize those who are overlooked with the combating of disrespect. This is exemplified in the recognition of the specific energy needs of UK households often stereotyped as uninformed or careless about usage (Jenkins et al., 2016: 177). However, they place recognition justice second to distribution and process.

In sum, the concept of dignity—where used in writings on ethical and normative issues in energy poverty and energy transition literature—appears briefly as part of the conventional set of normative "reminders," or the points to check, rather than in a thoroughly outlined concept. This also holds true for energy poverty literature. Where notions of decent living or housing are present, the need for access to energy services is highlighted as a means to achieve a dignifying life. But what this means exactly remains unclear. Claims for dignity are put forward by social movements and NGOs, and echoed in the writings on civil society actions, but not made analytically accessible. To take this a step further, we now focus on some empirical data showing how the three aspects of dignity derived from the literature, namely respect, self-respect, and self-determination, can be employed to reflect the complexities of energy poverty. In the following, we review the three aspects of dignity derived from the dignity literature - respect, self-respect, and self-determination. - to explore how they feature in experiences of energy-poor people and households.

[2] We use fuel poverty and energy poverty interchangeably. For an introduction to the distinction between the terms in part of the debate see Bouzarovski and Petrova (2015).

DISRESPECTED, ASHAMED AND DEPENDENT: HOUSEHOLDS IN ENERGY POVERTY

In the interviews, participants emphasized emotional burdens rooted in experiences like not being able to heat their homes or cook warm meals, or undergoing a disconnection. In the following, we review the three aspects of dignity derived from the dignity literature to explore how they feature in experiences of energy-poor people and households.

Stigmatization, Humiliation, Feelings of Inferiority

Humiliation, stigmatization and disrespect are described in a number of ways by energy-poor households, and they occur in various forms and arenas. The experience of a disconnection by the supplier is described as being especially humiliating. In Germany, a man in his thirties, who is a single parent of a two-and-a-half-year-old child, remembers the moment of the actual enforcement of a power disconnection: *"That was a punch in the face, frankly spoken"* (Franke, 2019: 60f.). He describes how he searched for help but had to struggle for several months without electricity in their home. Often, this experience is described as a loss of control, because the most basic things suddenly don't work. Your food goes bad in the fridge while you struggle with debt, you can't even wash your clothes by hand because the water is cold, you come home and want to switch on the light—an automatic move—but realize you will spend the evening in the dark as you search for candles without any light. You cannot comfort yourself or your family with a warm meal, or charge your phone in order to ask for help. People feel overburdened by the situation, and on top of the disconnection they feel incapable of managing. A woman in her fifties recalls "*tears, sadness and helplessness*" (Franke, 2019: 60f.).

When contacting institutions, be they energy suppliers or welfare authorities, people report experiences of disrespect and open humiliation. Feelings of inferiority are common among energy-poor people. A couple in Greece discuss their experience of an electricity disconnection, and at one point the woman mentions her husband's attempt to find a job and settle the bill: *"[Dyonisis went] to the unemployment office to find a job. He told me that the girls there, they laugh! Not they laugh with him, but they laugh that he still hopes he can, that somebody can hire him, ok?"* (Franke, 2019: 60f.) A man in Poland who lived through years of deprivation, including homelessness, remembers his contact with institutions like this: *"During the interviews I was asked such questions that made me feel like a used toilet paper."* (man, Poland, interview by Malgorzata Dereniowska). A single mother in her thirties reports her experiences with welfare state institutions in Germany: *"… this has simply been humiliating. Applications disappear [for social welfare] … it was awful. Then I was asked to go to that training, Women in Profession, or such a bullshit, where I felt like … well I am not stupid. I am getting upset again, sorry. But they do these things there, let's see how we open Word, how to create a document and save it and then we cook together for lunch. I could as well go to prison, there I would probably have a similar daily programme. I don't want to do something like that, but they force you to. … I find this is a bit dictatorship-like. It has nothing to do with free decisions and free life. And if you don't do it, they cut the money."*

Behind the conduct of these street level bureaucrats, there is a political discourse which emphasizes the self-responsibility of those in need, often depicted in the literature as "blaming the poor" for ending up in a state of deprivation (Dorey, 2010: 215; Greenbaum, 2015). This type of stigmatizing discourse can also occur in the field of energy poverty. In Germany, the left-wing party (Die Linke, opposition) keeps pushing in parliament for a ban on disconnections. However, the majority regularly votes against this proposal. Among the arguments is the claim that a policy like this would build a public welfare social security "hammock," which seduces people to intentionally evade paying their bills. In the records of German parliamentary debate, a 2019 contribution from the Christian Democratic Party (CDU, in government) reads like this: *"Studies have also shown that part of energy disconnections—and we have to talk about this as well—are due to an intentional misuse of the state's duties of primary care. Therefore, it is clear to me: a ban of power disconnections is a disincentive at the expense of the energy providers and the general public. Because those who say, "I don't pay my energy bill because I cannot or I don't want to," they do that because of a disincentive … "* (German Parliament, 2019: 15215). This very much reflects the long-term attitude of the UK's "fuel poverty" policy, as reported by Jenkins et al. (2016), where "policy-makers in England, Wales, and Scotland have only recently begun to recognize the specific needs of particular social groups—such as the elderly, the infirm, and the chronically ill—and their reliance on higher-than-average room temperatures... This shift counteracts a long-standing tendency to stereotype the "energy poor" and their "inefficient" use of scarce energy and monetary resources." (Jenkins et al., 2016: 177). Here, we are looking at well-known clichés of paternalistic and neoliberal welfare state policies that distinguish between the "deserving" and the "non-deserving" poor (Katz, 2013; Bridges, 2016).

Shame, Loss of Self-Respect, Not Living up to One's Own Self-Image

The presence of shame has been documented in research on energy poverty, often describing the feelings of those who cannot afford to pay their bills (Meyer et al., 2018) or those avoiding social contact because of their cold, dark or damp homes. Longhurst and Hargreaves (2019: 7) offer the case of a UK man who lives in social isolation and self-imposed disconnection from other humans: *"I don't ever speak, well I don't see no-one … I don't put lights on, no … the only thing what's going on now is the fridge … and the telly, because if I didn't have that I'd go loco."* (Longhurst and Hargreaves, 2019: 7). They also introduce the notion of embarrassment, giving the example of a woman who says, *"I don't have anyone come round. I don't have friends over... no-one. I don't think I've had a friend round since about 3 years … I don't like the condensation [water condensing on the windows] and that is a big thing for me. It's embarrassing."* (Longhurst and Hargreaves, 2019) In an article on the living situations of energy-poor people in Austria, Brunner et al. (2017: 139) describe how they refrain from asking for help from institutions, but also from within their own networks because they feel ashamed. One woman cited expresses shame regarding her abilities as a parent: *"It is embarrassing, it is disgraceful, if you cannot provide your own child with warm water."* (Brunner et al., 2017: 140). The study also depicts reduced social contacts due to shame, and the complete avoidance of heating and lighting in order to save money. Some who do invite friends over, do so with extra lighting and heating, to bolster the façade of normalcy (Brunner et al., 2017: 148).

In interviews conducted by our research team, we, too, found proof of energy poverty inducing a set of negative emotions like shame, stress, anxiety, and anger. The Greek couple introduced above reported that their relationship suffers from the financial trouble that led to the electricity and gas disconnection: *"[if you have] financial problems […] you'll have, you know, fights […] because you're angry. […] And when you're angry, sometimes you find the easiest target is the guy close to you."* (Franke, 2019: 52.) People also point out the uneasy combination of being treated as not-quite-deserving citizens while authorities are reluctant to provide help. For instance, asked about job center experiences, another informant from Germany reports: *"Oh, [they're] very bad. Really very bad. You got the feeling you are a second class human being. But help? No, they don't help."* The stigmatization and disrespect go along with a loss of self-respect. People feel ashamed of the situation, and so they try to hide it from friends, family and neighbors. For instance, the young father we interviewed said that he tried to avoid drawing attention to the situation. He opened up only to his parents, not wanting anyone else to know. He also recalls fearing that his child would unintentionally reveal the situation through kindergarten. For his child, this meant that no friends could come over to play.

A woman in her fifties recalls having tried to contact the welfare institutions to resolve an enforced electricity disconnection. In the contact, she experienced feelings of inferiority, gradually losing confidence in herself. She remembers how she started to see her struggle as a personal failure: *"You always feel like you want something impossible. So, [you go] into this begging mode somehow. And you feel bad because you maybe think, "Why don't you manage alone? Why do you not get this done?" And, yes, one feels a bit like, actually, a loser."* (Franke, 2019: 52.). The single father also mentions self-doubt. His most troubling shame is being unable to raise his kid "normally," which to him means cooking warm meals and having lighting. During the energy disconnection, he couldn't make hot cocoa for his child, a routine comfort they used to share, nor could he wash the dirty laundry after his son had played outside. Being able to wash one's clothing is included in the list of secondary capabilities (Day et al., 2016) that households are often deprived of when experiencing energy poverty. One mother in a family of five, who works part-time as a nurse on nightshifts while her husband has a low paid job in a different city, blames their difficulties with paying their bills on high housing and transportation costs. She said she hadn't bought new clothes for herself in 8 years, but what's even worse is not being able to provide a *"normal childhood"* for her kids, with holidays and the nice things other parents can afford. Thus, the benchmark for self-respect, leading a life according to one's own self-image, is dependent on society's sense of what a "normal" livelihood is. The normative self-image depends on what counts as decent for others, thus, how much energy one needs is a deeply relational issue.

Dependence on Family, Friends, and Institutions

Finally, can energy-poor people determine their own goals and develop the means to achieve them? From our literature review, we concluded that energy is among the means that help achieve decent living. Further, disconnection from energy causes multiple dependencies, since energy is a fundamental resource for participation and respected membership in society. The single father recalls how he had to turn to his parents for help, and how difficult this was as an adult: *"… when the son comes home from kindergarten, soaking wet, dirty, maybe peed in his pants and he could not throw the pants in the washing nor provide a hot bath for the son*" (Franke, 2019: 52.). Thus, he needed to visit his mother on weekends for things like laundry, warm meals, and charging his phone. In order to reduce these visits to a minimum, he used an external power bank and kept his phone usage to a minimum so the battery would live through to the next weekend. Dependence on one's parents in adulthood evokes different responses in different countries. In Germany, young people strive for independence at an early age, e.g., by moving out of their parents home and founding own households earlier than for example in Southern or Eastern European countries. Here, going back to your mother for household routines is rather unusual and can easily been seen as a sign of personal failure. We have several cases in Germany where asking family for help after a phase of independence is described as troublesome. A single mother, in school to escape low-paying jobs, reports how she broke off the relationship with her father over borrowing money. Longhurst and Hargreaves provide a similar example of a woman who said, *"Even if I go to my Mum … and say, "Mum, can I borrow £20 for some electric?" I find that embarrassing, so I try not to put myself in that situation."* (Franke, 2019: 7).

Turning to institutions for help can lead to a perceived dependence on the good will of officials, or even complete powerlessness. Interviewees described feeling forced to obey what the officials demanded and agreeing to measures they found inappropriate, as in the prior example of the single mother who found herself in professional training she did not need. But she had to agree: "*... if you don't do it, they cut the money."* A disabled woman in her fifties, relying on a wheelchair after an accident, and struggling with housing and utility costs after divorce, told us, *"I experienced a lot of degradations. You are only worthy if you do something, if you work. Even if it is just a dull job, and you never had a book in your hand … people are judged by work. … It is the same everywhere, if you need something. With the health insurance, with the housing company: "what do you want again, now?""* In another interview, a woman described being unable to state her case for weeks after the disconnection was enforced: *"They said they cannot do anything, you have to pay. … And you have no chance to even talk to the officers at all. … If you have no appointment you cannot go in at all, and as for telephone, you cannot call either. They just leave you standing there."* (our interview, 2019). A 40-year-old man told us about a gas disconnection due to his inability to afford the payment for his gas bill. In order to pay the gas bill and get reconnected, he went to the job center to ask for a loan. When asked by the interviewer about the mode of communication, he answered: *"Top-down, paternalistic. They consider themselves better, they have a job, they can do with us what they want."* An example from France shows how digitalization complicates things, with bureaucratic procedures becoming even more distanced and insecure, with dependency increasing. In France, a 40-year-old single mother of four, who spends €176 of her €1100 monthly income on gas and electricity, describes her experience of applying for welfare support: *"They gave me a code, but the code did not come in. It's too complicated. It's annoying. It does not work. And I am scared about taxes on the Internet. Because if the day [comes when] I can't pay the Internet anymore... how will I do it? Plus, here I am in front of a screen. Who can I say to "I can't do it'? There is no longer a relationship. This is also what is painful"* (interview by Ute Dubois, published in Rexel Foundation Occurrence Healthcare, 2018).

DISCUSSION AND CONCLUSION

This paper intended to use a conceptual understanding of dignity to investigate non-material forms of deprivation in the lived experience of energy-poor households. While notions of dignity and decent living are often touched upon in the literature on energy poverty, material deprivation has been the dominant issue in studies on the struggles of households to afford energy services. We showed how a more structured understanding of dignity can systematically help shed light on the subjectively experienced deprivation of one's moral status in society, and one's dignity (Forst, 2011) —as opposed to one's socio-economic status. From philosophical writings, three concepts were chosen to operationalize dignity and interpret cases stemming from interviews within our research teams and those reported in the literature. As shown, violations occur in all three aspects of our concept of dignity, namely, respect, self-respect, and self-determination. We demonstrated that these aspects of dignity are lacking in the way the deprived citizens have been treated. We argued that the negative outcomes of this maltreatment are seen in the form of disrespect, humiliation, shame and stigma as well as dependence. Of course, given the limited data, it is difficult to draw conclusions about the overall scope of these dignity violations, but the analyzed material shows worrisome tendencies.

Energy-poor people depend on others and institutions, which then become the very sources of disrespect and feelings of inferiority. However, in order to regain self-determination with regard to power supply, people cannot turn away from welfare-institutions or energy providers or even from difficult family relations. This forced dependence on people and institutions means that one cannot avoid experiences of disrespect. This very likely causes more anger, anxiety and lower self-respect in countries like Germany, for instance, where there is no politicization of energy poverty. By politicization of energy we mean the current trend of framing the deficiencies of social policies in political terms and making them part of the social movements' agenda. Unlike in Spain, for example, where social movements and solidarity networks formed to provide mutual support and protest against disconnections (Herrero, 2018), energy-poor people in Germany live with the responsibilization of the individual rather than societal structures. People blame themselves for failing to manage well and bring up their kids "normally." In such a context, an "upright gait" —as in Ernst Bloch's metaphorical description of dignity—is hard to achieve.

We want to emphasize the obvious relational nature of these dignity violations, thus agreeing with the recent emphasis on dignity as a relational issue in philosophical writings (e.g., Forst, 2011; Brandhorst and Weber-Guskar, 2017; Clark-Miller, 2017; Zylberman, 2018). A relational perspective attends to the fact that social phenomena emerge from the interrelation between actors and situations within specific contexts. We can see how subjectively experienced dignity violations relate to the standards of good living in society. The experience of shame described by interviewees over not being able to provide their children with a "normal" childhood illustrates this point accurately. Norms of "the good life" depend on wider norms in a given context, and people cannot simply escape these norms. Thus, analysis of energy poverty and energy deprivation needs to be contextual, from both a material and non-material perspective. It may contradict academic convention to measure and monitor energy poverty across contexts, but as we argue, in order to properly capture the complexities of energy poverty and deprivation, one needs to work with multiple perspectives and take the positionality of judgement into consideration. Borrowing Forst's (2011) notion of active dignity, which goes beyond basic provisions for life (passive dignity), an active understanding of non-material energy deprivations would emphasize that access to energy can be dignifying in one context and humiliating in another. To have active dignity in European societies means being a respected member of society, feeling this respect, and being able to turn it into self-worth. Most importantly, active dignity means the self-determination of one's own goals and the means to achieve them, rather than dependence on others. We already see this idea reflected in some energy poverty writings that use a capability lens, for instance in Day et al. (2016) notion of the secondary capabilities that form a bridge between Nussbaum's list of capabilities and a given societal context. While the list of primary capabilities resembles the notion of passive dignity more closely, the secondary capabilities link it to the energy services needed for respect in a given society. We would be happy to deepen such debate in further work.

Using Margalit (1996) ideas of a decent society, we also learn from the material under review that our societies are far from being "decent" given the experiences of energy-poor households. The interviews and material considered show how these households face humiliating experiences within their personal networks and in contact with institutions, experience feelings of inferiority and stigma as well as debilitating dependence, either in their social networks or through the "support" of institutions, where they often rely on the goodwill of frontline bureaucrats. This dependence is all the more humiliating with energy disconnections, where a sudden dependence is perceived as a significant drop in one's material and moral status. This is especially true in societies that haven't seen the politicization of energy poverty, often treating it as evidence of a person's inability to manage their lives. As the German political debate illustrates, politicians accuse people who are not able to pay their bills of cheating those who pay regularly (e.g., German Parliament, 2019: 15215). There's an opening here for research and thinking about persistent ideologies within the welfare state that lead to policies based on paternalistic notions of the deserving and non-deserving poor (Katz, 2013; Bridges, 2016). Additionally, the debate on "blaming the poor" can provide inspiration for the energy poverty and energy justice academic community in their critique of policies that blame the behavior of households and stereotype them as uninformed, careless, unwilling, and even cheating the welfare state.

In conclusion, dignity provides two new perspectives in energy justice research: a new analytic framework in normatively-oriented research (the social-philosophical literature enables the operationalization of dignity violated and dignity achieved), and a novel and complementary normative horizon for the development of energy policies. While concerns about energy justice have long driven researchers and practitioners to explore ways of measuring it, the dignity-based standpoint promises to create a more nuanced approach to the non-material aspects of energy distribution and consumption.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: data are qualitative in nature, comprising both interviews and documents.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

KG and ET elaborated the draft together in close cooperation. While the section Disrespected, Ashamed and Dependent: Households in Energy Poverty is mainly written by KG, all other sections were elaborated collectively, both contributing in equal shares. All authors contributed to the article and approved the submitted version.

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Energy Justice Through Solar: Constructing and Engaging Low-Income Households

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Minimal research has assessed the policy process of developing solar programs at the state level, and no research yet has investigated how these policies characterize and engage with the target populations they are designed to benefit. Grounded in Schneider and Ingram's social construction framework (SCF) and applying computational methods (i.e., text analysis and machine learning), this research examines how low-income households are socially constructed in policy provisions, how their social construction has been reinforced through public participation, and how to classify low-income households among target populations. Based on the case of Massachusetts, this research analyzes the 2020 Solar Massachusetts Renewable Target (SMART) Emergency Regulation as well as its public comments. We find that low-income households constitute a visible target group of this program and their characterizations as "deserving policy benefits" are positively constructed by policy makers. Furthermore, the conveyed messages and attitudes regarding the assigned benefits to low-income households have been reinforced through public participation. Despite this advantageous positive construction, low-income households have less political power (i.e., measured by topic prevalence in the public comments) than other target groups such as large corporations (e.g., solar developers or solar installers) and less ability to participate or be represented in the policy process, making their voices less likely to be heard by policy makers. With positive social construction but weaker political power, low-income households fall into the category of "dependents" instead of "advantaged," which may engender undesirable policy outcomes minimizing the intended long-term benefits of the policies to low-income households. This research reveals procedural injustices in energy policies and highlights the importance of more inclusive policy-making process, while also offering a novel theoretical lens to understand the rationale and dynamics of developing solar statutes targeting low-income households.

Keywords: energy justice, policy process, social construction, target population, solar, Massachusetts

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INTRODUCTION

Solar photovoltaic (PV) is among the most promising renewable energy technologies with widely acknowledged benefits associated with the environment, health, job creation, community solidarity, and sustainable development worldwide (Millstein et al., 2017; Lee and Shepley, 2020; Zhang et al., 2020). Some countries such as Brazil and China have begun utilizing solar penetration as a poverty reduction strategy in poor areas (Pereira et al., 2010; Geall et al., 2018). In the United States, however, despite the reduced costs, solar PV continues to be disproportionately installed in higher income communities. Research shows that the growth of solar deployment in the United States over the last decade has not occurred equitably across socioeconomic groups (Sunter et al., 2019; Reames, 2020). Research from GTM Research and PowerScout reveals that in the four states that account for 65% of residential solar installations, most households have incomes between $45,000 and 150,000, which are considered middle-income families, while there are few low-income solar customers involved (Kann and Toth, 2017). More recent evidence indicates that less than half of U.S. community solar projects have any participation from low-income households (Gallucci, 2019). In addition, racial disparities in solar adoption are also prevalent with a recent study showing that Black- and Hispanic- majority census tracts show on average less rooftop PV installed, a disparity that persists even when corrected for household income and home ownership (Sunter et al., 2019). Furthermore, the widening income and wealth gap (Curti et al., 2018; Stephens, 2020) is contributing to the disparities in solar deployment in the United States.

With the recognition of the distributional injustices and disparities that are evident in renewable energy adoption such as solar deployment across different populations, energy justice has become an established research area in the field of energy policy (Fuller and McCauley, 2016; Jenkins et al., 2016, 2020; Reames, 2016; LaBelle, 2017). While there are multiple analytical frameworks and approaches to understand and explore energy justice, both distributive justice and procedural justice are important to consider mirroring the demands of the environmental justice and climate justice movements (Baker et al., 2019). Distributive justice is outcome-oriented and focuses on whether the benefits and burdens of energy are equally distributed, while procedural justice concerns inclusion and equitable access to participation in the decision-making process (Baker et al., 2019). Most of the energy justice literature focuses on distributional disparities and the outcomes of disproportionate adoption, and there is a lack of research analyzing procedural justice of energy policy. This research focuses on the policy process of developing solar programs and contributes to the existing literature on energy justice.

To date, solar adoption in the United States has been driven strongly by the federal Investment Tax Credit (ITC), state renewable portfolio standards (RPS), and state level net energy metering (NEM) laws (Stokes and Breetz, 2018). Incentives provided within these policies generally apply only to those who buy their PV systems outright (i.e., either with a cash purchase or solar loan). These programs, therefore, have ended up targeting middle- and high- income households.

With increasing awareness of how these policies are exacerbating inequities by disproportionately benefiting wealthy communities, policy attention has shifted recently to expand solar opportunities for low-income households. It is widely acknowledged that solar PV has great potential for alleviating energy burdens for low-income households who have been suffering disproportionately from current energy practices and policies while also having to use a higher percentage of their income to pay their energy bills (Cook and Shah, 2018b). The potential benefits of solar to low-income households are large. The U.S. Department of Energy (DOE) has stressed the role of solar PV in helping low-income households reduce their energy burden, and a variety of states have taken measures to integrate solar investments in the Department of Health and Human Services' Low-Income Heating and Energy Assistance Program (LIHEAP) and the Department of Energy's Weatherization Assistance Program (WAP) funded projects (Brown et al., 2020). For example, DOE has authorized Colorado to be the first state to integrate rooftop solar into its WAP program and California has established the Solar on Multifamily Affordable Housing Program and the New Solar Homes Partnership. Many states have incorporated low-income carve-outs into their community solar programs to set aside a portion of money targeting and serving low-income people and integrated rooftop solar into their low-income weatherization assistance policies (Sunter et al., 2019). Solar deployment among low-income households has thus become an important policy objective for many state governments, and policy makers have created a variety of incentive programs focused on energy justice.

While many solar policies and programs targeting low-income households have been formulated and implemented, it is not clear yet whether these programs have achieved their intended objectives of expanding the benefits of solar PV to low-income households. Recent research continues to show minimal participation from low-income households in community solar projects, with the majority of community solar subscribers being businesses, higher education institutions, government agencies, and higher-earning households (Gallucci, 2019).

Existing literature on solar policies has focused on a range of issues including the barriers of promoting solar (Karakaya and Sriwannawit, 2015; Strupeit and Palm, 2016; Mah et al., 2018; Phua, 2020) and more inclusive program design through a more accurate model of utility bill payment performance (Davuluri et al., 2019). Other research has analyzed customers' motivation and satisfaction for low-income solar programs (Lee and Shepley, 2020), state strategies for designing community solar policy such as broadening both on-site and off-site PV (Cook and Shah, 2018a), and disparate rooftop PV installations by race and ethnicity (Sunter et al., 2019). An increasing number of reports have identified multiple barriers to solar adoption including the insufficiency of tax liability and the lack of homeownership in many low-income communities (Paulos, 2017). To summarize, relevant literature provides a valuable lens to understand solar policies and practices, but existing research struggles to explain the policy process of state governments' efforts that promote solar adoption among low-income households in an American context. Although a few recent studies have begun exploring solar programs from a policy perspective (Michaud, 2020), there is no research yet investigating how solar policies have defined, characterized and engaged with target populations, particularly the low-income households for which they are designed to benefit. This study aims at filling these research gaps.

Applying Schneider and Ingram's social construction framework (SCF) to the design of solar policies, this paper provides a new theoretical lens to offer deeper understanding of the rationale and dynamics of developing low-income solar policies at the state level. While the unique paradigm of the social constructionist perspective derives from sociological theories (Berger and Luckmann, 1991), it has been adapted by Schneider and Ingram (1993) to analyze policy design. Analyzing the social construction of target populations involves assessing "the cultural characterizations or popular images of the persons or groups whose behavior and well-being are affected by public policy" (Schneider and Ingram, 1993, p. 334). In other words, social constructions refer to "stereotypes about particular groups of people that have been created by politics, culture, socialization, history, the media, literature, religion, and the like" (Schneider and Ingram, 1993, p. 335). The concept of social constructions is important as it can help us understand the policy process ranging from agenda setting to policy evaluation based on the two primary propositions of the framework—target populations and feed-forward effects (Pierce et al., 2014). While target populations refer to the groups or individuals who achieve policy attention and thus have been chosen for or impacted by public policy, feed-forward effects refer to when a formulated policy "feeds forward to create new policy and politics" through citizen absorption of conveyed social construction as messages (i.e., assigned benefits and burdens) in policies and public participation (Schneider and Ingram, 1993; Pierce et al., 2014). Recent policy literature worldwide has already identified the importance of the characteristics of target populations in the policy process (Si, 2020) and established that the framing and construction of target population matters (Schneider and Ingram, 2017).

In this paper, we adopted a "computational grounded theory" approach (Nelson, 2020) that has been rarely used in the energy policy field and that combines both computational and qualitative methods. The data utilized include the 2020 Solar Massachusetts Renewable Target (SMART) Emergency Regulation along with some guidelines and its public comments, which were obtained from the official website of Massachusetts government. Grounded in the social construction framework and based on computational analysis through coding in Python, this research aims at answering the following questions:

a. How are low-income households defined and characterized in the policy process?
b. How have these characterizations been reinforced or changed through public discourse and public participation?
c. How are low-income households characterized among other target populations?

The first section of this paper introduces the conceptual framework and grounded theory: the policy design theory of social construction framework (SCF) proposed by Schneider and Ingram in 1993. Next, the methods are introduced including the case study design, data collection, data analysis techniques as well as ethical implications. The Results section then provides details on (1) low-income households as a target population; (2) the social construction of low-income households by policy makers; (3) reinforcement of the social construction of low-income households through public participation; and (4) topic modeling and the classification of low-income households. The discussion explores the impacts of these findings, and the final section reflects on some limitations of this study and concludes with future research directions.

CONCEPTUAL FRAMEWORK

Many studies have examined the technical and societal aspects of energy transitions (Burke and Stephens, 2018; Stokes and Breetz, 2018; Allen et al., 2019; Healy et al., 2019). There lacks research exploring the rationale and dynamics of solar deployment from a policy design perspective. The social construction framework (SCF) offers a novel lens to analyze solar policies, contributing to the understanding of why some target groups are more advantaged than others, how policy designs can reinforce or change such advantages, and why some of the seemingly advantaged groups do not actually benefit (Schneider and Ingram, 1993). This framework can help us understand the policy process based on the two primary propositions of the theory—target populations and feed-forward effects (Pierce et al., 2014).

According to Schneider and Ingram's framework, target populations can be classified and categorized based on their social constructions – stereotypes about target groups. Social constructions range from positive to negative. Positive social constructions include images such as "deserving" (deservedness of policy benefits) and "honest" while negative social constructions include images like "undeserving" (requiring policy burdens or penalties to change their behaviors) and "dishonest" (Schneider and Ingram, 1993). The theory contends that there are strong pressures for policy makers to assign benefits to powerful and positively constructed groups while devising burdens to negatively constructed groups (Schneider and Ingram, 1993). Therefore, the stereotypes become embedded in policy as messages that are conveyed and absorbed by the public and affect their perception and participation patterns, thus reinforcing or changing social constructions.

Furthermore, target groups who have stronger political power will tend to gain more benefits and less burdens, and vice versa (Schneider and Ingram, 1993). This is because those people are more active in public participation including voting and policy advocacy, so they are continuously drawing attention from policy makers and reinforcing their positive and engaged role. Therefore, the traditional notions of political power can be revealed through public participation. These feed-forward effects suggest social constructions have long-time effects on our society.

Social constructions and traditional notions of political power suggest a two by two factorial table shown in **Table 1**, which conceptualizes and categorizes target populations as four types. Therefore, target groups include advantaged (i.e., positive social constructions and stronger political power), contenders (i.e., negative social constructions and substantial political power), dependents (i.e., positive social constructions and weaker political power), and deviants (i.e., have neither a positive construction nor stronger political power). Advantaged target

TABLE 1 | Conceptualizing target populations: social constructions and political power.

Political Power	Social Constructions: Positive	Social Constructions: Negative
Stronger	Advantaged - Advantaged target population, such as elderly and business, is likely to receive deservedness of policy intervention and benefits.	Contenders - Contenders, such as unions and the rich, are typically considered as undeserved of government assistance as they are untrustworthy or morally suspicious, and those people are likely to be required policy burdens to punish and change their behaviors.
Weaker	Dependents - Dependents, such as mothers or children, are those who are viewed deserved of sympathy and policy. Low-income households that are targeted by the SMART program fall into this category.	Deviants - Deviants, such as criminals, are unlikely to be aided or impacted by public policy.

Source: Adapted from Schneider and Ingram (1993).

population is likely to receive deservedness of policy intervention and benefits while contenders are typically considered as undeserved of government assistance as they are untrustworthy or morally suspicious, and those people are likely to be required policy burdens to punish and change their behaviors. Dependents are those who are viewed deserved of sympathy and policy intervention to assist, and deviants are unlikely to be aided or punished by public policy.

It is acknowledged, however, that the two dimensions of target populations are hard to measure in reality, especially political power. We see this as one of the limitations of this framework. But it is quite useful when being applied to an empirical context where both social constructions and political power could be understood in a specific scenario. This research offers an example in the field of solar policy as well as insights on how to classify target populations based on their social construction and political power.

While this policy design theory has been applied in various policy fields, ranging from housing policies to veterans benefits (Sabatier, 2007), it has not yet been applied in detail to the context of solar policies. Prior research utilizing this theoretical framework to other policy fields offers evidence of the value of applying a social constructionist typology to understanding target populations in low-income solar programs in the U.S. For example, Drew (2013) utilizes the social construction and policy design theory to explain how and why the U.S. federal government pursued a policy agenda promoting homeownership for low-income households and argues that the social construction of homeownership, low-income households, and the private mortgage industry were instrumental in the policy design process. Similarly, Valcore (2018) applies the framework to examine the hate crime policy to explore whether or not variations in the social and political status of gays and lesbians are related to the inclusion of sexual orientation in the hate crime policy at the state level and contends that target groups seeking hate crime law protection have positive social constructions.

Additionally, Pierce et al. suggest that most research applying this framework focuses on the proposition of target populations while not considering explicitly the feed-forward effects (Pierce et al., 2014). This paper investigates both of the two primary propositions of the theory – target populations and feed-forward effects, thus providing novel insights on and empirical assessment of the application of the theoretical framework.

METHODOLOGY

Grounded in the SCF, this research adopts a "computational grounded theory" approach to better "combine expert human knowledge and skills at interpretation with the processing power and pattern recognition brought by computers" (Nelson, 2020). Schneider and Ingram (1993) suggest that interpretative and qualitative methods based on text are valuable methods for measuring and assessing social construction. Schneider and Ingram (2008) also contend that multiple elements integrated into policy design create social construction, including articulated policy goals, problems to be addressed, eligibility, policy tools, implementation strategy, etc. Pierce et al. (2014) argue that many scholars have utilized qualitative methods based on the SCF framework from 1993 to 2013, but few studies have applied a computational approach to analyzing data. This study combines both computational and qualitative methods to address the research questions and provides insights on the measurement of both social constructions and political power.

The SCF theory argues that not all target populations have a well-defined and unchanging social construction. Depending on policy objectives, for example, policy makers can portray low-income people as lazy individuals or as people whose poverty situations are not their fault. Therefore, the actual social constructions of target groups depend on specific contexts. Using the Massachusetts state solar policies as a case, this study analyzes data from the 2020 Solar Massachusetts Renewable Target (SMART) Emergency Regulation and its public comments. The data were obtained from the official website of the Massachusetts government[1] (downloaded in October 2020) and include the main regulation along with some guidelines and the public comments posted about the regulation. A total of 378 public comments were downloaded and then the 151 repetitive comments (the same comments were posted from multiple individuals from a single environmental organization) were removed. Seven additional public comments that were unreadable (included random numbers, letters, or red lines) were dropped. The total number of public comments prepared for the analysis was 220.

Analysis of the policy-making process of this specific case—a state-level solar policy in Massachusetts—was selected because

[1] https://www.mass.gov/info-details/smart-400-mw-review-emergency-rulemaking.

Massachusetts has been recognized as a national leader on solar, and the state has been actively implementing policies to encourage solar deployment. This case was also chosen because of the publicly accessible data documenting public comments.

The SMART Program is a nation-leading solar energy development program, which was officially launched in 2018 as a transition away from the former Solar Renewable Energy Certificates (SREC) program. The SMART incentive program is designed to benefit all qualified solar generation units and includes specific funding for low-income neighborhoods. The policy aims to encourage solar development by paying system owners a set rate per kilowatt-hour of power generated. The base rate is determined by the size of the installation and the utility territory in which it is located (i.e., in this program, the electricity distribution utilities and the sponsors of the program include Eversource, National Grid, and Unitil) (Shemkus, 2020). The compensation rate decreases as more projects apply for incentives. Projects with features the state hopes to encourage (e.g., integrated energy storage or location on a rooftop) have a few extra cents added to their rate, known as an "adder" (Shemkus, 2020). On April 14, 2020, the Massachusetts Department of Energy Resources (DOER) filed a revised SMART program with the Secretary of the Commonwealth as an emergency regulation. The main revisions of the 2020 ruling include: (1) an expansion of the SMART program size from 1,600 to 3,200 MW; (2) an expansion of the definition of a low-income customer; and (3) an additional prohibition of solar deployment on land where at least 50% of the parcel's area is designed as Priority Habitat or Critical Natural Landscape (i.e., the development of a web mapping tool to help identify these areas was also included) (SMART Emergency Regulation, 2020). These changes to the rule, especially the details about land-use, attracted considerable attention among stakeholders. Written comments were collected from April 14 to June 1, 2020. The public could submit written comments via email or mail to the DOER.

The texts of the new SMART ruling and the public comments were downloaded from the government website and transferred to plain texts through Adobe Acrobat Pro DC software and uploaded in the data folder of Jupyter Notebook. Then computational methods through Python programming code implementation were applied. Names of participants who posted public comments have been left out of the paper.

Multiple basic functions of computational text analysis were used in Python. The "word count" function, which sorts frequency of certain words of interest, is important in this research as it can help capture and measure attention being paid to different framings and themes by both the policy makers who drafted the policy and those who may read and interpret the policy. Specifically, to identify the visible target population of the incentive program, we first counted the 50 most frequent words to get an overall sense of the content of the regulation. Then, we counted how many times "income" appeared in the policy provision and in which contexts does the word appear in the policy provision based on the "word count" and "concordance" (i.e., index of instances of a given word) functions in Python, presenting each occurrence of the given word "income" together with some context. Second, to identify how low-income households are characterized by policy makers in the policy provision as well as their social constructions within the SMART provision, the "cooccurrence" function was executed in Python, which takes a filename containing a text file and a word as a string as input and outputs the most frequent words that occur in the same sentence as the target word. The same analysis was conducted with the obtained 220 public comments. To complement the computational analysis, we also examined the original data and combined qualitative methods to analyze the data in an inductive way.

Furthermore, to identify other target groups and clearly classify low-income households, our analysis used the topic modeling approach, which is an unsupervised machine learning method to uncover abstract topics within a text, to naturally obtain embedded themes and identify involved actors/stakeholders in the public comments. The data was analyzed at the document level (i.e., each public comment) through topic modeling. This investigation implemented the topic modeling algorithm of Latent Dirichlet Allocation (LDA), which does not take the document order into account. It uses the co-occurrence of words within documents, compared to their distribution across documents, to uncover abstract themes. By fitting the data into the LDA models, it is possible to create a list of weighted words, which indicate the subject of each topic, and a weight distribution across topics for each document. Analysis by topic distribution identifies representative texts for each topic and discusses the meaning of topics. We also created an interactive visualization through pyLDAvis to view the topics-keywords distribution, analyzing the meaning of each topic, the prevalence of each topic, and relation/relevance between each topic. The number of topics and the specific interpretation of the emerged themes (e.g., examining representative texts for each topic) were obtained with a qualitative approach.

RESULTS

Low-Income Households as a Target Population

The target population of a policy refers to "a concept derived from the policy design literature that directs attention to the fact that policy is purposeful and attempts to achieve goals by changing people's behavior" (Schneider and Ingram, 1993, p. 335). By specifying eligibility in the regulation along with its guidelines, policy establishes boundaries of target groups. Behavior change of target populations would be expected by articulating eligibility in the policy provision.

The stated policy objective at the beginning of the MA 2020 SMART Emergency Rule is to "establish a statewide solar incentive program to encourage the continued use and development of generating units that use solar photovoltaic technology by residential, commercial, governmental and industrial electricity customers throughout the Commonwealth" (SMART Emergency Regulation, 2020). Based on the policy objective in the original text and the most frequent words, we see that the statute aims at regulating solar generation within

Massachusetts. It is an incentive program containing words like "tariff," "compensation," "adder," "block," etc. There are some words which can help us further explore the eligibility of target populations in the policy provision, such as "income," "eligible," and "qualification."

Following that, by looking at a variety of "concordances" of "income," we find that the word of "income" appeared 42 times in total in the 2020 SMART Emergency Regulation, and 39 of them are used together with the word "low." This indicates that low-income households are one of the most critical and visible target populations and have been paid a lot of attention in terms of policy intervention in the SMART program.

We combine computational results and the policy provision in an inductive way to better illustrate the visible target population of the policy. By deeply looking into the regulation and its guidelines, a low-income customer is defined as "an End-use Customer that qualifies as a low-income customer under the applicable rate class with its local Distribution Company." Three types of low-income solar generation facilities are eligible for the benefit including: (1) Low Income Community Shared Solar Tariff Generation Unit, with at least 50% of its energy output allocated to Low Income Customers in the form of electricity or net metering credits; (2) Low Income Solar Tariff Generation Unit, with an AC rated capacity of ≤25 kW that serves Low Income Customers; and (3) Low Income Property Solar Tariff Generation Unit: with a rated capacity > 25 kW that provides all of its generation output in the form of electricity or net metering credits to low or moderate income housing (SMART Emergency Regulation, 2020).

By specifying eligibility criteria and differentiating incentive levels, the program delivers a clear message to the public that low-income households are targeted and prioritized under the SMART program and low-income customers should be able to receive the same benefits as other residents.

The Social Construction of Low-Income Households by Policy Makers

Schneider and Ingram (1993, p. 335) noted that "the actual social constructions of target groups, as well as how widely shared the constructions are, are matters for empirical analysis," suggesting that social constructions are measurable phenomena. They also noted that social constructions are usually conflicting. For example, with the words and framing included in specific policies, policy makers can portray low-income people in a certain way. Depending on what words are used, low-income households can be considered for special policy provisions because they do not work hard or because their poverty situations are a result of bad luck or structural issues that are not their fault. According to the SCF, positive constructions include policy images like "deserving," "intelligent," "honest," etc. while negative constructions include the opposite message such as "undeserving" (Schneider and Ingram, 1993).

To identify the social construction of low-income households embedded within the SMART program, we explored the "cooccurrences" (i.e., index of instances of a given word) of "low income" in the policy provision, presenting each occurrence of "low income" together with some context. The results show that the words of "low income" are always together with another word that further describes the population including words like "tariff," "community," "shared," "compensation," "less," and "equal" in the same sentence.

The results suggest that low-income people could benefit from the policy by receiving compensation for their expenses and a variety of compensation adders[2] for solar adoption. The policy delivers a message that low-income people are worthy of receiving policy benefits instead of policy burdens; this indicates that low-income households are positively constructed in the policy.

To gain better understanding regarding "less" and "equal," we came back to the policy provision as these words can be confusing. When looking at the original document, we find that the policy makers use these two words to refer to income eligibility or the capability of solar generation units (i.e., encouraging small scale solar generation units and distributive solar). For example, a low-income eligible area refers to "a neighborhood that has household income ≤ 65% of the statewide median income for Massachusetts" and a low-income solar tariff generation unit refers to "a solar tariff generation unit with an AC rated capacity of ≤25 kW that serves low-income customers" (SMART Emergency Regulation, 2020). This indicates that eligibility criteria of the target population are emphasized when constructing low-income customers in the policy provision.

Reinforcement of the Social Construction of Low-Income Households Through Public Participation

In addition to the first proposition regarding target populations, the SCF also suggests that social constructions, as the delivered messages about assigned benefits or burdens embedded in the policy, can be absorbed by the public and impact public participation. That being said, policy plays an important role in shaping citizen orientations and reinforces or changes certain views of citizenship that are in turn linked to distinct participation among groups. This process can have long-lasting effects on our society as it can affect future politics and policies. One of the important mechanisms of public participation in the policy process is the opportunity for public commenting on proposed policies (Innes and Booher, 2004). Public comments provide a mechanism for anyone to deliver public concerns to policy makers. Therefore, analyzing public comments of new policies is one way to identify the "feed-forward effects" of policies and understand the role of public participation in the policy process (Schneider and Ingram, 1993).

Using the "word count" and "cooccurrence" functions in Python to analyze the public comments, we are able to assess how the public perceives low-income households. Do

[2]Note: "The SMART program also offers 'adders' that will earn you more money if your system has certain characteristics. For instance, installing a battery storage system with your panels can qualify you for the energy storage adder, which will give you additional savings per kWh. Installing a system on a brownfield will also qualify you for an adder." See https://www.solarreviews.com/blog/massachusetts-smart-program-replaces-srecs.

the public comments reinforce a caring attitude toward low-income communities? Do the public comments reflect agreement that low-income people deserve policy benefits? The public comments provide insights on whether the characterization of low-income households constructed in the policy have been reinforced or changed through public participation.

Among the 220 public comments, about 27 participants mentioned "low income" in their submitted comments while 193 participants did not. The fact that nearly 13% of individuals mentioned "low income" people indicates that those communities did receive public attention to some extent[3].

The goal of this analysis is not to examine how many of the public comments mentioned low-income households. Rather, we aim to explore whether the social construction of low-income households has been reinforced through the public comment period. Therefore, we performed the "cooccurrence" function, which demonstrates that the public comments that contain "low income" are largely consistent with the characterizations presented in the policy provision – the deservedness of policy benefits for low-income households. Many comments included explicitly positive framing, such as the word "applaud" when talking about "low income," which indicates support for the policy and appreciation for the explicit consideration of low-income households and individuals. The social construction of low-income households through these public comments is revealed in the words like "vulnerable," "vulnerability," "risk," "justice," "benefit," "help," "inequity," "inclusion," etc. in the obtained public comments. These words show that the social construction of low-income households delivered by policy makers have been reinforced and strengthened through public participation, which means that the stereotypes are likely to have long-lasting effects that will impact future policies and politics.

Topic Modeling and the Classification of Low-Income Households

Despite the positive social construction of low-income households in the policy and the reinforcement of this policy stance through public participation, it remains unclear why low-income households are not benefiting from solar (current research continues to show disproportionate and unequal adoption of solar across demographics). Remember that we have not explored political power so far. According to the SCF, people with stronger political power are generally more active in public participation including voting and policy advocacy, thus continuously drawing attention from policy makers and reinforcing their positive and engaged role. In other words, the advantaged groups are likely to mobilize themselves to pursue their self-interests through public participation while dependents do not see themselves as effective in the public discourse and are likely to show passive styles of public participation (Schneider and Ingram, 1993).

Recognizing this, it would be helpful to explore and quantify political power by different target groups in this policy arena in order to classify low-income households in the social constructionist typology. We measured political power though the obtained public comments according to topic prevalence through topic modeling (i.e., unsupervised machine learning), which contributes to the application of the SCF and offers an initial attempt as well as an example regarding the measurement of political power through a machine learning approach.

Five topics naturally emerged in the public comments: (1) Topic 1 (4.6% of tokens) focuses on low-income households and is represented by solar organizations and coalitions, non-profits, and government agencies; (2) Topic 2 (55.3% of tokens) emphasizes the benefit-cost ratio and the land use issue, and this topic is represented by corporations (e.g., solar installers, solar developers, technology companies, digital energy service platforms, renewable energy resource companies, etc.); (3) Topic 3 (13.4% of tokens) is about the land use issue as well as the nature, climate issues, conservation, habitats, etc., and this topic is represented by environmental organizations; (4) Topic 4 (8.8% of tokens) represented by individuals from different towns talks about the land use issue (oppose the restriction of disqualification of habitats or natural lands in the regulation), job creation, economic development, and residents or landowners in towns; and (5) Topic 5 (17.9% of tokens) focuses on habitat conservation and forestation, and this topic is represented by environmental advocates. As we can see, several topics such as themes relevant to "land use" and "income" have received wide attention from the public, which are also main changes of the 2020 emergency ruling mentioned previously.

Analyzing the prevalence of different topics from different stakeholders reveals who is participating and who is dominating the conversation, which also offers a novel lens to measure political power in this context. Comments by large corporations such as solar installers or developers account for more than half (55.3%) of the corpus, representing the interests of the solar industry and mainly focusing on the revised land use provisions and local communities' revenues. Their stance is similar to the fourth topic represented by residents in towns, which accounts for about 8.8% of the corpus. Those residents who live in different towns are concerned about jobs, revenues, etc. By contrast, the third topic and the fifth topic represented by environmental organizations or environmental advocates are supporting the new land use ruling and advocating for the prohibition of solar installation on "Priority Habitat," "Core Habitat," or "Critical Natural Landscape." These two topics account for about 31.3% of the corpus in total. As we can see, there is a tension between the identified topics-the controversy between environmental protection and economic development. In addition, the least prevalent topic (about 4.6% of the corpus), which emerged from comments represented by solar coalitions, non-profits, and government agencies, emphasizes more about Massachusetts low-income residents, advocating for crafting low-income customers in a way that it identifies electricity customers who are currently low-income.

Based on the results, we argue that, in the public participation process, although low-income households did receive public attention to some extent and the social construction of low-income households were reinforced, the topic emphasizing and

[3]Note that the 151 repetitive comments that were deleted from the corpus all contain "low income." To strengthen the argument and perform better topic modeling afterwards, we did not include them in the analysis.

focusing on low-income households is the least prevalent in the corpus. Attention to low-income households is relatively low compared to other issues such as land use, and low-income households themselves or individuals who clearly represent them are not likely to be commenting on the solar policies – most of the comments addressing low-income households are from coalitions, organizations or government agencies. Questions also remain whether these participants could actually represent low-income households and deliver their actual concerns to policy makers.

DISCUSSION

This research contributes to the understanding of why some target groups are advantaged in the policy-making process, how policy designs can reinforce or change these advantages, and how to classify low-income households among target populations. This analysis shows that low-income households have been identified and prioritized as a visible target population in the SMART program, and the positive social construction (i.e., deservedness of policy benefits) of low-income households makes them more advantaged in the program. But with weaker political power compared with other target groups (i.e., large corporations such as solar developers or solar installers in this case), they are less likely to enjoy policy benefits and fall into the category of "dependents" instead of "advantaged."

The benefits of solar along with its decreasing costs provides a critical justification for policy makers to popularize solar. The political discourse on the climate crisis in Massachusetts also facilitated a transition to renewable energy. In other words, the long-standing political norms are beneficial for the growth of the solar industry within the state, which may provide the solar industry with some advantaged social constructions (i.e., we didn't specifically explore the social construction of large solar corporations as we did for low-income households). As a consequence, the Massachusetts' solar industry has been recognized as a national leader in the U.S.

Targeting low-income households is also justified by the emerging concerns around energy justice (Healy et al., 2019; Jenkins et al., 2020; Stephens, 2020) and environmental justice (Roddis et al., 2018; Lukanov and Krieger, 2019). These growing concerns play a key role in justifying the rationale of solar policies targeting low-income households and assigning policy benefits to that target group given the existing adoption disparities (distributional injustices). Therefore, low-income households have been constructed and "portrayed" as deserving policy benefits. Explicit investment in low-income households could also be considered a form of reparatory justice.

Furthermore, the conveyed message about assigned benefits to the public has reinforced the social construction of low-income households and strengthened their deservedness of policy benefits, based on the fact that the characterization of low-income households constructed by those who mentioned low-income people in their comments are largely consistent with the policy stance.

Despite the positive social construction of low-income households in the SMART program, however, due to long-lasting structural problems such as homeownership policies, historic contract granting utilities monopoly power over the grid (Burke and Stephens, 2018), etc., low-income households have weaker political power and therefore are less empowered to participate or be represented in the policy making process. Therefore, although low-income households are being targeted, the concerns, perspectives, and priorities from this target group were not likely to be delivered to policy makers through the public comment process (i.e., given the least prevalence of the topic focusing on low-income people in the corpus). By contrast, large corporations such as solar developers or solar installers dominate the discourse (i.e., the topic represented by this target group accounts for more than half of the corpus). These stakeholders are more likely to continue receiving policy benefits, because their voices and concerns are more likely to be considered by policy makers, reinforcing their advantaged and engaged role in the policy process. With positive social construction but weaker political power, low-income households fall into the category of "dependents" in the social constructionist typology of target populations (see **Table 1**).

Therefore, the program may not be actually benefiting low-income households who are having and continue to have disproportionately higher energy burdens than others. To change the status quo and make solar PV actually benefit low-income people, policy makers should design more inclusive policy process and focus more on procedural justice when formulating solar policies in order to allow low-income residents to engage directly or be represented. Leadership should be developed from underrepresented or marginalized communities to empower those individuals. As the results suggest, those who care about low-income households are more likely to be coalitions, non-profits, and government agencies. Non-profits may play an important role in terms of motivating as well as representing low-income households. Without meaningful and effective community engagement of low-income households in the policy-making process, it will continue to be difficult to have inclusive community support and engagement which is necessary to achieve the intended outcomes of these policies.

CONCLUSIONS

Applying the policy design perspective to the energy policy research provides a novel theoretical contribution and offers a deeper understanding of the rationale and dynamics of the policy process of developing low-income solar policies at the state level. By utilizing the SCF in an empirical context, this research contributes to the understanding of why some target groups are more advantaged than others, how such advantages can be reinforced through public participation, and how to categorize low-income households among target populations.

The patterns revealed here in the case of Massachusetts are likely playing out in other states and other jurisdictions that are trying to expand solar policies to be inclusive of low-income households. The data-driven and inductive approach shows that the social construction (i.e., stereotypes) of low-income households, who have been identified as a visible target population that deserves policy benefits, results in low-income households being advantaged by the program. The conveyed message about assigned benefits to the public has reinforced and strengthened the social construction of low-income households – the deservedness of policy benefits. Despite the fact that the policy stance is beneficial to that target group, they have weaker political power and are less empowered to participate in the policy process, making their voices less likely to be heard by policy makers and be truly enjoying the benefits of solar. By contrast, other target groups such as large corporations who have stronger political power are more likely to participate in the policy-making process and receive policy benefits in the long run, reinforcing their advantaged and engaged role. More broadly, this research highlights the ongoing challenge of more meaningful representation and direct engagement of low-income households when formulating solar policies and the importance of concerning procedural justice in order to address the issues of energy injustices.

Our research is an initial and novel contribution to the literature. Local governance and policy formulation, however, may contain a specific context. Further research in other scenarios needs to be done to explore how solar policies have engaged with low-income households. Also, since Massachusetts is a national leader on solar, a question remains regarding the applicability of the paper's conclusions to other states. In addition, further research using first-hand data is needed to better understand the policy process of state-level solar policies. Valuable future contributions could utilize other measurements to quantify social constructions and political power. Further studies could also assess the tensions embedded in solar programs, the degree to which public comments are well-considered by policy makers, how public discourse as portrayed in social media corresponds or diverges from public comments, and how a broader diversity of target populations is categorized and framed in solar energy policy.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available at: https://www.mass.gov/info-details/smart-400-mw-review-emergency-rulemaking.

AUTHOR CONTRIBUTIONS

YS developed the theoretical framework, collected and analyzed the data, and wrote the draft of the manuscript. JCS supervised the project, provided critical feedback, edited the draft, and helped shape the research. All authors contributed to the manuscript.

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Including Social Housing Residents in the Energy Transition: A Mixed-Method Case Study on Residents' Beliefs, Attitudes, and Motivation Toward Sustainable Energy Use in a Zero-Energy Building Renovation in the Netherlands

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Reducing household energy use in social housing buildings can substantially contribute to mitigating global climate change. While municipalities and social housing corporations are willing to invest in sustainable renovations and innovations, social housing residents' inclusion in the sustainable energy transition lags behind. This pilot study explored social housing residents' attitudes toward sustainability and sustainable renovation of their apartment building, as well as (factors underlying) their motivation toward two specific sustainable behaviors. Semi-structured interviews, containing both open- and close- ended questions, were conducted with 20 residents of one social housing building that was due for renovations. Results showed that respondents were concerned about climate change, including environmental justice beliefs, typically already engaged in various sustainable behaviors, and were motivated to add sustainable behaviors to their repertoire after the renovation. Yet, perceived social norms were not always supportive of behaving sustainably and respondents sometimes failed to recognize the sustainable value of these behaviors. Furthermore, while respondents were more positive than negative about the sustainable renovation, they nevertheless listed many concerns and problems regarding the renovation process, including procedural justice concerns. This small-scale study provided important insights into barriers and facilitators of the sustainable energy transition among social housing residents, who are at risk of lagging behind in the sustainable urban energy transition. Findings underline the importance of including residents in the sustainable renovation process through engagement, communication, and co-creation.

Keywords: social housing, sustainable energy transition, sustainable behavior change, sustainable renovation, value belief norm theory, theory of planned behavior, procedural justice

INTRODUCTION

Climate change poses a major challenge to societies worldwide, and contemporary generations are the first to experience the negative consequences first-hand. Several influential reports allude to the urgency of the problem (IPCC, 2018; IPBES, 2019), indicating that if we do not act now, the negative consequences of climate change will be irreversible. However, to achieve the necessary transitions to counter climate change, a fundamental shift in how we use the earth's resources is necessary. One important transition that needs to be made is in our energy use; we drastically need to decrease the use of fossil fuels and reduce our overall energy consumption to bring down the emission of greenhouse gasses that cause global warming (IPCC, 2018). While a large role is set aside for industries and the agricultural sector in this process, the residential sector also substantially contributes to the total energy consumption in Europe, mainly for space and water heating, lighting, and electrical appliances; estimates range that households use between 16 and 50% of total energy consumption (Nejat et al., 2015; Filippidou et al., 2016; Eurostat, 2019). A lot can thus be gained from reducing household energy use. Since existing buildings will dominate the housing stock for the next 50 years based on their life cycle, energy renovations in existing dwellings offer unique opportunities for reducing the energy consumption and greenhouse gas emissions (Filippidou et al., 2016).

One important area in which sustainable improvements to reduce energy consumption are essential and feasible is in the non-profit housing sector, also referred to as social housing. As social housing buildings are often not well-insulated, these buildings promise large potential gains in terms of reducing energy consumption (Kammen and Sunter, 2016). Moreover, social housing residents are also at risk of lagging behind in the energy transition (Santangelo and Tondelli, 2017). In the Netherlands, social housing accounts for one-third of the total housing stock (Braga and Palvarini, 2013; Filippidou et al., 2016), which is the largest percentage in Europe. Thus, in the Netherlands, sustainably renovating existing the housing stock cannot occur without taken into account social housing. At the same time there are numerous sustainable technological innovations available that would be suitable for renovating social housing buildings, enabling the reduction of energy consumption in these buildings (Wassenberg, 2004; Glad, 2012; Nejat et al., 2015). However, technological innovations alone will not results in a successful energy transition if these innovations are not accepted by stakeholders in the social housing market. Important stakeholders are municipalities, social housing corporations, and social housing residents. There is momentum in the social housing market for sustainable energy investments: sustainability and energy saving are central goals for municipalities and social housing corporations (Aedes, 2013; Filippidou et al., 2016), and their willingness to invest in sustainable renovations and innovations is generally high.

Yet, whether social housing residents accept and adopt sustainable changes to their residences and the accompanying technological innovations remains to be seen. It has been shown that people in lower socio-economic status groups generally tend to be late adopters of new behaviors (Franceschinis et al., 2017). It is sometimes assumed that social housing residents' willingness to accept sustainable renovations and adapt their energy-related behaviors may be low (Glad, 2012; Santangelo and Tondelli, 2017). Nevertheless, other possible underlying reasons include a lack of opportunities or an inadequate capabilities set (Kollmuss and Agyeman, 2002; Michie et al., 2011; Walker et al., 2014). In the current study, we will focus specifically on these possible underlying reasons and investigate social housing residents' beliefs, attitudes, and motivation toward sustainable energy use, also focusing specifically on perceptions of justice and injustice in this process.

Value Belief Norm theory (VBN; Stern, 2000; Steg et al., 2005) has been widely applied to study sustainable behavior intentions. The theory postulates that values, the general goals that people strive for in life, and more sustainable-behavior-specific beliefs are key determinants of people's sustainability attitudes and behaviors, including the acceptance of sustainable technologies and the adoption of sustainable energy-related behaviors. With regard to environmental behaviors, four types of core values have been discerned (Schwartz, 1992; Stern et al., 1998; Dietz et al., 2005; de Groot and Steg, 2008; Steg et al., 2014; Hornsey et al., 2016): two types of self-transcending values that motivate sustainable behavior intentions, namely biospheric values (i.e., valuing the environment) and altruistic values (i.e., valuing the welfare of other human beings and fairness considerations), and two types of self-enhancing values that hamper sustainable behavior intentions, namely egoistic values (i.e., valuing personal resources and achievement), and hedonic values (i.e., valuing pleasure and comfort). Moreover, awareness of consequences and the ascription of responsibility pose important sustainable-behavior-specific beliefs that shape the acceptance of sustainable technologies and the adoption of sustainable energy-related behaviors. However, as social housing residents' environmental values and beliefs have not yet been studied extensively, it is not yet known to which extent these values play a role in their sustainable behavior choices. In the current study, we aim to address this gap in the literature. We propose that these core values and beliefs also shape social housing residents' beliefs about sustainability in particular, as well as their willingness to engage in the sustainable energy transition, in important ways.

While VBN theory focuses on values, beliefs, and personal norms, underlying people's sustainable behavior intentions specifically, Theory of Planned Behavior (TPB; Ajzen, 1991; Fishbein and Ajzen, 2010) has been adopted widely to study various types of behavior. TPB postulates that people's attitudes (the way people feel toward a particular behavior), subjective norms (the extent to which people believe those around them engage in, and approve of, the particular behavior), and perceived behavioral control (people's perceived ability to adopt behavior changes) determine their intentions to engage in any given behavior. While VBN and TPB show similarities, two crucial factors that have been shown to determine whether people adopt specific behaviors: behavioral control and subjective norms should be included in the study of sustainable behavior change. As such, we use this TPB as a guiding framework to enhance understanding of social housing residents' intention to engage in two specific sustainable behaviors.

Social housing residents' attitudes toward proposed sustainable renovations and their intentions to adopt the required sustainable behavior changes after a renovation may furthermore be shaped in important ways by how they experienced the renovation process, especially since these renovations are oftentimes initiated by the social housing corporation and, as such, will not be the result of individual choice. A wealth of literature on procedural justice (e.g., Lind and Tyler, 1988; Tyler, 1989; Van den Bos et al., 1997) showed that how people have been treated during a process may count heavily toward their acceptance of an outcome (regardless of the outcome itself). Moreover, within the field of energy justice, procedural justice elements of providing information (transparency and accountability) and engaging end-users in the process (due consideration) have been deemed vital for a successful energy transition (e.g., Sovacool and Dworkin, 2015; Sovacool et al., 2016). As such, it is important to take into account social housing residents' experiences during the renovation process as well.

The social housing building focused on in this pilot study was due for renovation and therefore provided an ideal research context. At the time of study in 2019, the housing corporation had presented two possible plans for the renovation to the residents: a "traditional" minimal renovation aimed only at making necessary improvements to the building, and an "innovative" sustainable renovation aimed at making the building energy neutral (see **Figure 1**). The housing corporation, as well as the municipality involved, strongly favored the sustainable renovation, mirroring the generally high momentum for sustainable transitions described above. The housing corporation aimed to create support for the sustainable renovation among the building's residents in multiple ways, for example by organizing information and participation sessions for the residents and by involving the residents' committee in the decision-making process. With this study, the housing corporation wanted to gain additional insight into resident's motivations for sustainable energy use and the sustainable renovations of their social housing building.

The current study investigated factors underlying (a) residents' attitudes toward climate change, sustainability and sustainable behavior in general, (b) their attitudes toward the process of the sustainable renovation of their building, and (c) their intentions to engage in specific sustainable energy-related behaviors. A mixed methods design was used to gain insight into residents' current stage of change (Prochaska and DiClemente, 2005) in the sustainable energy transition, their attitudes regarding climate change and the need for sustainable behavior in general, and their environmental values. Residents' opinions and emotions about the decision-making process regarding the renovation were also researched. In addition, their attitudes, subjective norms, and perceived behavioral control regarding two specific new behaviors, which would be required of them if the sustainable renovation were to occur, were probed. By increasing insight into the factors that either facilitate or hamper social housing residents' willingness to engage in the sustainable energy transition, entry points for supportive policies and interventions can be identified.

METHODS

Participants

For this study, all residents were informed about the study with an information letter. Subsequently, all residents were approached by telephone by the researchers three times to invite them to participate. We asked the head of the household in each apartment to participate. Not all households were reached ($n = 26$) and not all of those we did reach wanted to participate ($n = 12$). We ended up with a sample of 20 participants, which is about one third of all households in the building. Appointments were scheduled with the respondents to conduct the interview in their apartment (or, when they did not want the interviewer to come to their home, they could opt for a location close to their apartment building especially set up for these interviews). All interviews took place in March and April 2019. Respondents were compensated for their participation with a gift voucher (€10).

Study Design and Materials

We conducted structured face-to-face interviews to gain insight into residents' attitudes toward sustainability and the sustainable renovation of their apartment building (see **Supplementary Material**). The interviews contained a mix of open-ended and multiple-choice questions. The questionnaire consisted of two parts. In the first part, we asked respondents about their attitudes toward sustainability in general and toward the potential sustainable renovation of the apartment building. In the second part, we asked for their environmental justice values, subjective norms, attitudes, and perceived behavioral control toward two specific sustainable behaviors; slow and constant heating of the apartment and active sun blocking using sun blinds.

At the start of the interview, the researcher shortly introduced herself and the study after which respondents provided informed consent. Subsequently, the questionnaire started. All interviews lasted for ∼60 min.

Part 1 – Attitudes and Beliefs Regarding Sustainability and the Sustainable Renovation of the Apartment Building

The questionnaire started with two open-ended questions to prompt participants about the sustainable behaviors they already took part in and about the importance of sustainability for them personally. Subsequently, we asked them about their stage of change regarding sustainable behavior with a five-point algorithm (Prochaska and DiClemente, 2005). Next, based on VBN theory, we presented them with 11 statements regarding the awareness of consequences, the ascription of responsibility and their personal norms regarding global warming. The items were a selection of the ones used by Steg et al. (2005) and could be answered on a 6-point Likert scale ranging from 1 = Totally disagree to 6 = Totally agree. The questionnaire continued with an open-ended question about their attitudes toward the sustainable renovation of

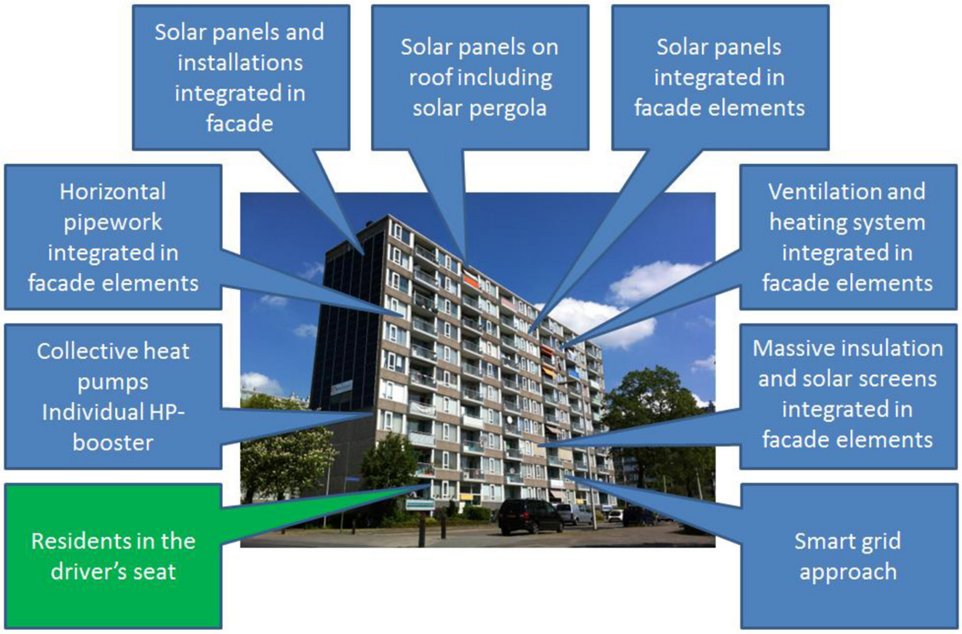

FIGURE 1 | The proposed sustainable renovation plan (© Utrecht Sustainability Institute).

the apartment building. After this general question, we asked them "if only thinking about the *positive/negative* sides of this renovation, how *positive/negative* they were" on a 6-point Likert scale ranging from 1 = not at all to 6 = very. Respondents could elaborate on their answer in a subsequent open-ended question.

Part II –Two Specific Sustainable Behaviors

After the general part of the questionnaire, we continued with a more specific part, based on a combination of TPB and VBN theory, in which we asked respondents for their values, attitudes, subjective norms, and perceived behavioral control regarding two specific sustainable behaviors. Together with the technical partners involved in the renovation and the social housing association, we decided on two behaviors that were essential for the renovation to be successful. Because of a new heating system, using a heat pump, residents had to set the temperature in each room separately once and then leave it as much as possible for optimal use of the system. This behavior was termed "heating constantly." Because of special glazing that will keep warmth in, sun blinds would be installed on the south-east side of the building. Residents would then have to actively use these blinds to keep their apartments cool in summer (and more easily warm in winter). This behavior was termed "active sun blocking." Both behaviors were questioned one by one.

After a short introduction of the behavior, we asked them in what way this required a behavior change for them and to specify their motives to either execute the behavior or not and to shortly motivate their answer as well. Respondents were presented with a list of possible motives (*Joy, Convenience, Comfort, Costs, Recognition (by friends), Fairness, Doing the right thing, Contributing to a better world, The environment, Nature, Pollution, Other, namely…)* based on the self-enhancing and self-transcending values important for sustainable behavior outlined by Steg and colleagues (de Groot and Steg, 2008, Steg et al., 2014) and discussions with the social housing corporation. We continued the questionnaire with nine multiple choice items on 7 point Likert scales (1 = completely disagree; 7 = completely agree) to prompt attitudes (good-bad; pleasant-unpleasant; beneficial-disadvantageous; useful-useless), subjective norms (most people would approve if…; most people around me try to….), perceived behavioral control (I am confident that I can …; I can decide for myself whether I will…), and intentions toward the behavior (I intend to…), based on the theory of planned behavior (Ajzen, 1991; Fishbein and Ajzen, 2010).

After completing this part of the questionnaire for both behaviors, the respondents were thanked for their participation.

RESULTS

Attitudes and Beliefs Regarding Climate Change and Sustainability

Most respondents feel positive toward sustainability, regarding sustainable behavior an important theme in their lives. Motives for attaching importance to sustainability varied; some respondents were driven by self-transcending values, focusing on being fair toward future generations and the environment, and some were driven by self-enhancing values, such as saving money.

"Sustainability is very much needed. That's a fact. Yes. It's common knowledge. And I believe that we, as citizens, really need to think about it and contribute to it." (R9)
"If we do not behave sustainably, we will not have an earth to live on in no time." (R13)
"Because ehh…well, in earlier days people thought about us. We have to think about others, the future." (R18)
"You also have to watch your spending, yeah. Things are becoming more and more expensive." (R12)

A minority of respondents explicitly states that sustainability is not an important issue for them or questions the effectivity and sustainable behavior.

"Yes, I believe it's all a bit nonsense." (R15)
"Yes, it's quite the issue nowadays. Really. Sustainability, environmental issues. I couldn't care less." (R19)
"I don't think it [behaving sustainably] will help. The Netherlands are taking it too far. But if I watch countries like the Czech Republic or Romania. If you see what they exhaust. Then [what we do in] the Netherlands will not help." (R20).

Exploratory quantitative analyses showed that most respondents are already behaving sustainably (i.e., maintenance phase). When asked about these behaviors, recycling and saving water were most often mentioned, followed by making less use of their car or driving an electric car, saving energy (e.g., turning the heating down). Of the people who indicated that they are not behaving sustainably yet, some are in the pre-contemplation phase, not having any intentions to start behaving sustainably, and the others are either in the contemplation or preparation phase. Based on this finding, we expect that a sustainable renovation can be successful, as the large majority is already focused on behaving sustainably or preparing to do so.

Moreover, respondents viewed global warming as a problem (M = 4.65; SD = 1.13). They also have a personal norm to save energy (M = 4.40; SD = 1.26), which is surprising, given their feelings of responsibility for causing global warming which are barely above the scale midpoint (M = 3.55; SD = 1.27).

Attitudes Toward the Sustainable Renovation of the Apartment Building

Respondents were more ambivalent regarding the sustainable renovation of the apartment building and the process thus far; they perceived both positive and negative aspects. When asked to indicate how positive and negative they felt about the renovation, they felt more positive (M = 5.61; SD = 0.61) than negative (M = 3.89; SD = 1.49). However, when prompted to elaborate on these answers, many more negative than positive aspects were mentioned (see **Table 1**). Regarding positive aspects, improved appearance of the building and more comfortable living were mentioned most. Regarding negative aspects, uncertainty regarding the renovation process, lack of communication, fear of high costs, and a degradation of facilities were mentioned a most. These negative aspects oftentimes referred to procedural justice concern and these contributed negatively to their attitudes toward the sustainable renovation of the apartment building.

TABLE 1 | Positive and negative aspects of the sustainable renovation of the apartment building.

Positive aspects	#Residents	Negative aspects	#Residents
Building appearance	10	Unclarity about process	12
Living comfort	8	Bad communication	9
Environmental benefits	4	Nothing happening yet	8
Cost reduction	3	Additional costs	8
Modern appliances	2	Deterioration in facilities	7
Positive early experiences	2	Building nuisance	7
No more district heating	2	Loss of faith	6
		Strangers in one's home	4
		Financial consequences for housing corporation	3
		Renovation is overdue	3
		Problems with residents' committee	2
		No contact person	2
		Resident's physical limitations	1
		Renovations differ between apartments	1
		Counteractions by government	1
Overall positive feeling [scale 1–6; *M (SD)*]:	5.61 (0.61)	Overall negative feeling [scale 1–6; *M (SD)*]:	3.89 (1.49)

Heating Constantly

Two respondents indicated already heating their apartment constantly, but for most respondents heating constantly required a behavior change. For some respondents this proved difficult.

"I hope not. I hope not. I hope that I am not required to change my behavior." (R13)
"And everything keeps being postponed over and over, so I don't know what to expect anymore." (R3)

Some respondents also indicated they had questions regarding the required behavior change, for instance about the possibilities for ventilating their home.

The majority of respondents, however, was motivated to adopt the required behavior change, even when that meant to counterintuitively (it felt "like wasting energy" (R1) to some) leave on the heating system when leaving the house.

"…I will leave the heating at 18 degrees, whether I am home or not." (R15)

With regard to motives, respondents most often mentioned an expected increase in living comfort and an expected reduction of costs (see **Figure 2A**). In addition, this behavior is also clearly recognized as self-transcending, as contributing to a better world,

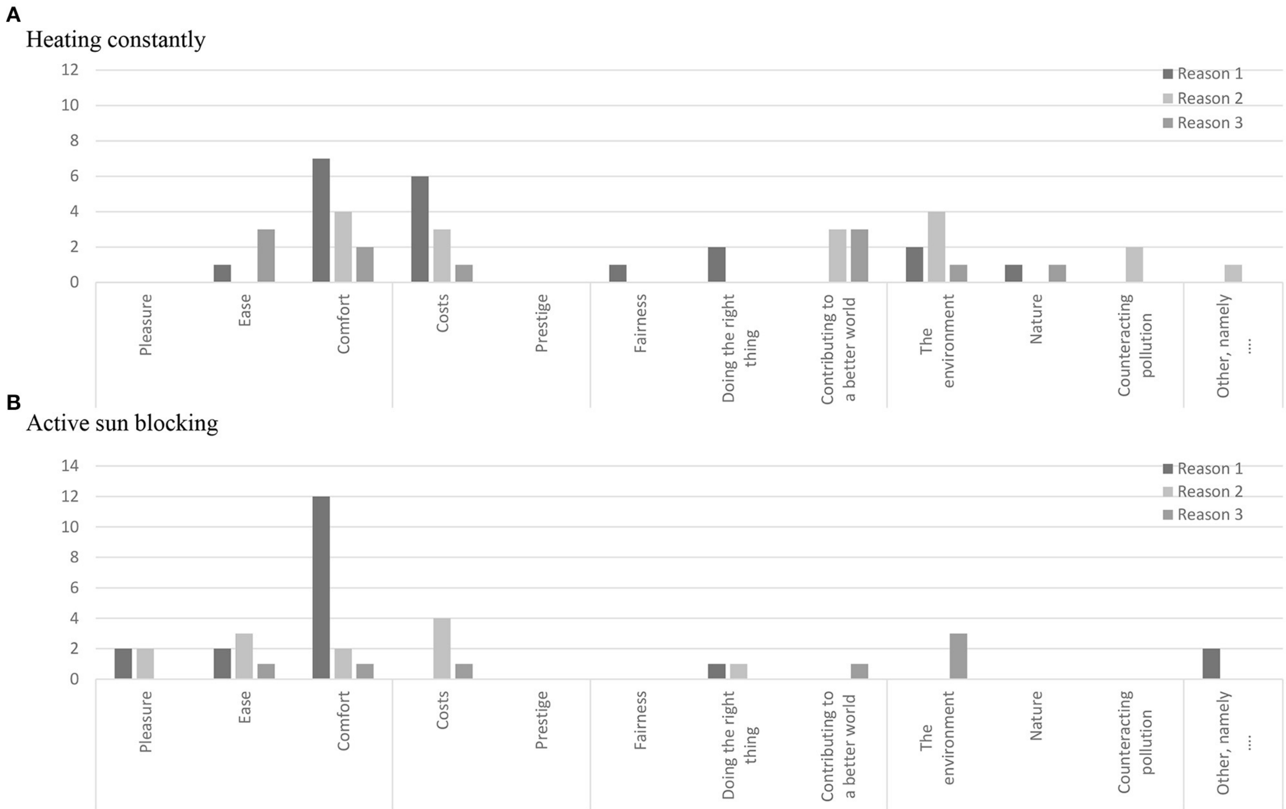

FIGURE 2 | Overview of values mentioned by residents as important for performing the two specific sustainable behaviors; **(A)** heating constantly and **(B)** active sun blocking, including number of times each value was mentioned as first, second, and third reason to perform the behavior.

protecting the environment and countering pollution are also mentioned regularly as motives for heating constantly.

Furthermore, exploratory quantitative analysis of attitudes, norms, efficacy and behavioral intentions clearly show that people have a positive attitude toward heating constantly ($M = 1.95$; $SD = 0.88$) and feel they can effectively execute the behavior ($M = 6.18$; $SD = 1.03$). However, the social norm regarding heating constantly is judged somewhat less favorably ($M = 4.63$; $SD = 1.82$). Nevertheless, this does not seem to impede on respondents' intentions to adhere to heating constantly after the renovation ($M = 6.35$; $SD = 0.88$).

Active Sun Blocking

In comparison to heating constantly, relatively more respondents indicated that they already actively blocked the sun from their apartment in the current situation.

> *"Well, actually, not that much [will change], as we are currently also doing that already." (R1)*
> *"We already close the blinds before leaving our apartment. We usually already do that the night before, if we know the sun will be shining... the sunshine hits our windows very early in the morning." (R9)*

Some residents also indicated they did want to engage in more active sun blocking after the renovation. For them, this primarily means starting to think about closing the blinds at an earlier stage than they are currently doing.

> *"So you can arrange everything yourself. Imagine that I would go outside and I know the sun will be shining in through our kitchen window, then I would want to block the sun there, you know." (R12)*

A few times, respondents mention that electronic control of the blinds would make it easier to adopt the behavior. Still, for a few respondents the required change proved difficult.

> *"Well, that will be a big change for me." (R20)*

Finally, some residents mention that they actually like the sun in their home, so they find it difficult to actively block the sun from their apartment.

> *"I like having the sun inside, so I will not quickly close the blinds." (R13)*

With regard to motives for actively blocking the sun from their apartment, an expected increase in living comfort is mentioned most often (**Figure 2B**). Self-transcending motives are mentioned rarely.

Finally, exploratory quantitative analysis of attitudes, norms, efficacy and behavioral intentions showed that people have a positive attitude toward heating constantly (M = 2.12; SD = 1.04) and feel they can effectively execute the behavior (M = 6.18; SD = 1.10). Again however, the social norm regarding heating constantly is judged somewhat less favorably (M = 4.58; SD = 1.53). Moreover, in the case of active sun blocking, this does seem to impede on respondents' intentions to adhere to heating constantly after the renovation somewhat (M = 5.79; SD = 1.84). Nevertheless, respondents still indicate they intend to actively block the sun.

DISCUSSION

The current study explored social housing residents' beliefs, attitudes, and motivation regarding the sustainable renovation of their apartment building. By focusing on social housing residents, who are at risk of lagging behind in the sustainable urban energy transition, this small-scale study provided important insight into the barriers and facilitators of the sustainable energy transition in this specific population that is not often reached in research. The results of this study showed that residents were concerned about climate change and most already engaged in sustainable behavior or considered doing so in the near future. They largely believed global warming was problematic and had a personal norm to save energy even though they seemed to feel little responsibility for causing climate change. Regarding the renovation process, they did mention several negative aspects, mostly related to procedural justice concerns, even though their overall rating of the process was more positive than negative. Finally, when prompting specific sustainable behaviors (i.e., heating constantly and active sun blocking), we found that residents were generally motivated and felt able to adopt these behaviors, but that perceived social norms unsupportive of these behaviors might impede on adoption sometimes. Overall, our study showed that social housing residents are motivated to participate in the sustainable energy transition, but attention needs to be given to creating the right circumstances to convert this motivation into sustainable action.

In contrast to earlier research about social housing residents' sustainability motivation (Kollmuss and Agyeman, 2002; Glad, 2012; Santangelo and Tondelli, 2017), our study showed that residents' motivation to engage in sustainable behavior was high. Interestingly, respondents were motivated both by self-transcending values as well as by self-interested values, while the latter usually hamper sustainable behavior intentions (e.g., de Groot and Steg, 2008; Crosbie and Baker, 2010; Steg et al., 2014). It might be the case that, in social housing buildings especially, sustainable renovations and municipality's and social housing corporation's investments in sustainable technologies can decrease energy consumption and, at the same time, increase living comfort and decrease costs for residents. Hence, in this case, self-transcending environmental-justice and biospheric values and self-enhancing egoistic and hedonistic values may both motivate sustainable behavior, creating a win-win situation. Taken together, these results suggest that participation in the sustainable energy transition may be more about creating an accepting and enabling (social) environment than about increasing motivation (Michie et al., 2011; Walker et al., 2014).

Furthermore, our results suggest that respondents were on average more positive than negative about the sustainable renovation of their building, again indicating support for the sustainable renovation. However, our results also indicate that the process of such a renovation can hamper people's willingness to engage in the sustainable energy transition. While they indicated being more positive than negative about the sustainable renovation, respondents did in fact mention many more negative aspects than positive ones. While most positive aspects referred to the outcome (e.g., improved appearance of the building, increased living comfort) or sustainability aspects, most of the negative aspects were related to the renovation process (e.g., uncertainties about starting dates or contact persons, communication issues). Many actions were taken by the social housing organization to allow residents to participate in the renovation process, both by providing information as well as by trying to carefully take into account the needs and opinions of residents during the renovation process (e.g., through information letters and a resident's committee; Sovacool et al., 2016). Nevertheless, the uncertainties and changes that happened in the course of the project (and which were all communicated to include residents in the renovation process) caused discontent and concern amongst residents. In this sense, informing residents at an too early stage may also backfire by overwhelming residents with uncertain information that needs to be corrected at a later stage. These results underline that procedural justice does not imply overwhelming residents with information, but importantly, entails including residents in the sustainable renovation process in the right way (see also Hauge et al., 2013).

While the sustainable renovation of the social housing building will contribute positively to residents' physical opportunities to engage in sustainable energy behaviors and residents are motivated to behave sustainably, it is important to take into account perceived behavioral control and social norms as well. The sustainable renovation introduces many new technologies into the building and requires residents to change their behavior in numerous ways. Importantly, the technological innovations introduced during the renovation can attain maximum energy savings only when the residents indeed adopt the required behaviors resulting in the greatest reduction in energy consumption. With regard to two behaviors deemed crucial in the renovation under study, "heating constantly" and "active sun blocking," we found that residents were overall willing to change their behavior, but need clear instructions on what to do. Some residents felt more hesitancy toward their ability to adopt the new behaviors and will need clear guidance on what to do. Simple instructions should in this case be complemented with real-life demonstrations and monitoring to achieve optimal reductions in energy use (cf. Berry et al., 2014). Moreover, social norms regarding the behaviors were not always positive. Residents felt that people close to them might not always be supportive of the desired behavioral changes. This could be due to the counterintuitive nature of the desired behavior changes (e.g., leaving the heating on when leaving the house or actively (and effortfully) blocking the sun from your apartment). It is therefore essential to clarify and emphasize the sustainability aspect of these behaviors, as failing to do so may negatively impact people's intentions to engage in these behaviors.

Previous evidence suggested that, compared to the general public, social housing residents' willingness to adopt energy-saving technologies and behaviors may be lower (e.g., Glad, 2012; Kammen and Sunter, 2016). This is problematic, because social housing makes up a substantial part of the share of residences, especially in the Netherlands, and reducing energy use in social housing buildings is thus a crucial component to a successful energy transition. In contrast to these previous findings, the current study suggests that social housing residents are in fact concerned about climate change and motivated to engage in sustainable behaviors. Their motivation for doing so may partially rest on potential self-interested motives, such as an increase in living comfort or a reduction of costs as compared to the general public (Ebrahimigharehbaghi et al., 2019), but in sustainable social housing renovations such as the one focused on in this study, this may actually prove an additional motivation as opposed to a competing one. In line with the COM-B model (Michie et al., 2011), our results thus imply that engaging social housing residents in the sustainable energy transition is less about increasing motivation and more about creating the right circumstances (i.e., opportunities and capabilities) to do so. Currently, the social housing sector and the political landscape are creating the necessary physical circumstances, through sustainable energy investments (Aedes, 2013; Filippidou et al., 2016); the sustainable renovation that was the focus of this study being a case in point. Yet, policy-makers should also focus on creating the social circumstances (e.g., social norms) that support the sustainable energy transition. However, more research on these underlying mechanisms in the energy transition as well as in different socio-economic groups and studies comparing these mechanisms across groups is necessary to more fully understand how to leave no one behind in the energy transition.

A limitation of our study could be that the underlying factors that we aimed to investigate at times overlapped. In our study it was often difficult disentangle motivations from values and beliefs about sustainability and efficacy from social norms. Furthermore, the limited number of respondents (both in terms of representation within the respective building and in terms of representation of the target group) requires that all findings should be interpreted with caution and replicated in future studies. Yet, it should be noted that the number of respondents is in line with what is common for qualitative studies in the field of energy consumption (Galvin, 2015).

Nevertheless, our mixed-method design did allow us to distill important lessons to take away from this sustainable renovation project. Our study showed that social housing residents are motivated to participate in the sustainable energy transition and are already engaging in various sustainable behaviors. However, it is important to create the right circumstances to convert this motivation into sustainable action. To that end, policy-makers should carefully take into account procedural justice considerations (i.e., inform but don't overwhelm residents). Furthermore, by providing clear instructions and emphasizing the sustainability aspects of the required behavior changes, we can empower social housing residents to make the sustainable energy transition. These insights will be valuable for new sustainable renovation projects, especially when they concern larger groups of residents (e.g., a social housing building or blocks of houses in a certain area). Overall, our results stress the importance of focusing on the "human side" of the transition process, against the backdrop of the systems in place and structural factors in the broader context. We hope that with this study we have provided housing corporations and their technical partners a number of tools to better engage, communicate and co-create with the residents.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available because due to the sensitive nature of the questions asked in this study, survey respondents were assured raw data would remain confidential and would not be shared. Requests to access the datasets should be directed to Michèlle Bal, m.bal@uu.nl.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee of the Faculty of Social and Behavioral Sciences of Utrecht University [reference number FETC18-085]. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

MB, FMS, and JDW designed the research. MB and FMS wrote the article and edited it. JDW and CVH conducted review. MB, FMS, CVH, and JDW received project funding. CVH was responsible for project administration. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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Energy Justice in Apartment Buildings and the Spatial Scale of Energy Sustainable Design Regulations in Australia and the UK

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Energy vulnerability is a growing concern in many OECD countries post-millennium. An increasing number of residents go without heating or cooling necessities to manage the financial strains of increasing energy costs, low wage growth, and rising housing costs. Housing design quality contributes significantly to a dwelling's energy use and the resident's potential energy vulnerability with good orientation enabling passive climate control or, alternatively, poor design resulting in a reliance on artificial heating, cooling, and lighting for livability. Housing design regulations are accepted as an important tool in planning for achieving energy sustainability and mitigating climate change. However, this article argues for greater recognition and knowledge regarding regulation's ability to protect against energy vulnerability at the residential scale, particularly in the growing number of apartments purchased for the rental market in Australia. By observing the energy sustainability of apartments deemed permissible by Australian and UK regulations, this research demonstrates the significance of building scale in regulations when applied to apartments buildings. An energy justice lens reveals a distinction between measurement at the whole building level and the individual apartment/resident scale in this building typology in particular.

Keywords: energy justice, apartment (residential building), design regulation, energy vulnerability, housing

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INTRODUCTION

Energy vulnerability describes residents at risk of being unable to reasonably afford energy consumption for their dwelling (Daniel et al., 2020). For those with low incomes, residential energy costs can be a high proportion of their available income. This cost places significant financial strain on the household, mainly when a rise in energy use occurs during a heatwave or longer than expected winter. Managing this financial precarity is difficult, especially when the resident has little alternative means to buffer these fluctuations. As a result, many energy vulnerable residents tightly restrict or reduce their energy consumption to the bare minimum.

This restriction or reduction of energy use for energy vulnerable residents can have significant health and well-being implications. While there are sustainability arguments for being mindful of energy use and requirements, in contrast, energy vulnerable residents forego basic living necessities to manage or reduce their expenditure only (Azpitarte et al., 2015; Thomson et al., 2017). They go without basic comfort levels: enduring sleepless nights in hot dwellings or foregoing winter heating, which can lead to an increased risk of respiratory-related illness from damp and mould growth

(Giles-Corti et al., 2015). This denial of a level of essential comfort also contributed to mental health issues as energy vulnerable residents struggle without these necessities and are conscious of this absence comparatively in their lives (Liddell and Guiney, 2015). Energy justice is a lens that highlights the inequity in energy vulnerability by proposing that energy is an accessibility right and that necessities should be available to everyone, irrespective of affordability (McCauley, 2018).

As well as rising energy costs (Potter and Tillet, 2017), there are common trends, both internationally and in Australia, of people managing additional financial strain from rising housing costs and low wage growth (Parkinson et al., 2019). Australia, for example, has experienced an average 5% nominal increase in annual house prices from 2005 to 2015 (Kohler and Van Der Merwe, 2015), the UK a 7% and London a 14% increase (Land Registry, 2020). This rise has occurred disproportionately to wage growth alongside increasingly high unemployment rates (ABS, 2017a; Bagshaw, 2018). During 2020, many households also had to manage pandemic related periods of reduced or an inability to work due to city lockdowns (Hutchens, 2020). To manage an affordable living, since 2006, there has been a 4% rise in the renting population of Australia (Australian Bureau of Statistics, 2016a) and a 14% shift in the rental housing type towards the relatively more affordable apartment buildings Australia wide (Australian Bureau of Statistics, 2016b). With this growth of the apartment typology as rental properties in Australia, it is essential to note that energy sustainable design is lower quality in rental properties and apartment buildings are particularly poor quality within the Australian rental building stock. Recent studies have documented rental apartments with a relatively high reliance on artificial heating and cooling and limited passive design measures (Australian Council of Social Services, 2017; Baker et al., 2018; Poruschi and Ambrey, 2018; Easthope et al., 2020).

This research examines energy vulnerability in apartments and how housing design regulation, focusing on passive energy design, can help alleviate energy vulnerability in apartments through the building scale at which compliance is defined. Scale, in this instance, is defined as the apartment building as a whole vs. the resident scale of each individual apartment dwelling within this building. The growing significance of the issue of energy poverty in Australia, particularly for residents in rental properties (Daniel et al., 2021), is beginning to be fully recognised by government planners and policymakers. In 2020, new requirements were introduced for efficient heating and cooling technology in rental properties and targeted financial subsidies for energy costs as a way to offset these pressures (D'Ambrosio, 2020). Given this recent recognition of the significance of the issue, it is crucial to examine further the contribution passive energy design can offer residents and how regulations around this can proactively alleviate energy vulnerability by reducing the requirement on artificial heating and cooling technologies.

Energy sustainability impacts various groups, with the impact of the built environment on climate change a commonly cited focus (Sovacool et al., 2014). Energy justice additionally recognises the importance of the scale of the resident experience in energy sustainability. The resident scale is significant as Henning (2020) argues that the impact of energy sustainability as energy vulnerability is unequally experienced at the resident scale. This article argues the significance of scale in energy sustainable regulations for apartment buildings particularly as an energy justice lens reveals a distinction between measurement at the whole building level and the resident scale in this building typology. This research finds that the Australian national housing design regulation approaches energy sustainability from the whole building scale and ensures that new buildings overall do not impede the city from meeting agreed climate change emission targets. This entire building scale incorporates energy sustainability protection for the resident in detached housing, but it does not appreciate the distinctions of scale in an apartment building. An apartment building comprises multiple individual apartments that can differ in performance to each other as long as the aggregate meets the regulation when measured on the whole building scale. This aggregate level of energy sustainability in regulation is essential as a positive step towards mitigating climate change. Still, it offers limited energy vulnerability protection to residents of apartments as differences in energy performance can occur between individual apartments in the same building. This unequal distribution of performance is particularly significant as this research found, that studio and 1-bedroom apartments, predominantly rental properties (ABS, 2018), are primarily building's poor performing ones. This article expands on the significance of this scale in energy sustainability regulations, particularly with the apartment building typology's growth in the Australian rental market.

This research examines the case study of energy sustainability in housing design regulations through the Australian National Construction Code Vol. One (NCC) (Australian Building Codes Board, 2019) foremost with contrast to London's Housing Supplementary Planning Guide (LHSPG) (Mayor of London, 2016). It investigates this by observing what design trends remain permissible by each regulation and the standard apartment market practises occurring in the buildings. This article first discusses the significance of the issue and follows with a review of the literature on housing design regulations in apartment and energy justice. It then outlines the methods used, results obtained, and a discussion on the significance of scale in regulations to address energy justice issues in apartment buildings.

How Scale Currently Operates in Housing Design Regulations

Energy vulnerability is an increasing issue in many OECD countries since the early 2000's due to rising energy costs internationally. The number of energy vulnerable residents is becoming increasingly prevalent in Australia, more so than in other countries. One in four Australian households is currently at risk of being unable to pay their energy bills or forego essential daily energy use (Azpitarte et al., 2015). A contributing factor to this increase is the relatively high energy costs in Australia compared to international rates. Australian states have some of the highest individual prices compared with the US and EU countries (IEA, 2015; Potter and Tillet, 2017). The state of South Australian prices were nearly 300% more than the US rates, closely followed by the Australian states of NSW, Queensland and

Victoria at the fourth, fifth and sixth highest rates in Potter and Tillet's study.

While energy vulnerability is the problem that many residents face, housing design and regulations offer a solution to this problem by seeking to improve the design's energy sustainability. The role of good housing design in alleviating energy use and reliance for heating, cooling and lighting has been well-recognised in practise and academia (Poor et al., 2018). Good design manages the sunlight exposure and accompanying radiant heat inside the dwelling to enable it to stay at a comfortable temperature without the use of artificial heating or cooling. Orientation is one significant design method for passively controlling sunlight exposure with the careful management of the design layout of the dwelling related to the exposure of the sun. Design that is mindful of this can carefully control the internal room temperature to be more moderate in summer and receive passive heating during winter. Conversely, poor orientation can contribute to the reliance of the dwelling on artificial heating, cooling and lighting due to the extremes of temperature and light levels that the dwelling is exposed to. Poor design, therefore, significantly impacts the energy used by the resident as they attempt to make the dwelling habitable. While improvements in heating and cooling technology are important to alleviating some of the stress of energy vulnerability (Pears, 2020), the impact of this improvement is limited if the dwelling design is poor and requires regular reliance on artificial heating and cooling.

Housing design regulations are a widely adopted tool to guide housing design in both planning and construction needs. They operate by assisting the evaluation of the design of a project and whether this design meets the minimum deemed acceptable (Tiesdall and Allmendinger, 2008). Good housing design, including orientation, is generally uncontroversial among development practitioners (Moore et al., 2014). However, achieving it within the building design is also acknowledged as complex due to the multiple contributing and interconnecting components in the housing product that are often in competition with one another (Berry, 2014). This interconnection and incompatibility of components directly complicate the building's design and forces prioritisations or trade-offs to be made between different components such as the aesthetics of design, cost and amenity in the project. Housing design regulations are a tool to ensure that the necessities of health, safety and amenity are met with these trade-offs occurring in the project (Freestone, 2012).

Planning regulations specifically stipulate requirements for those indirectly affected, the *externalities,* by the project. Externalities are people, such as neighbours, members of the public and future citizens impacted by the proposed building design but do not have a direct voice in its form or construction through direct or financial involvement in the project (Freestone, 2012). Climate Justice and energy sustainability acknowledge the indirect impact of the built environment on climate change as an externality. Climate Justice highlights distant examples of the environment, populations disproportionately affected by the consequences of climate change such as coastal city flooding due to increased seawater levels, and future generations who will need to manage a world affected by climate change (Sovacool et al., 2014). Planning regulations typically acknowledge these externalities and therefore stipulate that new buildings mitigate or positively reduce their effects on climate change by ensuring that the overall building is energy sustainable on the whole.

Research on climate change design regulations has highlighted the relatively low requirements in Australian regulations compared to international stipulations (Moore and Holdsworth, 2019) and the need for international standardisation in requirements if regulations are to mitigate the global issue of climate change (Horne, 2006). Rickwood et al. (2008) also note the need for further research on energy use contribution to emissions, including in densely built environments. These articles focus on building regulation requirements for mitigating climate change generally. Two studies: Heffernan et al. (2017) and a scoping report for new apartment regulations in Victoria, Australia (ARK resources, 2016), both focus instead on the application of the regulations in apartment buildings. As a result of this focus, they both reveal flaws in the regulations that lower the requirements when applied in the apartment building type. The scoping report, in particular, investigates the same NCC regulation as this research and highlights how the apartment building form impacts the efficacy of the regulation. It explains that the shared concrete walls, ceiling and floor that typically occur in an apartment but are less prevalent in a detached house, traps the heat gained by sun exposure from the full height glazing at the front. Compared to a detached house, this lowers the apartment dwelling's heating requirements in winter but leads to significantly high cooling needs in summer. The report highlights that the NCC does not capture the extremity of seasonal difference in apartments as it sums both requirements into an overall energy efficiency score. This aggregation permits apartments to perform at a worse energy efficiency rate in summer than is allowable in a detached house by the same regulation. This literature highlights the need for further understanding of regulation performance in apartment buildings precisely and how this particular building form can negatively impact the already low energy sustainability levels required by the regulation. Although housing design regulations for climate change are standard, in market-based property economies, the intervention of planning regulations to the resident's experience of the internal space as a home is generally avoided and argued against via the logic of the market (Simmons, 2008). Through this logic, building scale is introduced into the design regulation. Regulation compliance can be defined at either the whole building overall as occurs for regulations for climate change or at the individual apartment within the overall building by recognising that an apartment building is composed of multiple apartment dwellings with individual residents having different experiences. Market logic proposes that if one assumes the apartment market functions well, the explanation for poor design is that it is simply a result of the market responding to and only providing what is desired or chosen by the homebuyer. Regulations are therefore not valid at this scale. This explanation's central idea is that apartment quality is assured through the purchaser who buys the apartment. This logic, however, breaks down with the multiple complexities of the apartment housing product and its role within the housing market (Simmons, 2008). Consumers are unpracticed in evaluating design due to the infrequency of purchasing a home (Marsh and Gibb, 2011). This is further complicated by the unfamiliarity of living in apartments in Australia and the "off-the-plan" before construction method of sale of apartments (Dow, 2015).

The most significant contributing factor is the prevalence of apartments as investment properties for the rental market. Apartment purchases in Melbourne have been recently dominated by investors, with the 2016 census finding that 67% of apartments in the Greater Melbourne area were private rental accommodation and only 68,123 out of 207,408 apartments as owner-occupied (ABS, 2017b). Investment properties disconnect the apartment user—the renter—from the apartment producer (Carmona et al., 2010). The purchaser, the individual with the power to choose the apartment's qualities, is a landlord who may never directly experience the space as a home. Instead, the qualities that they perceive as necessary relate to financial gain possible in the purchase of the property, known as split incentives, rather than those that contribute to the dwelling's livability (Prasad, 2004). Liu and Judd (2018) explain that the rental sector's split incentives mean that the renting resident rather than the homeowner is responsible for paying for the energy usage. Consequently, there is little incentive for investors to prioritise energy design quality especially if they are required to pay additional upfront for these benefits. Daniel et al. (2020) also concur that this perception of housing as a commodity in Australia, particularly regarding investment rental properties, creates barriers to energy efficiency improvements due to the perceived added upfront costs and lack of return on capital investment. The process of renting further disempowers the residents to select sustainable energy design in individual apartments. Melbourne's low rental vacancy rate reduces the choice and options for renters as they cannot refuse the low design quality offered (Hulse and Yates, 2016). There is also little prior disclosure of the property's energy efficiency in the rental application process, as this disclosure is voluntary (Moore and Holdsworth, 2019). Furthermore, the rental market's competition often discourages applicants from requesting further information for the risk of tarnishing their reputation as a "desirable" tenant. Together these market failures suggest an essential role for planning regulation to assist market delivery of the value of energy sustainable design quality in apartments as argued by Daniel et al. (2020) and recognise the apartment rental market as an externality (Berry, 2014).

Despite this justification for the intervention of planning regulation in the direct resident's experience of energy vulnerability in apartments, regulation at the resident scale remains controversial among practitioners (Glossop, 2015). It is argued that direct resident experience is a matter for construction regulations only as these regulations manage the minimum requirements for the health and occupational safety in the new build, mainly focusing on the resident directly affected in the project (Booth, 1996). However, Daniel et al. (2020) highlight that Australia' construction currently lack basic health protections related to energy vulnerability for the resident, despite health being a generally accepted topic for intervention for construction regulations (Glossop, 2015). Instead, when Australian construction regulations address energy sustainability issues, mitigating climate change via the whole building scale is again the focus, and the resident scale isn't addressed. This debate on the validity of planning regulation intervention alongside the inadequacy of energy vulnerability protection in apartments in construction regulations highlights the greater understanding needed on energy sustainability in apartment buildings. Further evidence is required on the role of planning regulations to protect the resident's experience in apartments, precisely rental properties, and the impact that regulation building scale has on providing sufficient protection against energy vulnerability. This research seeks to address this gap by observing building designs that have received planning permission to reveal the design practises in the apartment market that remain permissible by the current housing design regulations. These observations analyse the building's scale, whether at the whole building or the individual resident apartment level, that the regulations are applied at and corresponding industry trends.

Energy justice provides a lens to examine the scale of application in housing design regulations. It acknowledges the resident experience scale in energy vulnerability and justifies regulation intervention from a perspective of equity (Henning, 2020). In addition to energy sustainability being a global issue of climate change, energy justice research argues that the impact of energy sustainability is disproportionately felt at the individual scale in energy vulnerability. Consequently, there is a substantial body of energy justice literature on the resident's experience as a result.

Henning (2020) summarises energy justice to include research on how certain population groups have an increased risk of energy vulnerability, why this disproportion and patterns in risk levels occur, as well as resident practises and their implications when experiencing energy poverty. Research by Islar et al. (2017) investigates access to energy as part of a minimum level of well-being that all citizens should have and how this access forms a universal right. McCauley (2018) extended this by arguing for an accessibility approach to energy justice and not a focus on affordability and price as occurs in energy poverty research. Walker and Day (2012) also argue that this asks for a situated approach for justice that recognises that, in addition to equal access, some people need increased assistance to realise their fundamental rights leading to a role for policy and regulation. As a lens on the resident scale, energy justice is therefore used by this research to contribute an understanding of equity and justice in energy sustainability.

The resident scale of energy sustainable regulation raises equity issues when renters, as externalities, dominate a specific apartment size type in the whole building. Of the 67% apartments as rental properties in Greater Melbourne, rental properties represent a high proportion of the smaller apartment bedroom types. Renters occupy 91% of studios, 80% of 1-bedroom but less than half of the 3-bedroom (48%) and above (38%) present (ABS, 2018). Without regulation protection at the resident scale, there is a significant risk of unequal distribution of poor performing apartments in these types prevalent as rentals with limited self-agency, as highlighted earlier.

Despite this energy justice contribution to understanding justice in energy sustainability via the residents' experience, Simcock and Mullen (2016) note that the energy justice literature, to date, fails to incorporate fine-grain policy analysis related to these experiences. This research body lacks a connexion between the resident scale to the equity objectives in energy vulnerability policies and planning regulations on energy sustainability. Furthermore, Sovacool and Dworkin (2015) highlight how energy justice literature lack pragmatic recommendations on how values can be practically introduced to planning and housing design regulations to include equity within the energy sustainability issue. For housing design regulations to assist energy vulnerability in apartment buildings, there is a significant need for further research into energy justice at the individual apartment scale but with a clear focus on how regulations can practically implement justice. This article seeks to address this gap of pragmatic policy recommendations in energy justice knowledge by observing of the in-practise application of two different regulation approaches.

This article has, so far, highlighted crucial gaps in the understanding of the role of scale in design regulations on energy sustainability, with the whole building scale looking to mitigate climate change and the resident scale addressing energy vulnerability. Some progress has occurred in acknowledging the significance of energy vulnerability in Australia and ensuring minimum efficiency for heating and cooling technology in dwellings (D'Ambrosio, 2020). However, the benefits available through passive energy housing design and good orientation is a significant opportunity that is yet to be realised in regulation. Instead, it is argued that regulation should not intervene with the resident's experience of energy sustainability directly within the home as the resident can select what level of quality they deem as necessary (Simmons, 2008). However, this article notes the externality of renters within the apartment market. Housing design regulation that defines energy sustainability at the whole building level fails to protect the individual apartment resident within the building. Using an energy justice lens, this article highlights a gap in understanding the implications of scale in apartment regulations and their ability to acknowledge and alleviate energy vulnerability through design. It will do this through the research question; how definitions of scale in energy sustainability regulation operate in apartment buildings and the impact this has on the efficacy of regulations alleviating energy vulnerability? This article also seeks to contribute to the gaps in energy justice literature by focusing on pragmatic recommendations for policy improvement and application in regulation and design practise.

RESEARCH DESIGN

To investigate the research gaps identified above, case study research of housing design regulation was conducted. The different requirements for satisfactory energy sustainability housing design were explored in the two regulation approaches of Australia's *National Construction Code Vol. One* (NCC) (Australian Building Codes Board, 2019) and London's *Housing Supplementary Planning Guide* (LHSPG) (Mayor of London, 2016). These requirements in the regulations were empirically investigated through a spatial observation and assessment of the design of apartments built under these regulations. This spatial observation focused on Melbourne, Australia and London, UK, as two cities experiencing acute housing affordability problems alongside current apartment construction booms.

Case Study Research

Case study research can provide an in-depth understanding of an issue by examining not only the particular situation and its context but also critically engaging with the interactions and relationships between these elements (Yin, 2014). Case study research acknowledges that complex situations, such as housing design policy, cannot always clearly define or distinguish the boundaries between the phenomena and its context. Looking at the relationships and interactions between the housing energy sustainable design regulations and its context can provide a detailed account of the situation through which to better understand the issue, in this case, of design regulation's effectiveness.

Investigating the case study of housing energy sustainability regulations across two different sites enabled this research to understand the complexity of design regulations in achieving equity and environmental sustainability (Yin, 2014). This expansion of housing design regulations studied was not intended to produce a comparison between the two approaches or specify a more successful tool. Nor was the expansion planned to validate a particular theory through repetition. Instead, analysing what is not occurring in each place enables the researcher to appreciate the particulars of housing design regulation better and appreciate the breadth and complexity possible (Oxley, 2004, p. 190). Reviewing differences and similarities furthered the understanding of the topic, more so than any critical evaluation of a city's design regulation or validation of the theory through replication.

From a systematic review, the two countries of Australia and the UK were selected for their legal framework similarity: a case law system. This framework structures each country's approach to values and regulations. Australia first undertook developing technical building codes in the early 1970s, the National Construction Code (NCC) and introduced a designated environmental sustainability section J in 2000 (ABCB, 2020). The NCC is a statutory regulation that applies to all building types, including detached and apartment buildings, consistently across Australia. Still, as mentioned earlier, the regulations are applied at the whole building level, and the code does not recognise each apartment within the whole apartment building. While New South Wales, Australia, has introduced the SEPP 65 and the Apartment Design Guide to address this regulation gap at the individual apartment scale, this regulation only applies to builds within a select region of Australia. This additional regulation level is discretionary to each Australian state government planning department and has not been introduced in all states of Australia. In Melbourne, Australia, there has recently been a rapid increase in the growth in apartment planning approvals and construction (ABS, 2019; Department of Environment Land Water Planning, 2015). This apartment development was orientated, particularly towards private rental, with Melbourne becoming both an Australian and world leader in apartment development for investment (CoreLogic, 2016; ABS, 2017b). Melbourne's burgeoning apartment design and construction period occurred with only the NCC for design guidance, with specific apartment planning design regulations that include energy requirements not introduced by the Victorian government in 2016 (2016, 2016). The UK, by comparison, has a long history of government intervention specifically into apartment design quality, including internal design. Both London and the UK regulators have experimented with different forms of sustainable design intervention via planning and technical codes (Lowe, 2011). London also has an extensive history of leasehold provision of housing and high-density development but has only recently experienced a heightened increase in private rental apartment development (Craggs, 2018). In the same period as Melbourne, London also experienced an increased period of apartment planning approvals and construction with pressure to bring high numbers of private rentals onto the market (Booth, 2017). The two examples have a substantial degree of policy transfer in both directions (Gurran and Whitehead, 2011), and similar pressures on the private rental market in apartments due to economic and housing affordability tensions but in different regulatory contexts (Austin et al., 2014). As such, this reflection offers insight into the contrasting efforts towards regulation and government intervention internationally, and subsequent prospects for design regulation to lead to improved energy sustainability and equity.

This research focused on regulations relating to orientation in the housing design regulation applicable to each study site, the Australian National Construction Code (NCC) and London's Housing Supplementary Planning Guide (LHSPG). As outlined earlier in this article, orientation is critical to the energy sustainability of the apartment due to excessive solar heat gain and light gain. When a window, as a poor insulating material relative to a solid wall, is placed on the side of a dwelling that is exposed to the greatest summer sun i.e., west, then the apartment has high reliance on artificial cooling. Alternatively, an apartment's energy sustainability is impacted by facing an orientation with inadequate solar gain, either south in the southern hemisphere or north in the northern. Passive energy design instead suggests that windows should be placed on the northern side in the southern hemisphere and south in the northern as this orientation offers satisfactory sun levels in winter, and these windows can be easily shaded to prevent overheating in summer. East facing windows are a permissible second-best option as they permit light from the cooler, morning part of the day. Dual aspect, where windows are placed on two sides of the dwelling, also helps control the temperature by allowing cross ventilation through the dwelling while offering multiple options for managing sunlight exposure.

Although regulations offer an effective tool to be able to manage energy sustainability, there is a need for greater empirical understanding of how regulation operates and in different situations. This research has only investigated the impact of orientation on apartments' energy sustainability due to the spatially dependent nature of this regulation and, therefore, applicability to the study focus. However, the findings of this research, highlight the need for further empirical research into energy sustainability in apartments and greater investigation of the various other design features, such as window height, wall material and colour choice and room air circulation, that contribute to energy sustainability and their corresponding regulation. Further understanding of other regulation modes and their ability to improve energy sustainability would also be beneficial. This greater understanding is significant for the future development of energy sustainable apartments and energy justice in cities.

Empirical Observation of Design Patterns Still Permissible by the Regulations

A pragmatic ontology privileges the truth that is physically realised. This pragmatism aligns with an empirical methodology by focusing on observation and experience to provide a greater understanding of the material reality (Biesta, 2010). This research empirically observed apartment buildings with planning approval whose designs were therefore permissible to be built. These designs highlight the design values deemed acceptable by that specific planning regulation. Repeating this process across multiple regulations provides an insight into the range of definition and approach of energy sustainability in housing design regulations. Healey (1993) proposed that content analysis of different planning documents using a communicative planning method can empirically reveal the definition of design quality valued by the stakeholders involved in the document's production. By comparing a topic between one plan to another, Healey proposed that it is possible to understand the range across which a planning document can define design quality. This comparison includes both those elements that were included and those that were not within the plan.

Healey's (1993) mode of content analysis limits the observation to only the language included within a design plan. Scholars have criticised the language used in design regulations as vague and subject to interpretation (Ben-Joseph, 2005; Carmona et al., 2010). This ambiguity of meaning could affect the functionality and agency of the regulation to underpin improved design quality. For example, different regulations may appear to include the same topic of quality at the language level, and yet the method used by each regulation to measure compliance may have a different, observable impact upon the level of quality the regulation detects and therefore deems just. The many criticisms of the language of regulation indicate that an analysis focused on this level alone would not capture the tool's full extent, their functions for design quality and the values agreed upon in the consultation process. Therefore, in addition to analysing how the design regulations define design quality, this research extends Healey's (1993) content analysis by observing the regulation's actual spatial design impact within the apartment plans to understand better the scope of design quality each regulation permitted as acceptable.

In addition to noting the textual description of orientation requirements in the NCC and the LHSPG regulations, the researcher observed the measurement method outlined by each regulation and the design layout of orientation that remain permissible. The researcher notes each of the apartment orientations in the floor plate faces, and the corresponding size type of each apartment. They also record the proportions of orientations available across a floor plate, whether one orientation is not present or complemented by a dual aspect design. If the orientation is split over two orientations, i.e., northeast, the greatest orientation is observed and the researcher notes this detail on the results. Trends in the general design layout, location and size type of individual apartments were also observed as a supplementary context for each of the buildings studied. This observation also included applying each regulation to the buildings that originated in the opposite city to broaden the understanding of how each regulation operated.

The buildings to be studied were selected from an extensive list of buildings constructed between 2010 and 2015 compiled from local authority registrars of planning permission applications. This period saw an increase in apartment development in both Melbourne and London. The list was refined from over 100 entries per location down to 10–15 buildings. This occurred via the definition of an apartment building as a building height above 4 levels and exclusively residential in use above the ground floor. Affordable apartment buildings were also selected, with affordable defined as rent equal to or $<$ 30% of a household's disposable income (Yates, 2007). This was checked via a randomised sample of 10 apartment listings per building on an online real estate listing website at the time of selection. No other design elements were highlighted or excluded through this data refinement process. The similarities in design that occurred between the set enabled the research to observe industry practises around design quality in situations with tighter margins that force efficient design in each location. Building plan observations were conducted until data saturation was achieved, and no further new information was collected from additional buildings. This process resulted in a total of 18 buildings in Melbourne and 12 buildings in London studied.

The researcher conducted a desktop analysis using plans that have received planning approval. These plans enabled the researcher to mirror how the regulations would be used for the assessment of the planning permit and the level of information that was generally produced at this stage of the building process. Building plans also allowed the researcher to practically analyse many apartment buildings as onsite measurement would be time-consuming to organise and conduct. In Melbourne, the plans were provided either by the planning department for each local authority or the building's architect directly due to research permission requirements by one local authority. In London, the building plans were downloaded directly from the local authority's website. The researcher also supplemented the desktop analysis of the building plans with site visits to each apartment building. While it was not possible to arrange access internally to the apartments studied, the general character, proportions of the building and location from external observations added further richness to the study (Wheeler, 2004).

SPATIAL OBSERVATIONS OF APARTMENT DESIGNS BUILT UNDER THE DIFFERENT ENERGY SUSTAINABILITY REGULATIONS

The spatial observation of apartment designs, size-types and orientation across multiple apartment buildings revealed permissible design patterns in each regulation. All of the Melbourne buildings studied utilised a double-loaded corridor layout without preselection, where apartments are accessed from an internal central corridor and fan outwards in all directions. This industry practise of design layout maximises the yield of apartments possible for the site but results in floor plates of the buildings composed of apartments facing all orientations. These orientations remained permitted by the regulation. Predominantly these apartments were single-aspect, in that they only had windows on one orientation which is problematic for energy sustainability if the apartment faces a poor ordination with no alternative available. The NCC also permitted single-aspect apartments to face any orientation. While the building as a whole may be compliant with the energy sustainability regulations, the individual apartments with their different orientations in the floorplate have differing levels of design quality.

Within these floor plates, there were distinctive patterns in the orientation design of the different apartment size-types, either 1-bedroom or 2-bedroom apartments (see **Table 1**). Firstly, the researcher observed that there was not an exclusive allocation of a specific orientation to either bedroom size-type. At just over a third, a comparatively small proportion of the Melbourne buildings had all of the 1-bedroom apartments on a floor plate exclusively of poor quality of orientation and facing exclusively south with insufficient light levels. A similar minority of the buildings had all of the 2-bedroom apartments on the floor plate only with high-quality orientation in that they either face north or were dual access. No buildings had the opposite, with 1-bedroom apartments with only high-quality orientation and 2-bedrooms with only poor-quality orientation.

Instead, the results showed that different quality levels in orientation were available in both apartment size types across most of the buildings. This result indicates that a choice in quality level existed for all apartment sizes in Melbourne. The existence of some exclusivity, however, importantly highlights that the Australian regulations permit this exclusivity and offer no protection to the apartment resident.

While the researcher did not observe a significant exclusivity in size to quality level, they observed that the 2-bedroom sized apartments predominantly occupied the better performing orientations in the Melbourne buildings, and the 1-bedroom apartments mainly occupied the lower quality orientation. Predominately, in this instance, was defined as 65% or more of each apartment size type present on the floor plate. Eight out of the eighteen buildings had 2-bedroom apartments located mainly with the best orientation, and nine buildings had 2-bedroom apartments predominantly in the medium orientations in the floor plate. Only one building placed a 2-bedroom apartment in the poor-quality orientation of south. The majority of 1

TABLE 1 | Percentage of Melbourne's apartment size types that fill each orientation.

	Orientation		
	Optimal (north in australia or dual aspect)	**Moderate (east)**	**Poor (west or south in australia)**
B.1 total apt	**30%**	**20%**	**50%**
Studio	0	20%	0
1 Bedroom	0	20%	100%
2 Bedroom	100%	60%	0
B.2 total apt	**60%**	**0**	**40%**
1 Bedroom	60%	0	65%
2 Bedroom	40%	0	35%
B.3 total apt	**30%**	**40%**	**30%**
Studio	0	10%	0
1 Bedroom	0	10%	100%
2 Bedroom	100%	80%	0
B.4 total apt	**0**	**60%**	**40%**
1 Bedroom	0	45%	100%
2 Bedroom	0	55%	0
B.5 total apt*	**50%**	**0**	**50%**
Studio	0	0	20%
1 Bedroom	0	0	80%
2 Bedroom	100%	0	0
B.6 total apt	**55%**	**20%**	**25%**
Studio	40%	0	0
1 Bedroom	60%	60%	25%
2 Bedroom	0	40%	75%
B.7 total apt	**0**	**60%**	**40%**
1 Bedroom	0	0	100%
2 Bedroom	0	100%	0
B.8 total apt	**35%**	**15%**	**50%**
1 Bedroom	15%	0	50%
2 Bedroom	85%	100%	50%
B.9 total apt	**60%**	**15%**	**35%**
1 Bedroom	40%	100%	60%
2 Bedroom	60%	0	40%
B.10 total apt	**20%**	**30%**	**50%**
1 Bedroom	0	100%	65%
2 Bedroom	100%	0	35%
B.11 total apt	**40%**	**40%**	**20%**
Studio	25%	85%	100%
1 Bedroom	0	15%	0
2 Bedroom	75%	0	0
B.12 total apt	**50%**	**10%**	**40%**
Studio	0	0	0
1 Bedroom	0	20%	100%
2 Bedroom	100%	80%	0
B.13 total apt	**20%**	**45%**	**35%**
1 Bedroom	0	35%	100%
2 Bedroom	100%	65%	0
B.14 total apt	**55%**	**15%**	**30%**
Studio	0	0	10%
1 Bedroom	0	0	70%
2 Bedroom	100%	100%	30%
B.15 total apt	**60%**	**0**	**40%**
Studio	0	0	0
1 Bedroom	0	0	100%
2 Bedroom	100%	0	0
B.16 total apt	**25%**	**35%**	**40%**
Studio	15%	0	0
1 Bedroom	0	0	100%
2 Bedroom	85%	100%	0
B.17 total apt	**20%**	**50%**	**30%**
1 Bedroom	30%	50%	100%
2 Bedroom	70%	50%	0
B.18 total apt*	**40%**	**0**	**60%**
Studio	0	0	0
1 Bedroom	0	0	90%
2 Bedroom	100%	0	10%

**Denotes the apartments whose orientation was split over two sides, B.5 slightly orientated towards northeast and B.18 slightly towards northwest.*

bedroom and studio apartments, conversely, fulfilled the more inferior quality locations available to complete the floor plate, with a higher proportion of thirteen out of the eighteen buildings locating 1-bedroom apartments in the poor orientation quality location and five having a mixture between the medium to poor quality locations. No studio or 1-bedroom sized apartments were predominately located in their building floor plate's best orientation location.

Alternatively, all except one building in the London set complied with the LHSPG requirement to avoid the poor orientation levels completely within the building. While dual loaded corridors were still common, 11 of the 12 buildings, if one of the apartment's studied from London faced a poor orientation, the apartment was supplemented by a secondary aspect (see **Table 2**). This dual aspect apartment offers more sunlight control and cross-ventilation for the resident. There was no pattern in apartment size type for those that were dual aspect. This regulation mode did not result in all buildings using the best orientation only or being an exemplar of energy sustainability. However, it did establish

TABLE 2 | Percentage of London's apartments that fill each orientation.

	Orientation					Orientation			
	Optimal (south in london)	Moderate (east)	Poor (west or north in london)	Dual		Optimal (south in london)	Moderate (east)	Poor (west or north in london)	Dual
LB.1 total apt	20%	50%	0	40%	**LB.7 total apt**	10%	30%	0	60%
LB.2 total apt	30%	20%	0	40%	**LB.8 total apt**	40%	30%	0	30%
LB.3 total apt	30%	30%	0	40%	**LB.9 total apt**	0	0%	0	100%
LB.4 total apt	0	20%	0	80%	**LB.10 total apt**	0	10%	0	90%
LB.5 total apt	0	0	0	100%	**LB.11 total apt**	50%	0	30%	30%
LB.6 total apt	20%	30%	0	50%	**LB.12 total apt**	20%	50%	0	30%

that the minimum acceptable level of quality is avoiding the worst orientation.

None of the Melbourne apartment buildings complied with the LHSPG requirement, with all having at least one individual apartment with singular aspect of a poor orientation of south or west. Two buildings, however, avoid west-facing apartments. One building achieves this by including a short section of single loaded corridor that enables those facing a poor orientation to be dual aspect and the other by orientating the building away from a shared wall with the neighbouring building.

HOW REGULATION SCALE AFFECTS THE ENERGY JUSTICE ACHIEVED IN APARTMENT BUILDINGS

Energy justice's focus on equity at the scale of the resident offers a lens to evaluate the significance of scale within housing design regulations in apartment buildings (Henning, 2020). The NCC regulates the energy performance of new buildings at a whole building scale to provide protection for the externality of climate change, as well as the energy vulnerability of residents with passive design minimising artificial energy use. Defining compliance at the whole building scale sufficiently protects residents in detached housing as the resident occupies the building regulated entirely.

However, this research found that when this whole building scale was applied to an apartment building, the regulation offered little energy vulnerability protection to the residents. The NCC and regulation in general that uses the whole building scale fails to acknowledge that apartment buildings comprise of individual dwellings with separate residents within the entire building envelope. Unlike detached housing, each apartment's energy sustainability can vary relative to the building's sustainability taken as a whole. The orientation and, therefore, energy sustainability of the separate apartments can vary within the floor plate greatly. As long as the whole building complied, the research found that the NCC permitted apartments to face all orientations. Within the studied Australian apartment buildings, a majority of individual apartments were found to face south or west with substandard sun exposure or north, which in the Australian context is a more temperate orientation. The residents whose apartments face south or west were unjustly burdened by regular reliance on artificial heating, cooling and lighting to manage this poor-quality orientation comfortably. Therefore, measurement at the whole building scale permits inequity as floor plates in the Australian apartment buildings studied were composed of a series of higher than average performing apartments whose gains were offset by other poor performing apartments.

Housing design regulation that defined energy sustainability at the individual apartment scale, by comparison, provided greater protection from the worst orientation and, therefore, the individual resident. The LHSPG regulated against single aspect apartments being located in the North orientation that, in the Northern Hemisphere, received insufficient radiant heat and warmth in winter and a west orientation to avoid overheating in the summer afternoon. As a consequence of the regulations being defined at this resident scale, the worst orientations possible within the floor plate were not filled by apartments, but either subtracted from the floor plate or utilised for services. Apartments were only located on the better orientations. The LHSPG, therefore, establishes a minimum base level for orientation that is accepted through the regulation scale and improves the passive design of apartment buildings for every resident. This scale also ensures that one apartment is not able to compensate for the energy sustainability of another, and the whole building is the sum of the worst-performing apartment or better.

Therefore, this research builds upon the call by Daniel et al. (2020) for greater regulation into energy sustainable housing design by highlighting the significance of scale in housing design regulation for apartment building types. By focusing on the resident, energy justice reveals the inequities occurring with regulation requirements defined at the whole building scale in apartments and the need to expand and apply regulation compliance to the residents' apartment level if the regulation is to help alleviate energy vulnerability. This research has shown that justice is misconstrued when an apartment building's energy sustainability is observed at the inappropriate scale of the whole building. This practise masks the poor performance of some apartments and the inequity in the whole building outcome. The ability of the resident scale within apartment design regulation to improve housing design quality is also recognised in the new planning housing design regulations for Victoria, Australia (within which Melbourne is located); the Better Apartment Design Standards (2016, 2016). The energy sustainability requirement within this regulation stipulates a minimum performance level for each apartment in the building to mitigate the national NCC regulation's shortcoming being defined at the whole building scale. This inclusion in an apartment specific regulation further supports the findings of this research regarding the significance of regulation to recognise the resident scale present in apartments buildings, but not as necessary for detached housing.

Research has shown that renters and those renting apartments are the most at risk demographic within Australia to experience energy vulnerability (Australian Council of Social Services, 2017; Poruschi and Ambrey, 2018). This research also contributes new evidence of the externality of renters in apartment buildings and the consequent need for energy sustainability regulation in apartment buildings. In Melbourne, studio and one-bedroom size type apartments are almost exclusively rental properties making up 91 and 80%, respectively, of the existing stock. More of the large apartment size types (i.e., 2-bedroom and above) are owner-occupied (ABS, 2018). The NCC regulation did not place restrictions on which size type of apartment could be located in the good or poor orientation locations, nor the proportions of these types in these areas. Although it was permissible within the NCC regulation to exclusively situate one particular type in the poor orientations, market logic did offer a degree of guidance in this case as many buildings studied elected not to undertake this exclusively. Instead, the majority (over 80%) of the poor orientation was filled with the 1-bedroom apartment size types while the larger, 2-bedroom types occupied a majority of the best orientation. However, multiple Melbourne buildings did ignore these market patterns and exclusively filled the poor orientation locations with studio and 1-bedroom size-type apartments. As a result, this research has shown that rental properties occupy a majority of the poor orientation locations and apartments with poor energy sustainability and that renters are disproportionately affected by the insufficient regulation protection offered when energy sustainability compliance is measured at the whole building level.

The pervasiveness of this market pattern, that rental properties occupy a majority of poor orientation locations, highlights how impeded residents of rental properties are in demanding better energy performing apartments through the market. As highlighted by Liu and Judd (2018), split incentives remove any incentive or consequence for investors or landlords to select more than the worst-performing orientation for their tenants as it is the tenants, not the investor, who manages the unacceptably high running costs of the investors' selection. Conversely, the financial windfalls of a better performing apartment in this rental context bring no benefit to the investor, who have little trouble attracting tenants with the low rental vacancy rates in Australia. Owner occupiers' value and therefore create market demand for better-orientated apartments that developers respond to. By comparison, the investor has little incentive or consequence to demand better quality for their tenant than these poor energy-performing apartments, and renters lack agency to demand more from their landlords. Due to these structural barriers within the rental sector, this research has demonstrated the energy injustice occurring in rentals in Australian apartment buildings and how renters are disproportionately and unjustly burdened with poor orientation and regular reliance on artificial heating, cooling and lighting to live comfortably. This evidence of the externality of renters within the apartment housing market provides further justification for energy sustainable regulation at the resident scale and the need to establish a minimum acceptable level of energy sustainable quality across all apartments, regardless of size or, by association, tenure type. Building upon recent evidence of the need for greater energy sustainability protection via regulation in rental properties (Daniel et al., 2021), this research demonstrates the significance of the scale of the regulation requirements within apartment buildings. Specifically, it has argued the importance of individual resident scale in apartment design regulation for rental properties whose residents have little agency in a low vacancy rental market.

CONCLUSION

To conclude, this research demonstrates the significance of scale in housing design regulation on energy sustainability, focusing on the application in apartment buildings. It outlines how building scale can impact the degree of protection the regulation offers residents from energy vulnerability and the energy justice achieved by the planning control overall. In addition to protecting climate change at the scale of the whole building, this research found significant need for regulation to recognise and provide protection at the resident's experience scale within apartment buildings. This scale defines compliance at the individual apartment scale, recognising every apartment within a building to achieve a minimum level of energy sustainability throughout. When regulation compliance is defined at the whole building scale, this research highlighted how one apartment's above-average performance can compensate or mask the more unsatisfactory performance of another but still comply overall. This regulation compliance scale produces inequity across the building in general, but specifically, this article also showed that these poor orientations were predominantly filled by 1-bedroom apartments targeted at the rental market. This finding further justifies the need for resident scale energy sustainability regulation, especially with the rental market growth in Australia's apartments and the limited agency renters have to demand quality in a competitive market. When focused on the resident scale, housing design regulation offers a vital planning tool to extend energy sustainability beyond climate mitigation and ensure a more just energy sustainability in apartments.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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Humanising the Energy Transition: Towards a National Policy on Energy Poverty in the Netherlands

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Energy poverty is emerging as a national agenda in the Netherlands. Local authority leadership and action on this agenda, and European Union reporting requirements around the energy transition have aligned to create an opportunity to establish a national agenda on this issue. Early action on energy poverty by local authorities stemmed from their recognition of the value of addressing environmental, health, social welfare and poverty goals through measures to address the problem. In contrast, the experiences of vulnerable energy consumers have limited recognition in national policy. Meanwhile EU requirements for climate reporting include a specification for measuring and monitoring energy poverty. This growing momentum has resulted in an emerging interest in energy poverty as a means to achieve a just transition at a national level, as reflected in the Dutch National Climate and Energy Plan. In this paper, we profile the case of the Netherlands, and outline the opportunity we see for the development of an energy poverty agenda in national energy transition policy, as part of a multi-level energy governance effort. We report on a national stakeholder workshop that we led, linking the lived experience of energy poverty in the Netherlands with policy solutions. Following the clear call for a national policy in this workshop, we also outline a strategy for engagement with energy poverty in the Netherlands, published recently in a white paper on this topic.

Keywords: energy poverty, energy justice, energy transition, energy governance, the Netherlands

INTRODUCTION

In this paper we profile the case of the Netherlands, and outline the opportunity we see for the inclusion of the energy poverty agenda in the national energy transition policy as part of a multi-level governance process that includes municipalities and the EU level in driving forward new national policy, indicators and measures on energy poverty. Energy poverty is only an emerging agenda in the Netherlands, principally driven by local authorities' recognition of the value of addressing environmental, health, social welfare and poverty goals through measures to address the problem, and European Union (EU) requirements for reporting on energy poverty as part of the Energy Transition. There is, as yet, no national policy, and the national government has been reluctant to articulate energy poverty as distinct from poverty in general. This creates challenges at a local level, where local authority and regional action is inconsistent, and suffers from the lack of a national framework in accessing funds and developing activities. Even if reluctantly, the recent

Dutch National Climate and Energy Plan (NECP) approved in November 2019 touches on energy poverty, particularly in relation to its contribution to a just energy transition. This has created an opportunity for a national policy on energy poverty, which links strongly with policy on energy transition.

This paper was inspired by a process of engagement that we led in 2019–2020, including a stakeholder workshop and the authorship of a white policy paper on this topic. Our key research question is: what does the national government of the Netherlands need to do to address energy poverty in its energy transition policy? We ask this question in the context of the multi-level governance space for energy poverty policy in the Netherlands, which is shaped by municipal, regional and EU actors. To answer it, we bring to bear existing evidence on the national situation, theoretical insights from the governance literature, and inputs from an interdisciplinary stakeholder workshop on energy poverty in the Netherlands in 2019 (ENGAGER, 2019). We use these insights to identify a specific pathway to integrate the needs and concerns of the energy poor into a just energy transition in the Netherlands.

We begin by framing this work theoretically in the context of ideas and insights from (energy) governance literature, and outlining the method we used in researching this paper. We then document the current situation with regards to energy poverty in the Netherlands, including the state of the agenda, the state of the problem and the nature of energy governance in the Netherlands. We continue to show how the Climate Agreement (2019) necessitates a more thorough engagement with the energy poverty agenda at national level, presenting our proposal for integrating energy poverty into just transitions thinking in the Netherlands.

We conclude that engaging with the energy poverty agenda at national level is an opportunity to transform the Netherlands' planned low-carbon energy transition into a just transition. The multilevel governance space in which Dutch debates on energy poverty are currently taking shape, creates a promising context to address energy poverty through just energy transition policy. However, the current lack of a dedicated national framework hampers the effectiveness of local level initiatives, as well as risking the energy poor being left further behind in the energy transition. National energy transition policy must recognise energy poor households as needing additional support, engage them in policy design and monitoring, and ensure better outcomes for the energy poor in the short and long term. Here we demonstrate an alternative pathway to address energy poverty at the national policy level which could provide an inspirational example for other national governments that are trying to tackle energy poverty while simultaneously stimulating a low-carbon and just energy transition.

GOVERNING THE JUST ENERGY TRANSITION; THE SPACE FOR ENERGY POVERTY

The Dutch governance landscape, including as it applies to energy poverty policy and energy transition, can be characterised as a "multi-levelled governance" space whereby, first of all, each citizen is nested at the bottom of a "Russian Doll like" set of territorially-layered jurisdictions, of which each has its own set of governance functions and competences, and are in constant processes of negotiation, institutional creation and decisional reallocation (Hooghe and Marks, 2003; Jeffery and Peterson, 2020). In the Netherlands, citizens are governed by municipal governments, Provincial governments, national government, and the European Union, as the main supranational governance structure. This paper reflects on the interaction between these more "vertically-oriented" multi-levelled governance spaces for energy poverty and energy transition policy-making, also sometimes known as "multi-levelled government." Yet, we acknowledge in several places that "multi-level government" is equally increasingly understood as also involving various "intensified (horizontal) interactions between government and non-governmental actors" at each level, in addition to more specialised or sector-based governance (Bache et al., 2016).

Secondly, we think it is helpful to also make the connexion with energy justice debates, as an emerging framework in energy social science for the analysis of energy transitions and energy policy. The aim of energy justice is to contribute to a just energy transition through a just distribution of rights (distributive justice), recognition of needs (recognitional justice), and just decision-making within the energy system (procedural justice) (Sovacool et al., 2016). In this paper we consider how these dimensions contribute to the design of just energy transition policies, in the multi-levelled governance space of the Netherlands, though with a particular focus on the interaction between national, municipal and EU levels.

The Dutch energy poor are presently mostly "recognized" through the work of municipalities, whilst the EU is simultaneously legally obliging all national governments to render energy poor people visible throughout their territory by requiring all Member States to set criteria for defining energy poverty in the national context, taking into account 'necessary energy services for basic standards of living [see Governance Regulation on the Energy Union and Climate Action (EU) 2018/1999 and Electricity Directive (EU), 2019/944]. From a "(re)distributional" perspective, lacking attention to energy poverty nationally so far, seems worrying, since nearly all major decision-making and resource allocation for decarbonization and (just) transition currently stems from national law and policy mostly. The lack of a national programme and associated resources for proactively addressing (vulnerability to) energy poverty as the transition moves forward, might therefore seriously risk affecting the Dutch energy poor in the absence of limited alternative resources that could be harnessed either through the EU or municipalities (Straver et al., 2020).

METHODS AND DATA

The paper offers a commentary on the process by which policy and action on energy poverty in the Netherlands has developed in recent years. As such, it draws on a range of sources, including existing studies of energy poverty in the Netherlands, both qualitative and quantitative, and policy documents and communications on this topic in recent years, from the Dutch government and other actors in the Dutch energy transition. These studies and policy documents are referenced in parts 4–6 of this paper as appropriate, and are selected inclusively: we include all the studies that have been done on this topic, and all relevant policy texts. Further, the authorship team includes researchers that have been working on energy poverty for some years, and who are among the first to conduct research on this topic in the Netherlands. Some of the inputs below are therefore informed by an extensive engagement with this topic over time, and an associated deep familiarity with the subject matter. The authors represent a multidisciplinary background contributing legal expertise, gender analysis and stakeholder participation experiences.

Alongside these inputs, the authorship team ran a process of engagement with interdisciplinary stakeholders and academics, from the Netherlands and beyond in 2019–2020. The process and its outputs form part of the insights of this paper, and as such these deserve a more detailed description. The engagement process began with a multi-stakeholder, interdisciplinary and international workshop held in Amsterdam on the 30th and 31st of October 2019, funded and organised by the EU's COST Action ENGAGER—European Energy Poverty: Agenda Co-Creation and Knowledge Innovation (ENGAGER, 2019). The workshop brought together researchers, politicians, policymakers, energy companies and NGOs to discuss the state of energy poverty in the Netherlands, using lived experience examples to trigger thinking about potential for policy and practical solutions. During the workshop, clear challenges for addressing energy poverty in the Netherlands were identified, as well as possible solutions. The most apparent challenge was the lack of recognition of energy poverty at a national level, and the associated lack of national policy on this topic. This stimulated a small group of researchers and academics who were at the workshop to continue this engagement, working together to draught a White Paper on Energy Poverty (Straver et al., 2020).

To create the White Paper, we drew on a number of sources: the workshop experience, existing evidence on the national situation from sources described above, and empirical and theoretical insights from the international academic literature on this topic combined with lessons learned in other European nations. We are aware that each nation has its own political and socio-cultural context, which makes the adaptation of approaches to tackle energy poverty highly contextual. However, sharing our experience of intervening in the Netherlands to call for a national policy, and in particular in linking energy poverty and energy transition thinking, may prove useful for other nations that are designing energy poverty or energy transition policies.

THE NETHERLANDS, ENERGY POVERTY AND THE ENERGY TRANSITION

This section paints a picture of the state of play with regards to energy poverty in the Netherlands, outlining the energy poverty agenda and the experience of energy poverty in this country followed by a description of the governance context for energy transition and energy poverty.

The Energy Transition Context of the Netherlands

A defining feature of the Dutch energy transition is the phasing out of natural gas and its progressive substitution by less carbon-intensive heating alternatives, such as district heating and electricity. This "heating transition" is uniquely informed not only by national decarbonization targets, but also by major societal unrest arising in the recent years in response to severe damage caused by earth quakes and tremors to many homes across the Northern Province of Groningen due to prolonged natural gas extraction in the region. The Groningen gas field is Europe's largest natural gas field, and the main source for heating, hot water, and cooking for most Dutch households (72% in 2016, CBS, 2018). In part due to the blocking of new extraction permits to the concession holders for the field, Exxon Mobile and Shell, as a result of successful lawsuits against the Government by citizens, interest groups, and local governments since 2014, the Government conceded in 2018 to phase out all-natural gas extraction from the Groningen field, first by 2030 and later by 2022 (Rijksoverheid, 2020). From a perspective of recognition justice, as well as the distribution of national rights and burdens, it is of particular interest how civil society and lower-level government successfully managed to invoke higher-level human rights norms under the European Convention on Human Rights to change national natural resources policy.

It is uncertain how this rapid phasing out of natural gas consumption from the Groningen gas field might affect household energy prices over the coming years—the Netherlands became a net importer of natural gas for the first time in 2018, largely from Norway and Russia (PBL, 2018). Yet, the replacement of natural gas by electricity especially is presently running in parallel to significant changes in the relative prices of these two energy carriers in the household sector. Eurostat data indicate that electricity prices paid by the average Dutch household dropped from 17.67 c€/kWh in 2010 to 14.27 c€/kWh in 2020 thus making the Netherlands one of the only three EU countries (along with Hungary and Malta) in which electricity prices went down in 2019–2020. This −19% decrease in the price of electricity over that 10 year period, comparing to an average increase of +23% for the whole EU, resulted in the Netherlands reporting the lowest price of electricity per kWh[1] in the EU as of the first semester of 2020 (Eurostat, 2021a). On the contrary, the price of natural gas went up by 46% between 2010 and 2020 (as compared to an 17% increase as an average for the whole EU in the same period) and, as a result, in the year 2020 Dutch domestic consumers paid the second most expensive natural gas[2] in the EU after Portugal (Eurostat, 2021b).

In the coming years, it is expected that the government will continue intervening in end-user prices of natural gas and

[1] Relative to general price and income levels of each EU Member State as measured by Eurostat's Purchasing Power Standard (PSS) units.

[2] As before, prices measured in Purchasing Power Standard (PSS) that account for differences in price and income levels of each country.

electricity consumption via taxation to further reduce the weight of natural gas heating in the building sector (OIES, 2019). The government has already announced that taxes on natural gas consumption for households will be progressively raised over the coming years, while those on electricity will be lowered. Lastly, in the longer term, there are also major concerns and uncertainties about the household energy mix and the costs of the heating transition (Schellekens et al., 2019). The current household energy mix is natural gas (86%) and electricity (14%) for heating, cooking and hot water (PBL, 2018). The energy efficiency of residential buildings is low, with 61% having an energy efficiency label of C to G (ibid). Tenure data demonstrate that 6 out of 10 Dutch households are home-owners while 4 out of 10 are tenants (PBL, 2018).

The National Energy Poverty Agenda in the Netherlands

There is a limited understanding and recognition of energy poverty at the national government level, resulting in hardly a national policy interest in alleviating energy poverty. In contrast, Dutch national interest in a just transition is growing. A recent statement of the Ministry of Internal Affairs says that the energy transition needs to be "affordable and just" (Ministerie van Binnenlandse Zaken en Koninkrijksrelaties, 2020). In addition, the political opposition have filed several (narrowly rejected) motions in recent years, stating that the government should implement energy poverty alleviation measures. Despite these initiatives, Dutch national energy planning to date has done little to address the most vulnerable energy consumers. The Netherlands lacks a national definition or policies on energy poverty, rendering the interests of the energy poor invisible (Straver et al., 2020). The political position held by the central (liberal) government, is that alleviating energy poverty is a matter of mitigating poverty, and should be addressed through social welfare policy, not through energy policy. The lack of national policy on energy poverty is a barrier within the decentralised system, because without a national policy there are no centrally defined goals. Further, while decentralisation does enable tailor-made policy interventions appropriate to specific contexts, it can also lead to inconsistency, under-provision of services or lack of control (de Jong and Vonk, 2019).

The government's National Climate and Energy Plan (NECP, 2019) follows this position by only reluctantly addressing the topic of energy poverty. After a reprimand of the Commission on this minimal reporting in the draught NECP, the final NECP acknowledges the various studies on Dutch energy poverty that have been published to date (discussed below, with emphasis on the PBL, 2018 study). It lists a set of general anti-poverty measures implemented by municipalities, but presents energy poverty as matter of general poverty alleviation via traditional social welfare action. In response, the European Commission finally concluded that the Netherlands has not yet addressed new EU legal requirements to properly set criteria for the definition and measurement of energy poverty (European Commission, 2019). In particular, the Commission's evaluation of the final NECP observed that the government made no mention of specific additional measures, but instead only refers to existing anti-poverty policies that have been predominantly decentralised to municipalities.

Measuring Energy Poverty in the Netherlands

Research on energy poverty in the Netherlands is in its infancy. Initial quantitative work has mainly focused on measuring energy poverty in terms of the affordability of the energy bill (PBL, 2018; Schellekens et al., 2019). There has also been some qualitative lived experience research which has helped to add detail to our understanding of the daily lives of those facing a shortage of energy services (Woonbond, 2013, 2019; Straver et al., 2017), as well as a gender analysis of energy poverty in the Netherlands, which revealed a strong difference in energy poverty levels between women and men (Clancy et al., 2017). Further research combining mixed methods and comparative analysis would contribute to a deeper understanding of the experiences of energy poverty and provide data for the emerging policy agenda (ENGAGER, 2020b).

A challenge for furthering the Dutch debate on energy poverty, is that when energy poverty is measured through the headline indicators of the European Energy Poverty Observatory (EPOV), the Netherlands shows a low incidence compared to most other EU countries (EPOV, 2021). According to one of the most elaborate studies of energy poverty in the Netherlands by the *Netherlands Environmental Assessment Agency* PBL (PBL, 2018), a semi-public, but independent national institute for strategic policy analysis, and as subsequently confirmed in the Dutch NECP (2019), only 2.6% of Dutch respondents faced difficulties with affording adequate warmth in their home in 2016, while approximately 2% were in arrears on energy bills. These numbers are in line with the corresponding EPOV indicators that consistently show an incidence below 3% for SILC indicators (inability to keep the home adequately warm and arrears on utility bills) since the mid-2000s (EPOV, 2021).

Yet, disaggregation of data seems key to properly recognising who is energy poor in the Netherlands. Just slightly scratching the surface of these national averages, reveals that difficulties with heating the home to be a problem for up to 16% for those living in social housing (free or regulated rent), whilst up to 7% of households in the lowest income deciles experienced arrears (EPOV, 2021). Similarly, the average share of the population meeting EPOV's high energy expenditure indicator seems low, compared to other EU countries—at about 11% of the population. Yet, this figure rises to 20–58% for the two lowest income deciles (EPOV, 2021).

Qualitative research reflected in the reports on expenditure on housing for households in the Netherlands (Woonbond, 2013, 2019) shows that Dutch households facing energy poverty faced similar challenges to those in other nations. Households confronted by stressful living conditions (recent divorce, illness, care duties due to physical or mental illness of family members), were often unaware of or unable to care about energy use and energy bills. Owning used and energy inefficient appliances such as fridges or freezers, also created an energy poverty problem for households, but families lacked the means to invest in newer and more energy efficient appliances. People resort to coping strategies like heating restricted areas of the house—a phenomenon called spatial shrink. Some turn on their heating only for a limited number of hours each day, for example when (grand-)children are around. People also indicate waking or going to sleep several hours later or earlier than normally preferred, or limiting visits from family members. They are sometimes simply living in too cold, draughty, mouldy and unhealthy homes. This lived experience research by Woonbond, the association for housing, additionally showed the necessity to offer repeated energy saving advice, as households save more when they receive advice several times. Finding out about the intrinsic motivation of a household to save energy is an important aspect of motivating households to be aware of energy consumption in the long-term.

In addition, the PBL offered quantitative analysis of the affordability of energy bills in the Netherlands, using household energy expenditure, disposable income and other necessary expenditures, and measure affordability with two complementary indicators: the energy ratio and the payment risk. The "energy ratio"—also known as "energy burden" (Bouzarovski and Tirado Herrero, 2016)—is the share of disposable income that a household spends on energy. Following early fuel poverty measuring approaches developed in the UK, Dutch studies on the affordability of energy—have used an energy ratio of 10% (of a household's income spent on domestic energy) as a threshold to define energy poverty. In addition, the PBL (2018) considers that a household suffers a "payment risk" if after paying housing and energy costs their budget is insufficient to cover minimum subsistence expenditures. Using these two indicators, the number and percentage of households in energy poverty was estimated based on nationally available data on living costs (see **Table 1**). These figures suggest that up to 13.6% of Dutch households were experiencing financial difficulties related to energy poverty. A majority of those households were renting their dwelling and their income was below the median.

Shortcomings in the above calculations have been acknowledged. Many Dutch households struggling to afford the energy services are still unaccounted for in data, and thus invisible to policymakers and researchers. PBL (2018) indicates that their study could not account for a group of roughly 900,000 households (13% of all Dutch households) which have circumstances that make it difficult to assess energy expenditure (e.g., students, entrepreneurs with a year of poor performance, households that share a residence, households with a business at home, or people living in unusual dwellings, such as houseboats or multi-occupancy dwellings). Evidence from other countries suggests that such groups also face difficulties with energy expenditure (Cauvain and Bouzarovski, 2016).

TABLE 1 | Households with high energy ratios and payment risk in The Netherlands (2014).

	Number of households	Percentage of households
High energy ratio and payment risk	269,000	4.0%
High energy ratio only	385,000	5.7%
Payment risks only	259,000	3.8%
Any of the above	*913,000*	*13.6%*
None of the above	5,800,000	86.5%

Based on: PBL (2018).

Furthermore, some households under-consume energy to save on energy expenditure hence their energy expenditure-income ratio might be under the 10% threshold because of their very low energy consumption. These households with under-consumption are not accounted for in Dutch quantitative studies, although a substantial portion of these households may be covered by PBL's category of households with a payment risk (PBL; Straver et al., 2017; Schellekens et al., 2019). According to the EPOV (2021), an average of 4.4% of the Dutch population had abnormally low energy expenditures (indicator M/2: households whose absolute energy expenditure is below half the national median), amongst which between 5.5 and 10% of the lowest income deciles. These figures suggest under-consumption among energy poor households even if there is insufficient quantitative data on how low their energy use actually is.

Finally, another shortcoming in monitoring energy poverty is the lack of disaggregated data on household energy consumption, hiding the intersectionality of energy poverty amongst users and their consumption patterns. As discussed above, disaggregated data on energy poverty indicators for the Netherlands suggests that there is a higher incidence of energy poverty in social housing (reduced or free rent), amongst lower income groups, apartments, or in densely populated areas where the energy efficiency of residential buildings are low (Straver et al., 2020; EPOV, 2021). Importantly, households are fluid systems too: co-parenting and multi-generational households are not reflected in the official data of household composition (Clancy et al., 2017). Better disaggregation on various household characteristics that are known to increase energy vulnerability is needed. This includes vulnerability based on gender, pensioners, children, migration background, disability, family size) (Clancy et al., 2017).

Energy Governance in the Netherlands

Although the Netherlands is geographically small, it is home to 17.5 million people that are governed through a fine-meshed network of governmental institutions and layers. This multi-layered Dutch governance landscape is both a blessing and a curse for energy transition governance. The following sections narrow in on the role of different layers of government in shaping energy transition and energy poverty policy at the moment.

National Governance

The existing Dutch domestic decarbonisation policy framework is based on the Coalition Agreement after the 2017 elections (NECP, 2019). There is no mention of energy poverty in the national policy framework for energy transition, however it does create some opportunities for this agenda. The energy transition ambitions of the Dutch government are rooted in the Energy Agreement of 2013, and the Climate Agreement of 2019, and legally cemented through the Climate Act of May 2019. As already referred to in section The Energy Transition Context of the Netherlands, as part of the current Dutch Climate Agreement, the national government committed to the ambitious national objective of transitioning 1.5 million households of the 7.5 million Dutch households from natural gas to a different energy source for heating and cooking by 2030 (NECP, 2019). This will involve major infrastructural interventions in people's homes, such as the installation of new heating systems and retrofit measures in residential buildings, or the construction of district heating networks across Dutch municipalities.

In turn, commitments on decarbonization targets were shaped under influence of UN climate negotiations, EU climate law, as well as ground-breaking national climate litigation through the case of *Urgenda vs. the Netherlands*. In this case, civil society organisation *Urgenda* successfully legally challenged the adequacy of Dutch climate targets, based on the European Convention on Human Rights. Successive Dutch court judgments in 2015, 2018, and 2019 legally obliged the national government to mitigate GHG emissions by 25% by 2020, a faster pace than the rate of 17–20% mandated by the EU (NECP, 2019). These developments clearly reveal that energy transition policy and its agendas are well-established and shaped at national level, through multi-levelled processes / through interaction with civil society and supra-national governance processes.

Lower-Level Governance

Should we consider the national level a first layer of the national multi-levelled governance model of the Netherlands, then the 12 provinces present a second layer of the Dutch energy governance landscape. Each province has its own democratically elected government, and some of these have adopted regional energy poverty agenda's (Provinces of Utrecht, Zuid-Holland and the three Northern provinces Groningen, Friesland and Drenthe). These provinces are funding and stimulating research, provincial programmes and supporting municipalities in their projects and programs on energy poverty. The province of Utrecht has allocated a budget of €8.9 million on working towards a just energy transition, which includes financing and subsidising projects and renovation solutions for energy poor households.

The third level is the regional level. The Regional Energy Structures (RES) are a new energy governance arena, intended to reach decisions on decarbonisation options for 35 regions within the Netherlands. Each region has a target of renewable energy production for electricity, heat and infrastructure. Provincial and local government collaborate with companies, utilities and citizens to create regional choices on the decarbonisation of their region. Due to the lack of national policy combined with a lack of data on the phenomenon, RES plans do not currently address energy poverty. A local component of the RES consists of the municipal processes in developing *Heat Transitions Visions* at neighbourhood level, and the creation of timelines for this, through a similarly collaborative process at the local level.

Municipalities (the fourth level) are considered the directors of the heat energy transition in the Netherlands. The multi-level governance model of the Netherlands devolves much of the implementation of energy transition policy to municipalities, who are also responsible for implementation of social welfare policy (Straver et al., 2020). The 355 Dutch municipalities are presently granted a major executive and decision-making power in the implementation of the (heat) energy transition, especially through their work in developing *Heating Transition Visions* and setting the pace for neighbourhood-based heating solutions and timeframes. Some Heating Visions already published by several cities (Amsterdam, Amersfoort, Nijmegen) explicitly refer to addressing and preventing energy poverty as an integral concern to the transition. Concerning the integration of energy poverty in the local energy transition, the role of municipalities must be seen in the context of a wider decentralisation movement in the social domain that commenced in 2010. Through the so-called "Participation Law" of 2010, municipalities gained extensive devolved (implementation) responsibilities for decentralised social service provision, and poverty alleviation, including expectations of tailoring policy solutions to local households' needs (Dijkhof, 2014).

Through their engagement with socially vulnerable groups and poverty eradication activities, local authorities are acutely aware of the phenomenon of energy poverty (ENGAGER, 2019). Municipalities recognise the value of addressing multiple policy goals through energy poverty interventions, with a focus on stimulating energy efficiency to both reduce energy consumption for climate change and affordability reasons. However, local government efforts to address energy poverty are constrained by the absence of a national framework, lacking a clear mandate and adequate resources. Local government stakeholders advocate for national level policy instruments and a legal framework addressing energy poverty to support their work (ENGAGER, 2019).

ENERGY POVERTY: A FAST RISING AGENDA IN THE NETHERLANDS

The agenda of energy poverty is fast rising in the Netherlands. The devolved governance context has allowed the agenda of energy poverty to be taken up by municipalities and provinces, in innovative ways, bringing together climate change and poverty targets on the ground. At the same time, in parallel, the EU's demands for integrating energy poverty into transition planning are also placing pressure on the national government to act systematically on this agenda, alongside other international commitments.

Innovative Action on Energy Poverty at Municipal and Regional Level

Many municipal-level and local-scale energy poverty projects exist in The Netherlands, placing municipalities at the forefront of Dutch energy poverty policy making and demonstrating a strong bottom-up approach in agenda setting (Straver et al., 2020). Local governments have latched on to the energy poverty agenda as a fitting response to the challenges observed in their local communities that have the potential to be addressed by local action. Municipalities' decentralised responsibility for the implementation of social welfare is the reason that energy poverty amongst socially vulnerable groups came to light. In recent years, municipalities have also gained an important role in the implementation of central government's objectives on the energy transition, stimulating local (neighbourhood) approaches and solutions, though often with limited resources (Straver et al., 2020).

A large group of municipalities are actively developing strategies, action plans and regional agreements towards a just energy transition for all. For example, the municipality of Arnhem plans to implement a 3 year energy poverty program worth one million euro's which will benefit at least 2,500 energy-poor households, and emphasises the benefits on welfare and health for energy poverty households. The Groningen City Council also reserved €230,000 annually for energy poverty alleviation in 2021–2024, following earlier *ad hoc* budgets of €140,000 and €400,000 in 2019–2021. These activities are complemented by a €1.4 million subsidy provided by the national government to implement small energy efficiency improvements in homes ("low hanging fruit") to meet short-term energy transition targets. While the national government does not brand this subsidy as energy poverty-related specifically, the municipality has framed the support this way. The funding is so far spent on helping *all* households—not specifically targeted to vulnerable or energy poor ones—especially by deploying energy coaches (that provide free advice and insulation packages up to 60 euros). In 2021, the national subsidy was increased to 2 million. The Major of Groningen is also proposing a novel Energy Transition Fund, funded by revenues from exploiting renewable energy farms on municipal land, that can at least be partially targeted to tackling energy poverty.

The Role of International Commitments in Raising the Agenda

Aside from the bottom-up engagement on energy poverty in the Netherlands, also the EU has been progressively moving Member States to understand and address energy poverty since 2009 (Directive, 2009/72/EC). Recently it adopted legislation which now legally obliges all Members States to develop a "set of criteria" for defining energy poverty, and assess how many households are affected by it, taking into account "necessary energy services for basic standards of living" in the domestic context [(Regulation (EU), 2018/1999; Directive (EU), 2019/944); Commission Recommendation (EU) 2020/1563]. The same legislation also calls for EU Member States to develop national action plans aimed at decreasing the number of people suffering situations of energy poverty and to formulate a national indicative objective, along with a time frame, to eliminate energy poverty in case a "significant" number of households can be found to suffer from it. (Directive (EU), 2019/944) starts from the premise that any proportion of households in energy poverty can be considered to be significant.

Significantly, EU Governance Regulation on the Energy Union and Climate Action 2018/1999 requires all Member States to submit all their findings on energy poverty in the domestic context in NECPs in support of the EU's climate action and energy transition objectives (European Commission, 2018). This now effectively creates an obligation on the Netherlands to (a) define energy poverty, as demanded by EU law; (b) report and be transparent on it; (c) formulate objectives and policy to address it as necessary. Moreover, it creates a multi-levelled conversation between the European Commission and national government—upon which sub-national level actors might also act in terms of pointing out insufficient compliance of the Netherlands with EU law. Indeed, as pointed out by the European Commission, the requirements are not currently met by the Dutch government, but ultimately, the Netherlands and all other EU Member States cannot escape implementing and complying with legal requirements set out in EU regulations and directives.

In short, there is now an imperative to create national policy on this topic. Setting appropriate Dutch ambitions for the realisation of a just transition, must include national goals for mitigating household energy poverty and for ensuring equitable and affordable access to the "domestic energy services" as socially and materially necessary to guarantee basic standards of living, health, well-being and social inclusion (Directive (EU), 2019/944; Regulation (EU), 2018/1999; Bouzarovski and Petrova, 2015).

Finally, other Dutch international commitments beyond the EU are also critical here. Providing access to clean and affordable energy services for all citizens is a target the Dutch government is committed to through its support for the United Nations Sustainable Development Goals. Similarly, access to clean and affordable energy services is increasingly recognised as a human rights issue, for example through the EU Pillar of Social Rights, or through interpretation of the rights to adequate living standards, housing or health, protected by several international and European binding treaties that the Netherlands is a party to Hesselman (2021).

AN INTERVENTION: PROPOSING A NATIONAL ENERGY POVERTY POLICY

Having described the current energy poverty landscape in the Netherlands and explored the rise of the energy poverty agenda, in this section An Intervention: Proposing a National Energy Poverty Policy, we propose an intervention for integrating energy poverty in the energy transition. This proposal is built from the process of engagement we conducted between 2019 and 2020, and reflects the authors' understanding of the need for policy action, as well as the widespread consensus of the stakeholders attending the workshop we ran in 2019 on the need for a national energy poverty framework. It is also built on a deep understanding of the Dutch policy context, as well as state of the art academic understandings about the policy interventions to mitigate energy poverty.

The aim of the intervention is to propose an additional national policy in which energy poverty is integrated with the current energy transition policy. This would require government departments to work together towards goals for both policy agendas. It also would require a comprehensive national monitoring and measuring system for energy poverty. At present, understandings of the problem and its dimensions are vague, due to a lack of national measurement.

Integrating Energy Poverty and the Energy Transition

Dutch Ministries have siloed goals and responsibilities and do not yet collaborate on the issue of addressing energy poverty. The Ministry for Economic Affairs and Climate Policy (EZ) is responsible for realising CO_2 reduction targets, while the Ministry of the Interior and Kingdom Relations (BZK) is responsible for phasing out natural gas in the built environment, and the Ministry of Social Affairs and Employment (SZW) is concerned with social welfare and employment. When energy poverty is positioned as a social welfare problem, it falls clearly within the remit of SZW, but when it is more closely associated with the energy transition it belongs in EZ. This is a clear indication that collaboration between departments is essential to share budget, mandate and policy instruments to achieve a just energy transition in which energy poverty is eradicated (Clancy et al., 2017).

The lack of coordination between government departments is apparent in the current situation. Should SZW take on mitigating energy poverty, the emphasis might be on offering financial support and reducing energy prices. This, on its own, is not a sustainable solution, not least because research indicates that governments that focus only on lowering energy bills do not entirely solve the problem for the households facing energy poverty difficulties (Feenstra and Clancy, 2020). Further, lowering energy bills is a short-term measure that does not contribute to achieving decarbonisation targets in the long run. Investments in energy efficiency (of the household, or of appliances) are able to address both climate and energy poverty goals.

The Netherlands has a unique governance culture of "poldering" (striving for consensus), that paves the way for close cooperation between policy actors. We argue that there is much to gain from a more in-depth perspective on energy poverty combined with a more integrated approach of social policy, energy policy and urban planning. There are opportunities to address multiple challenges through energy poverty policy. Defining an energy poverty policy may give strategic direction to the way housing stock can be made sustainable, while setting up an energy poverty monitoring framework gives insight on who is vulnerable when it comes to energy use, and it contributes to monitoring current energy policy implementation. It enables energy retrofitting priorities to be established, focusing on the needs of the different household groups and accounting for their housing stock characteristics. This allows energy retrofitting policies to be assessed for their capability of tackling energy poverty.

Measuring and Monitoring Energy Poverty Nationally

Based on our research and insights gained from the stakeholder workshop, a recommendation is to implement a national measurement and monitoring system for energy poverty. There are plenty of experiences to draw on from other nations, and insights to use from academic research. Since this agenda emerged in the UK (Boardman, 1991), there have been prolonged debates about how best to measure energy poverty, which we will not revisit in detail here. A range of indicators can be found on the EU Energy Poverty Observatory (EPOV, see Bouzarovski and Thomson, 2019). Following the legislative mandate of (Regulation (EU), 2018/1999) and (Directive (EU), 2019/944) on common rules for the internal market for electricity, EU member states are putting in place quantitative measurement frameworks that contribute to better recognition of energy poverty by stakeholders and support targeted action (European Commission, 2018).

A recent example of the uptake of EU recommendations for the monitoring and reporting of energy poverty through indicators is the case of Spain. In this country, a growing societal and institutional recognition of energy poverty in the last decade has gone hand-in-hand with the publication of quantitative studies (e.g., Romero et al., 2014; Tirado Herrero, 2017; Tirado Herrero et al., 2018) that subsequently led to the adoption in 2019 of a specific national policy framework (the Spanish National Energy Poverty Strategy). The Spanish Strategy, which has an ambition to reduce the incidence of energy poverty by 25% between 2019 and 2024, has adopted almost unquestioningly the four headline indicators recommended by the European Energy Poverty Observatory (EPOV). According to the Spanish NECP, an annual update of those four indicators calculated in accordance to EPOV methodologies is published by mid-October every year by a public business entity (IDAE) attached to the State Secretariat for Energy.

The consensus is that energy poverty is a complex problem, and that it is measured best by using multiple indicators (Trinomics, 2016; Castaño-Rosa et al., 2019; ENGAGER, 2020a; Feenstra and Clancy, 2020; Straver et al., 2020). This allows capturing its complexity, and avoids the situation in which some experiences of energy poverty (e.g. spatial shrink, social isolation or household debt) are overshadowed by the aspects of domestic energy deprivation that are institutionally recognised and captured in indicators (e.g., energy bill cost, energy efficiency). Using a combination of indicators contributes to capture the diverse drivers and impacts of energy poverty, enables governments to design policy interventions that recognise and address the multi-dimensional nature of the problem.

In the case of the Netherlands, a monitoring framework sensitive to national conditions and capable of accounting for the multiple dimensions and experiences of energy poverty in the Dutch context should incorporate metrics beyond the ones already reported in the quantitative studies presented in section The National Energy Poverty Agenda in the Netherlands. Such a proposal, laid out in our White Paper as well (Straver et al., 2020), would include, for instance, indicators on household indebtedness to energy providers, dependency on social services for the payment of utility bills or difficulties in moving up the energy efficiency label ladder, or from natural gas-based to alternative heating systems as prescribed by Dutch energy transition guidelines. In addition, available data on energy poverty in the Netherlands so far, suggests it is imperative to collect disaggregated data too, for certain groups will be certainly more widely or deeply affected.

A call for mixed methods in energy poverty measuring and monitoring is also emerging, including the Netherlands (PBL, 2018; ENGAGER, 2020b; Straver et al., 2020). This builds on academic and policy work on the lived experience, which offers new and important insights into this complex topic (e.g., Middlemiss and Gillard, 2015; Middlemiss et al., 2018). Lived experience research uses qualitative methods to document people's lives in the face of reduced access to energy services. It offers insights into how people learn to cope with reduced access to energy services, what kinds of trade-offs they make, how different policies impact their lives and how their experience is affected by intersecting challenges. Qualitative monitoring methods using data based on the lived experience of the energy poor can provide useful insights into the impact of energy poverty policy on the energy poor. Furthermore, qualitative monitoring methods could reveal how the implementation of energy poverty policy is affected by a range of other policies that it intersects with, such as social welfare policy (ENGAGER, 2020b).

Equally, the lived experience is an opportunity to involve the energy poor in policy design. This can include talking to people experiencing energy poverty about specific policies before implementation as is being done in Scotland (Ipsos MORI Scotland, 2020). Given the devolved nature of Dutch governance, and the growth of this agenda from the bottom up (municipality/regional governance) in the Netherlands, the value of monitoring in the lived experience would be particularly high in the Netherlands. Insights from qualitative panel studies, with a cohort of households selected for diversity, and studied over time, would be hugely useful, in a context in which much of the decision-making power is held at local levels. There may also be the possibility to use such work as a means of monitoring poverty more generally—to share the costs of such monitoring between departments.

CONCLUSION

The last decade has seen a surge in energy poverty policymaking in the EU following its increased recognition as an issue on its own right different from—even if closely related to—other forms of monetary and material deprivation. In this process some Member States (e.g., Spain) have willingly followed the European Commission directions and are putting in place specific national monitoring and policy action frameworks aimed at quantifying and reducing the incidence of energy poverty. A risk of such dedicated efforts is, however, the creation of a new (energy poverty) policy silo lacking integration with pre-existing energy, climate and social policies. Other EU nations, on the contrary, reluctantly agree with EU recommendations and disregard or superficially treat energy poverty within key strategic documents such as National Energy and Climate Plans (NECPs). In the case of Northern and Western European Member States such as Germany, Denmark, Sweden, objectively low incidence rates have motivated their national governments to consider energy poverty within general income-related poverty thus advocating for traditional social welfare approaches for its alleviation (Bouzarovski et al., 2021).

While we are critical of such stances, our analysis of the Dutch case suggests that an initial resistance to openly accept energy poverty as a distinct challenge may effectively create opportunities for its integration with more prominent policy developments relevant to specific national contexts. In the Netherlands, the adoption of ambitious GHG emission mitigation targets, the Urgenda court case and the Groningen gas field earthquakes make energy transitions appear as a more compelling, salient issue in political and policy discussions. As argued in our White Paper (Straver et al., 2020), we see a window of opportunity to plug energy poverty into just energy transitions policy developments once the Dutch policymaking process realises that a significant fraction of households in the Netherlands, many of whom are experiencing energy vulnerability to some degree, face difficulties in moving from gas-based to alternative heating and, more generally, risk being harmed or "left behind" by the transition. Such developments have triggered an incipient discussion around energy poverty in the House of Representatives of the Netherlands and may lead the way to proper institutional recognition of the issue in the future.

With regards this last point, The Netherlands is a country with a rich legacy as a social welfare state. The national government wrongly assumes that energy poverty is tackled through existing social welfare policies. This situation is not unique to the Netherlands. Energy poverty is also overlooked in other countries with extensive social welfare policies, in which national governments believe that energy poverty will be dealt with through existing poverty eradication policies (see for e.g., Großmann and Kahlheber, 2017 on Germany). Addressing energy poverty can be politically sensitive since it can be seen as a failure of the welfare state to fulfil its function. However, as demonstrated above, energy poverty is still very much a challenge in the Netherlands, with many households unable to afford the energy services they need to live comfortably at home. In a sense, the framing of this problem as "energy poverty" is less acceptable in the Netherlands as a result of the common feeling that the welfare state is looking after people adequately, whilst moreover, energy consumption is still largely seen as a space of the free market.

Part of our approach in our white paper and indeed in this paper, was to clearly frame the problem of energy poverty through the just transition, which is a much more acceptable policy framing in the Netherlands. In a governance culture which values planning for the future, it makes sense to frame energy poverty problems as requiring better integration into future plans. Integrating knowledge of energy poverty into the just energy transition agenda creates a window of opportunity to raise this important challenge politically in the Netherlands. Perhaps this can also inspire those interested in raising the energy poverty agenda in other nations to find alternative routes to address this issue.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/supplementary materials, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

MF: conceptualisation, formal analysis, project administration, writing—original draft, and writing—review and editing. STH, KS, and MH: validation, visualisation, writing—original draft, and writing—review and editing. LM: conceptualisation, formal analysis, writing—original draft, and writing—review and editing. All authors contributed to the article and approved the submitted version.

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Exploring Residential Rooftop Solar Potential in the United States by Race and Ethnicity

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Over the last decade, the United States has experienced continued growth in residential rooftop solar photovoltaic (PV) adoption. However, solar adoption disparities have been shown across household income, homeownership status, and more recently racial and ethnic demographics. A key component to ensuring a just clean energy transition is understanding the existing landscape to establish realistic goals. Motivated by studies on solar adoption disparities, this descriptive study aims to evaluate the distribution of estimated single-family rooftop potential across racial and ethnic majority census tracts to discern whether rooftop potential disparities may justify solar adoption disparities. Across all census tracts, the median rooftop potential was 80%. Three-fourths of all census tracts had a rooftop potential >72%, regardless of racial/ethnic majority. Compared to majority-white census tracts, majority-Black, majority-Hispanic, and majority-Asian census tracts had slightly lower rooftop potential, 6, 7, and 9%, respectively, while majority-American Indian census tracts had an 11% higher rooftop potential. The slightly lower rooftop potential in communities of color compared to majority-white and non-racial/ethnic majority census tracts, alone, was not of the magnitude to justify documented racial/ethnic disparities in solar adoption. This study concludes, that while a majority of homes in communities of color are solar suitable, an equitable clean energy transition is only possible with policies, programs, and incentives that center on racial equity while recognizing the interplay between race, income, and homeownership status.

Keywords: energy justice, just transition, solar energy, race and ethnicity, single-family homes

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INTRODUCTION

The United States has experienced continued growth in residential rooftop solar photovoltaic (PV) adoption over the last decade. Federal policies like the solar Investment Tax Credit (Internal Revenue Code, Section 48), various state and local policies, rapidly declining costs, and increasing demand have resulted in 18 GW of installed solar capacity in 2020, up from 0.6 GW in 2010, enough to power 3.6 million homes (Solar Energy Industries Association, 2021). Solar costs have declined nearly 70% over the last decade allowing for expansion into new markets (Solar Energy Industries Association, 2021). A Pew Research Center survey found a growing share of homeowners considering installing solar panels. In 2019, approximately 46% of homeowners reported giving serious thought to adding solar panels to their homes, up from 40% in 2016 (Kennedy and Thigpen, 2019). However, in the era of the clean energy transition, scholars have demonstrated that distributional inequities are evident in the adoption and the social, environmental, and economic benefits of residential solar (Kwan, 2012; Vaishnav et al., 2017; Lukanov and Krieger, 2019; Sunter et al., 2019; Brown et al., 2020; Reames, 2020; Schunder et al., 2020). This has led many to call for a "Solar with Justice" or an energy justice approach to the clean energy transition (Clean Energy States Alliance, 2019; Fortier et al., 2019; Carley and Konisky, 2020). Solar adoption disparities in the United States have been shown across household income, homeownership status, and more recently racial and ethnic demographics (Kwan, 2012; Vaishnav et al., 2017; Lukanov and Krieger, 2019; Sunter et al., 2019; Brown et al., 2020; Reames, 2020; Schunder et al., 2020).

Although studies in solar adoption motivations found that low-income and non-low-income adopters are more alike than different, it has long been recognized that solar adoption growth has not been equitably distributed across household income classes and is instead linked to spending power (Kwan, 2012; Schunder et al., 2020; Wolske, 2020). Higher-income households represent a greater share of solar adopters than their share in the population (Barbose et al., 2018). For instance, in a study of residential solar installations in California, New Jersey, Massachusetts, and New York (which represented 65% of all residential PV installations at the time) 87% of solar installations were completed by households with annual incomes of $45,000 or greater (Kann, 2017). Although households with annual incomes <$45,000 represented 25% of the total population, those households were underrepresented in the solar market, accounting for just 13% of PV installations (Kann, 2017). Solar adoption has been gradually migrating toward lower-income ranges over time, reflecting both a broadening and a deepening of U.S. solar markets. For example, households with incomes <$100 k grew from 39% of solar adopters in 2010 to 48% in 2018, while households with incomes >$200 k dropped from 26 to 16% of solar adopters (Barbose et al., 2020). Moreover, higher rooftop potential, or the percentage of solar suitable rooftops, does not only exist in higher-income communities. Homes in low- to moderate-income (LMI) communities also offer significant rooftop potential (Reames, 2020). The National Renewable Energy Lab (NREL) has explored LMI solar adoption as well as rooftop potential that exists in LMI communities. LMI households, defined as having income levels lower than 80% of the area median income (AMI), make up 43% of the population in the United States. Similarly, NREL estimates that the LMI rooftop potential is ∼42% of all the United States' solar rooftop potential, or ∼330 GW (Sigrin and Mooney, 2018). However, higher rooftop potential rates do not necessarily result in higher rates of solar installations, especially if the higher rooftop potential is in LMI communities (Reames, 2020).

Beyond income, other socioeconomic and demographic characteristics are associated with rooftop solar penetration. For instance, homeownership status is another characteristic of distinct solar adoption disparity (Barbose et al., 2018). Homeowners are far more able than renters to install rooftop solar and benefit from solar installation incentives (Borenstein, 2017; Crago and Chernyakhovskiy, 2017). The split-incentive challenge is a well-known and well-studied principal-agent problem in the energy literature (Bird and Hernández, 2012; Gillingham et al., 2012; Reames, 2016, 2020; Melvin, 2018). The split-incentive problem occurs when landlords or property owners, as the energy improvement decision-maker, decide against investing because they receive no direct benefit from doing so (Bird and Hernández, 2012; Gillingham et al., 2012; Reames, 2016, 2020; Melvin, 2018). This is important to note considering that 75% of renters pay all energy costs directly, not landlords (United States Energy Information Administration, 2018). Geographic areas with higher percentages of renter-occupied housing have lower solar penetration rates (Graziano et al., 2019; Reames, 2020). A study on rooftop solar potential in western New York found that areas with higher shares of renters had less rooftop area compared to areas with higher shares of homeowners (Schunder et al., 2020). However, the Schunder et al. (2020) study did not distinguish between single- and multi-family buildings.

More recently, studies have found that race and ethnicity are significant indicators for solar adoption (Kwan, 2012; Sunter et al., 2019; Reames, 2020; Schunder et al., 2020). Large racial and ethnic disparities in solar deployment are apparent. Kwan (2012) found that areas with a higher share of Black population were associated with lower solar adoption. Sunter et al. (2019) further established significant racial and ethnic disparities in national solar deployment, even after accounting for household income and homeownership. Compared to census tracts with no racial/ethnic majority, majority-Black and majority-Hispanic census tracts had 69% and 30% less installed solar, respectively, while majority-white census tracts had 21% more solar (Sunter et al., 2019). The relationship between solar adoption and race and ethnicity can also be dependent upon the geography, or location, of analysis. For instance, Reames (2020) found that race and ethnicity were not statistically significant predictors for census tract solar penetration rates in Riverside, CA, Chicago, IL, and Washington, DC. However, for the majority non-white San Bernardino, CA, the percentage of non-white population in a census tract was positively associated with solar penetration (Reames, 2020).

Furthermore, a substantial amount of research explores the causes and consequences of residential segregation, primarily from the fields of sociology and public health (Wilson, 1987; Sampson, 2012; Sharkey, 2013). Urban sociologists associate residential segregation with concentrated social and economic disadvantage (Klinenberg, 2002; Sampson, 2012; Sharkey, 2013). Thus, exploring the interplay between the dynamics of racial segregation and residential energy is necessary to understand geographic disparities in rooftop solar potential. In western New York, Schunder et al. (2020) found that communities with a greater percentage of racial and ethnic minorities had ∼60% of the rooftop potential found in majority-white communities. This difference was especially pronounced for majority-Black communities which had the lowest rooftop potential (Schunder et al., 2020). In this instance, communities with low incomes and high minority populations not only had relatively low rooftop potential but also had limited access to potential community solar sites in their neighborhoods (Schunder et al., 2020). Again, it is important to note, this study did not distinguish between single- and multi-family buildings. Moreover, this type of analysis into racial/ethnic disparities in rooftop potential is absent at the national scale.

A key component to ensuring a just clean energy transition is understanding the existing landscape to establish realistic rooftop solar deployment goals. Or put another way, what is a realistic goal based on the rooftop potential that exists in underserved and underrepresented communities? In this case, the exercise of exploring the solar rooftop potential that exists in communities of color may assist with the development of well-thought, targeted and attainable energy transition goals. For instance, knowing how many households could be targeted and exactly where those rooftops are located. This study is motivated by the numerous studies on solar adoption disparities and aims to evaluate the energy justice landscape relative to the rooftop potential estimated to exist in communities of color. Further, it asks whether racial and ethnic disparities in rooftop solar potential explain documented racial and ethnic disparities in solar adoption.

MATERIALS AND METHODS

This research utilized a publicly available data source, the National Renewable Energy Lab's (NREL) Rooftop Energy Potential of Low-Income Communities in America (REPLICA). The REPLICA dataset provides census tract-level estimates for the number of solar suitable residential rooftops in the United States, determined by rooftop shading, azimuth, tilt, and a minimum 10 m^2 area (Mooney and Sigrin, 2018). The model year vintage of REPLICA is 2015.

REPLICA estimates that the majority of solar suitable residential rooftops (68.4%) exist on single-family dwellings (61.8 million rooftops) and exceed multi-family rooftop potential across all income groups (Sigrin and Mooney, 2018). If solar were installed on all solar suitable single-family rooftops, the estimated annual energy-generating potential was 683 TWh, compared to 316 TWh for multi-family dwellings (Sigrin and Mooney, 2018). Therefore, this study focuses exclusively on only solar suitable single-family homes.

From REPLICA, three variables were calculated for each census tract. First, the *total rooftop potential* (TRP) for each census tract was calculated by dividing the total number of single-family *solar suitable rooftops* (SSR) by the *total number of single-family rooftops* (TR), Equation (1).

$$TRP_{ct} = \frac{SSR_{ct}}{TR_{ct}} \times 100\% \quad (1)$$

Next, the *share of rooftop potential* (SRP) on either LMI-occupied rooftops or renter-occupied rooftops was calculated. REPLICA estimates the proportion of LMI-occupied and renter-occupied solar suitable rooftops. Equation (2) illustrates that the total number of single-family solar suitable rooftops for each group, where subscript g is either the total number of LMI-occupied or renter-occupied single-family solar suitable rooftops, is divided by the total number of single-family solar suitable rooftops for that census tract. For example, if a census tract has 100 single-family homes, 50 solar suitable rooftops, and 20 LMI-occupied solar suitable rooftops, the census tract stats would be, TRP $= (50/100 \times 100) = 50\%$, and $SRP_{LMI} = (20/50 \times 100) = 40\%$.

$$SRP_{g,ct} = \frac{SSR_{g,ct}}{SSR_{ct}} \times 100\% \quad (2)$$

In addition to rooftop potential data, REPLICA includes United States Census Bureau tract-level demographic and socioeconomic estimates from the American Community Survey (ACS, 2011–2015, 5-year). Of import to this study are census tract-level characteristics on race and ethnicity and median household income. Similar to Sunter et al. (2019), to explore racial/ethnic relationships with rooftop potential, census tracts were categorized as no majority or majority by racial/ethnic groups (Black/African American, Hispanic/Latinx, American Indian, Asian, or white). A census tract with more than 50% of the population identified as one race or ethnicity was categorized as a majority census tract for that race or ethnicity. More diverse or census tracts with no race/ethnicity having a proportion >50% were categorized as a no-majority census tract (Sunter et al., 2019).

The analysis consists of three components. First, the distribution of rooftop potential, LMI- occupied share of rooftop potential, and renter-occupied share of rooftop potential were explored across all census tracts, no-majority census tracts, and racial/ethnic majority census tracts. Next, to compare results across different groups, the locally weighted scatterplot smoothing (LOWESS) method was applied to fit local linear relationships between rooftop potential and median household income and percent renter-occupied (Sunter et al., 2019). LOWESS is a popular nonparametric smoother and "can be used to locate a smooth curve among the data points without requiring any advance specification of the functional relationship between the variables" (Jacoby, 2000). The smoothing parameter, which gives the proportion of observations to be used in each regression, was 0.65 (Jacoby, 2000; Sunter et al., 2019). Lastly, two regression models were executed to further explore how rooftop potential varied across race and ethnicity while controlling for median household income, percent renter-occupied, and state effects. One model with no-majority census tracts as the reference and another model with majority-white census tracts as the reference. Census tracts are embedded within states and differences across states may impact outcome variables. Therefore, this analysis used a state fixed effect approach to model rooftop potential. All statistical analyses were performed using Stata version 16.1.

In the **Table A1** presents descriptive statistics. There were an estimated 79,289,041 single-family homes and 61,111,100 single-family homes with solar suitable rooftops. Thus, the national rooftop potential was 77.1%. An estimated 29.6 million LMI-occupied single-family rooftops represented just over one-third (36.6%) of the total single-family rooftop potential. An estimated 9.95 million renter-occupied single-family homes represented 16.3% of the total single-family rooftop potential. The final data set included 70,759 census tracts or 97% of all census tracts in the United States. Majority-white census tracts represented 83% of all tracts, followed by majority-Black census tracts (9%), no-majority census tracts (5%), majority-Hispanic census

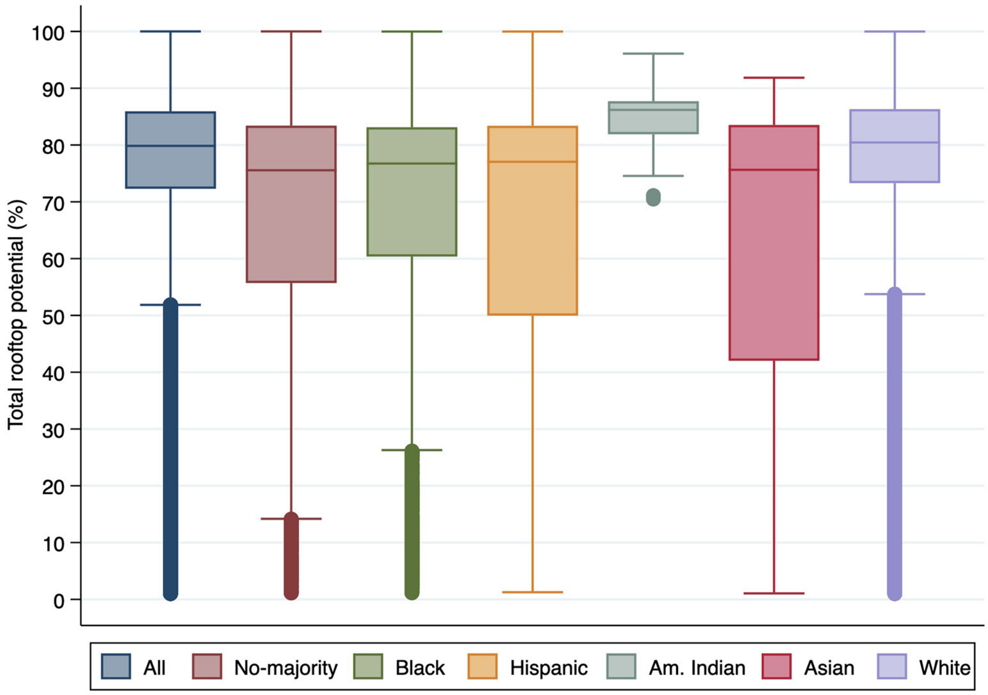

FIGURE 1 | Distribution of total rooftop potential.

tracts (3%), majority-Asian census tracts (0.7%), and majority-American Indian census tracts (0.2%).

Figure A1 illustrates the distribution of census tracts across race, ethnicity, and median household income deciles. A higher number of majority-white and majority-Asian census tracts were distributed across higher-income deciles. While a higher number of other communities of color (Black, Hispanic, American Indian) and no-majority census tracts were distributed across lower-income deciles.

RESULTS

Racial/Ethnic Distribution of Total Rooftop Potential

Figure 1 illustrates the distribution of rooftop potential across all census tracts, no-majority census tracts, and racial/ethnic majority census tracts. Across all census tracts, the median rooftop potential was 79.8%. Moreover, three-fourths of all census tracts had a rooftop potential >72.3%.

Majority-American Indian census tracts had the highest median rooftop potential, 86.2%. The interquartile range (IQR) was small, and all majority-American Indian census tracts had rooftop potential >70%. Nearly three-quarters of majority-American Indian census tracts were located in just five states (Arizona, New Mexico, South Dakota, North Carolina, and Montana) with relatively high solar resources, according to NREL's National Solar Radiation Database (https://nsrdb.nrel.gov).

The second-highest median rooftop potential was 80.4% (IQR, 72.3–89.5%) for majority-white census tracts. Majority-Hispanic and majority-Black census tracts had similar median rooftop potentials, 77% (IQR, 50–83.4%) and 76.7% (IQR, 60.4–83.1%), respectively. Both no-majority (IQR, 55.7–83.4%) and majority-Asian (IQR, 42–83.5%) census tracts had a 75.6% median rooftop potential. Rooftop potential for majority-Asian census tracts had the broadest IQR.

The mean rooftop potential for majority-American Indian census tracts (85%, *SD* =4) was nearly 19% higher than in no-majority census tracts (66.3%, *SD* = 23.7), nearly 10% higher than across all census tracts (75.3%, *SD* = 17.3), and nearly 8% higher than for majority-white census tracts (77.1%, *SD* = 17.3). While the mean rooftop potential in other communities of color demonstrates that a majority of homes are solar suitable, the rooftop potential was slightly lower, compared to the mean rooftop potential across all census tracts and majority-white census tracts. For majority-Black census tracts, the mean rooftop potential (67.4%, *SD* = 23.7) was 10% and 8% lower than majority-white census tracts and all census tracts, respectively, but 1% higher than no-majority census tracts. For majority-Hispanic census tracts, the mean rooftop potential (64.2%, *SD* = 26.3) was 13, 11, and 2% lower than majority-white census tracts, all census tracts, and no-majority census tracts, respectively. For majority-Asian census tracts, the mean rooftop potential (62.1%, *SD* = 26.9) was 15, 13, and 4% lower than majority-white census tracts, all census tracts, and no-majority census tracts, respectively. The mean rooftop potential for majority-white census tracts was nearly 11% more than no-majority census

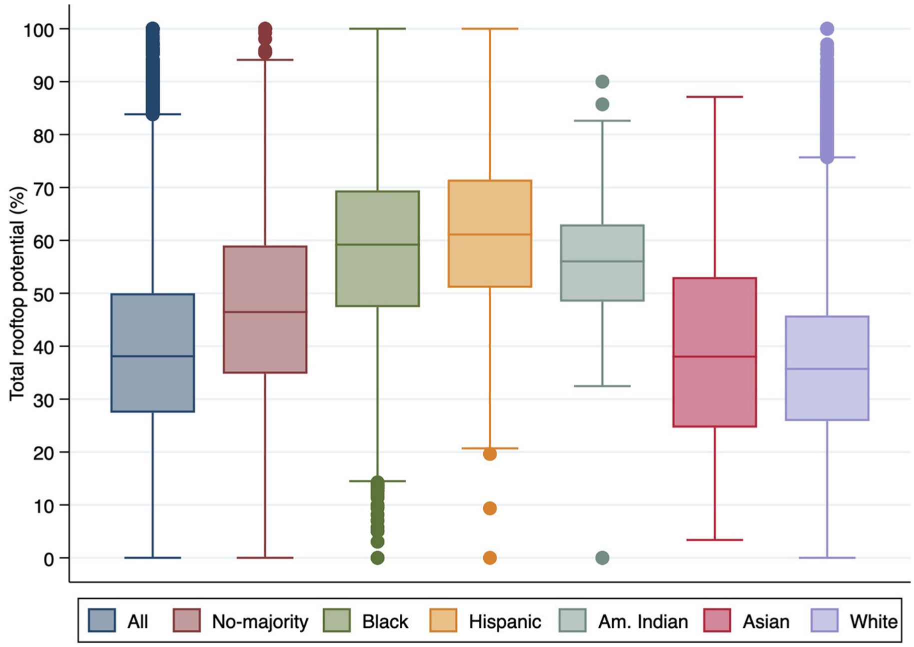

FIGURE 2 | Distribution of LMI-occupied share of rooftop potential.

tracts and nearly 2% more than the mean for all census tracts. An analysis of variance showed only the mean rooftop potential for majority-Hispanic and majority-Asian census tracts were not statistically different from one another.

Racial/Ethnic Distribution of the LMI-Occupied Share of Rooftop Potential

Figure 2 illustrates the distribution of LMI-occupied share of rooftop potential across all census tracts, no-majority census tracts, and racial/ethnic majority census tracts. Across all census tracts, the median LMI-occupied share of rooftop potential was 38.1% (IQR, 27.4–50%).

The median LMI-occupied share of rooftop potential was higher in communities of color compared to all census tracts, majority-white census tracts (35.7%, IQR 25.9–45.8%), and no-majority census tracts (46.5%, IQR 34.8–59%). In most majority-Hispanic, majority-Black, and majority-American Indian census tracts, LMI-occupied households represented a majority share of rooftop potential. Majority-Hispanic census tracts had the highest median LMI-occupied share of rooftop potential, 61.1% (IQR, 51–71.5%). The median LMI-occupied share of rooftop potential for majority-Black census tracts was 59.2% (IQR, 47.4–69.4%) and 56% (IQR, 48.4–63%) for majority-American Indian census tracts. The median LMI-occupied share of rooftop potential for majority-Asian census tracts (38%, IQR 24.6–53%) was slightly higher than for majority-white census tracts, lower than in no-majority census tracts, and nearly the same as across all census tracts.

The mean LMI-occupied share of rooftop potential for majority-Hispanic census tracts (60.5%, $SD = 14$) was 24% higher than majority-white census tracts (36.5%, $SD = 14.9$), 21% higher than across all census tracts (39.5%, $SD = 16.7$), and nearly 14% higher than in no-majority census tracts (46.9%, $SD = 17.1$). The mean LMI-occupied share of rooftop potential for majority-Black census tracts (57.9%, $SD = 16$) was 21.4% higher than for majority-white census tracts, 18.4% higher than across all census tracts, and 11% higher than in no-majority census tracts. The mean LMI-occupied share of rooftop potential for majority-American Indian census tracts (55.1%, $SD = 12.8$) was nearly 19% higher than for majority-white census tracts, nearly 16% higher than across all census tracts, and 8.2% higher than in no-majority census tracts. The mean LMI-occupied share of rooftop potential for majority-Asian census tracts (39.2%, $SD = 17.8$) was nearly 3% higher than for majority-white census tracts, 0.3% lower than across all census tracts, and nearly 8% lower than in no-majority census tracts. The mean LMI-occupied share of rooftop potential for majority-white census tracts was 10.4% less than no-majority census tracts and 3% lower than the mean for all census tracts. An analysis of variance showed only the mean LMI-occupied share of rooftop potential for majority-Black and majority-American Indian census tracts were not statistically different from one another.

Racial/Ethnic Distribution of the Renter-Occupied Share of Rooftop Potential

Figure 3 illustrates the distribution of the renter-occupied share of rooftop potential across all census tracts, no-majority census tracts, and racial/ethnic majority census tracts. Across all census

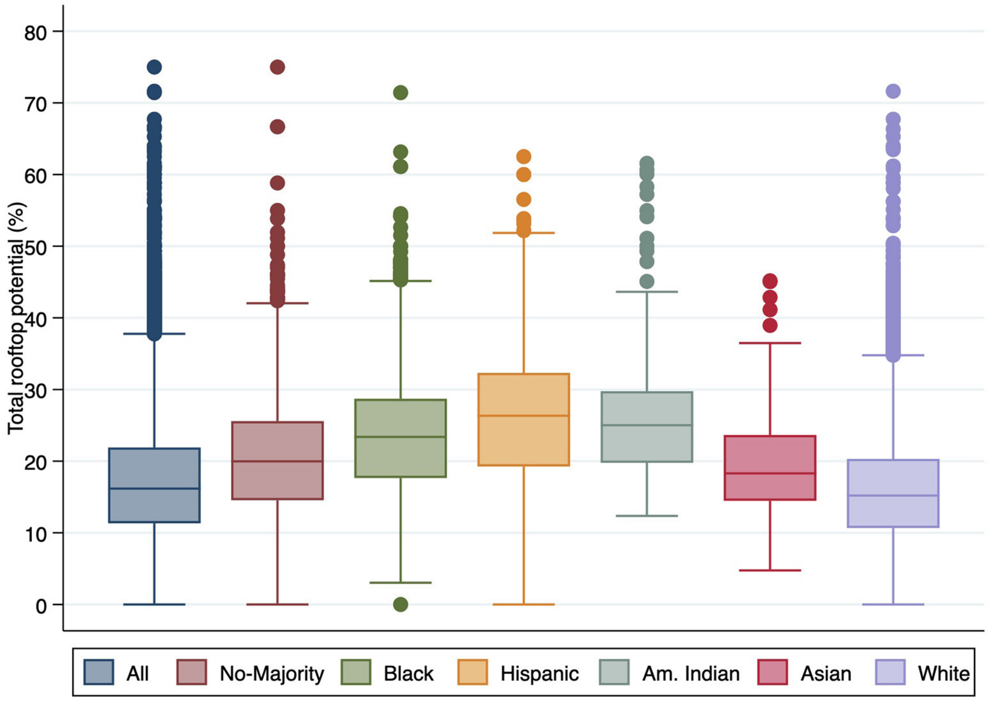

FIGURE 3 | Distribution of renter-occupied share of rooftop potential.

tracts, the median renter-occupied share of rooftop potential was 16.2% (IQR, 11.3–21.9%).

Similar to the LMI-occupied share of rooftop potential, the median renter-occupied share of rooftop potential was higher in communities of color compared to all census tracts, majority-white census tracts (15.2%, IQR 10.7–20.3%), and no-majority census tracts (20%, IQR 14.6–25.6%). The median renter-occupied share of rooftop potential was highest for majority-Hispanic census tracts, 26.3% (IQR, 19.3–32.3%). The median renter-occupied share of rooftop potential for majority-American Indian census tracts was 25% (IQR, 19.8–29.8%) and 23.4% (IQR, 17.7–28.7%) for majority-Black census tracts in no-majority census tracts. For majority-Asian census tracts, the median renter-occupied share of rooftop potential (18.3%, IQR 14.5–23.6%) was higher than across all census tracts and majority-white census tracts but lower than no-majority census tracts.

Majority-American Indian census tracts had the highest mean renter-occupied share of rooftop potential (26.7%, $SD = 10.2$), which was nearly 11% higher than majority-white census tracts (16%, $SD = 7.1$), nearly 10% higher than the mean for all census tracts (17.1%, $SD = 7.8$), and 6.3% higher than no-majority census tracts (20.4%, $SD = 8$). Similarly, the mean renter-occupied share of rooftop potential for majority-Hispanic census tracts (26%, $SD = 8.9$), was 10% higher than majority-white census tracts, nearly 9% higher than the mean for all census tracts, and nearly 6% higher than no-majority census tracts. The mean renter-occupied share of rooftop potential for majority-Black census tracts (23.4%, $SD = 8$) was 7.4% higher than majority-white census tracts, 6.3% higher than the mean for all census tracts, and 3% higher than no-majority census tracts. For majority-Asian census tracts, the mean renter-occupied share of rooftop potential (19.1%, $SD = 7$) was 3.1% higher than majority-white census tracts and 2% higher than across all census tracts, but 1.3% lower than no-majority census tracts. The mean renter-occupied share of rooftop potential for majority-white census tracts was 4.4% less than no-majority census tracts and 1.1% lower than the mean for all census tracts. An analysis of variance showed only the mean renter-occupied share of rooftop potential for majority-American Indian and majority-Hispanic census tracts were not statistically different from one another.

Relationship Between Rooftop Potential and Median Household Income

Figure 4 shows LOWESS smoothing curves for the relationships between rooftop potential and median household income across no-majority and racial/ethnic majority census tracts (**Figure A2** shows the LOWESS smoothing curve for all census tracts). In no-majority census tracts, the rooftop potential remains relatively flat, hovering between 65 and 70% across median household income. Majority-Hispanic and majority-Asian census tracts exhibited positive trends between rooftop potential and median household income. For majority-Hispanic census tracts, rooftop potential increased sharply with income from just under 50% in lower median household income census tracts to around 75% in census tracts with median household incomes around $100,000. Rooftop potential for majority-Asian census tracts nearly doubled from 45 to 80% as median household income increased to around $200,000. Rooftop potential exhibited

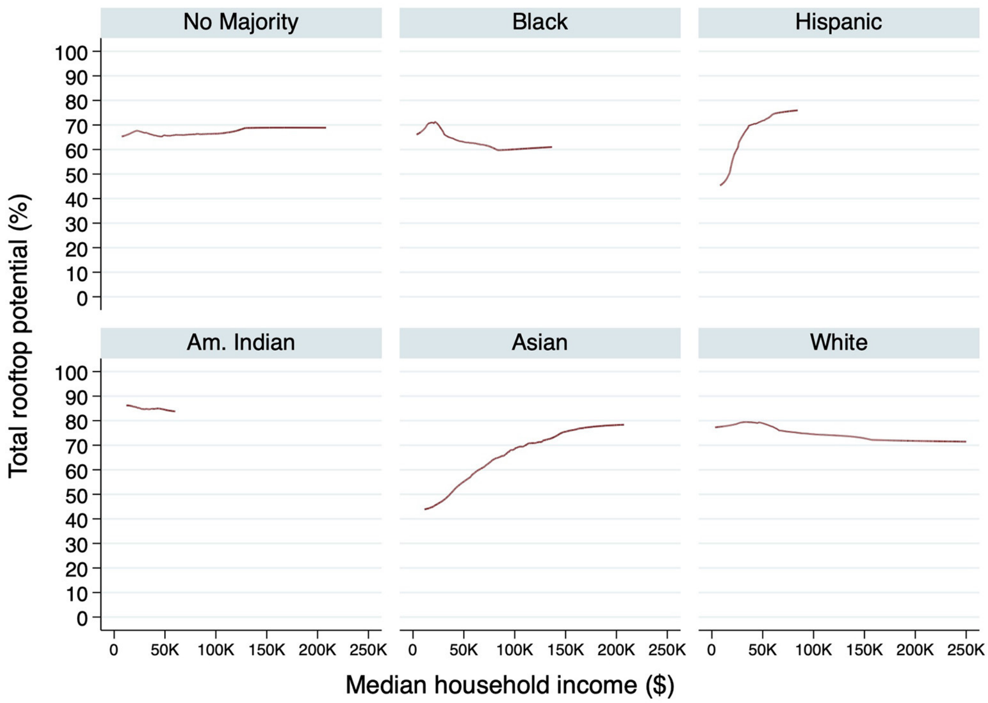

FIGURE 4 | Relationship between rooftop potential and median household income across no-majority and racial/ethnic majority census tracts.

negative trends for majority-American Indian, majority-Black, and majority-white census tracts as median household income increased. Majority-American Indian census tracts had a slight decline in rooftop potential as median household income increased. For majority-Black census tracts, rooftop potential declined from around 70% in census tracts with lower median household incomes to around 60%, with a slight increase in census tracts with median household incomes around \$100,000 or greater. Majority-white census tracts exhibited a gradual decline in rooftop potential from 80 to 70% as median household income increased. The LOWESS smoothing curve for majority-Black census tracts is a somewhat truncated version of the LOWESS smoothing curves for majority-white census tracts and all census tracts (**Figure A2**), exhibiting a 10% lower rooftop potential range and no census tracts with median household incomes >\$150,000.

Relationship Between Rooftop Potential and Percent Renter-Occupied Homes

Figure 5 displays LOWESS smoothing curves for the relationships between rooftop potential and percent renter-occupied single-family homes across no-majority and racial/ethnic majority census tracts (**Figure A3** shows the LOWESS smoothing curve for all census tracts). While **Figure 5** shows declining trends in rooftop potential as the percentage of renter-occupied households increased, in some communities, the rooftop potential remained high, >70%, even as the majority of homes were renter-occupied. Rooftop potential declined only as the percentage of renter-occupied households increased beyond 80% for majority-Black census tracts, 60% for majority-Hispanic census tracts, and 65% for majority-white census tracts. However, rooftop potential declined with lower percentages of renter-occupied homes, beyond 40%, in both no-majority and majority-Asian census tracts. The LOWESS smoothing curve for all census tracts (**Figure A3**) illustrates a similar pattern to majority-white census tracts, with a rooftop potential decline beyond 65% renter-occupied. In contrast, the percentage of renter-occupied households had little impact on rooftop potential for majority-American Indian census tracts, which remained consistent as the percentage of renter-occupied homes increased.

Regression Results

Results for two regression models (see **Table A2**) examining the rooftop potential for racial/ethnic majority census tracts while controlling for median household income, percent renter-occupied homes, and state effects revealed that majority-American Indian census tracts maintained an advantage in rooftop potential compared to both no-majority census tracts and majority-white census tracts. On the other hand, census tracts that were majority other communities of color, on average, had just slightly less rooftop potential compared to both no-majority census tracts and majority-white census tracts.

Compared to no-majority census tracts, majority-American Indian census tracts had 16% greater rooftop potential, while majority-white census tracts had a slight 5% greater rooftop potential. Majority-Asian census tracts had 3.1% less rooftop potential, majority-Hispanic census tracts had 1.4% less rooftop

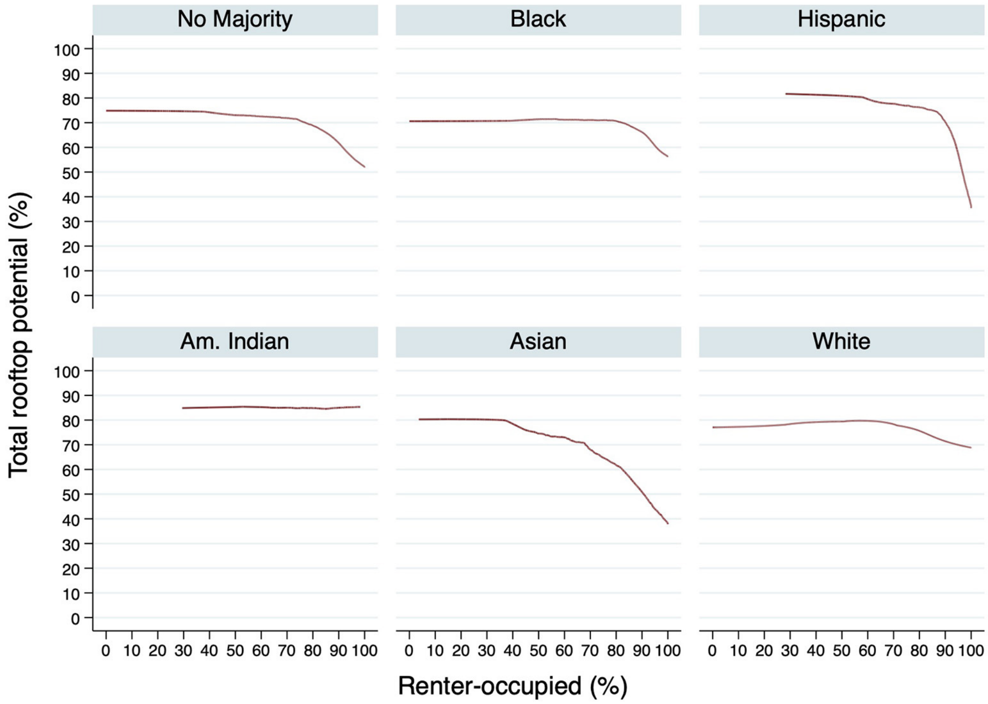

FIGURE 5 | Relationship between rooftop potential and percent renter-occupied homes across no-majority and racial/ethnic majority census tracts.

potential, and majority-Black census tracts had only 0.93% less rooftop potential than no-majority census tracts.

Compared to majority-white census tracts, majority-American Indian census tracts had 10.6% more rooftop potential. All other communities of color had slightly less rooftop potential (all <9%) compared to majority-white census tracts. Majority-Asian census tracts had 8.5% less rooftop potential, followed by majority-Hispanic census tracts with 6.8% less rooftop potential, majority-Black census tracts with 6.4% less rooftop potential, and no-majority census tracts with 5.4% less rooftop potential compared to majority-white census tracts. The model statistics for both models are, $R^2 = 0.39$, $F = 812.99$, $p < 0.001$.

DISCUSSION AND CONCLUSIONS

This study explored the racial and ethnic distribution of residential rooftop solar potential for single-family homes across 97% of census tracts in the United States. While every four out of five census tracts were majority-white, census tracts with majority populations of color, on average, exhibited relatively high rooftop potential. Majority-American Indian census tracts had the highest mean rooftop potential of all groups. While research on the adoption of rooftop solar in tribal communities is limited, efforts to support adoption and grow a local tribal solar workforce exist. For instance, the U.S. Department of Energy has financially supported tribal residential solar programs (https://www.energy.gov/indianenergy/office-indian-energy-policy-and-programs), and national non-profit organizations like GRID Alternatives (https://gridalternatives.org/what-we-do/tribal-program) and Solar Energy International (https://www.solarenergy.org/native-american-communities/) work with American Indian communities to expand solar access. Although rooftop potential in communities of color was on average lower than the national rooftop potential average, communities of color all had median rooftop potentials >75%. Thus, in many communities of color, at least three out of every four homes are estimated to be solar suitable, based on rooftop shading, azimuth, tilt, and a minimum 10 m^2 area (Mooney and Sigrin, 2018). While this analysis explores solar suitability-based technical potential estimates, it should be noted that roof quality or condition can be a major impediment to solar. The U.S. Census Bureau's American Housing Survey (AHS) estimated that more than 5% of U.S. housing units had sagging roofs, are missing roofing material, or have holes in the roof (United States Census Bureau, 2019). Higher incidence of poor roof conditions is associated with lower-income households, racial/ethnic minority households, and renter-occupied households (United States Census Bureau, 2019).

Communities of color had a larger share of rooftop potential on LMI rooftops than majority-white and no-majority census tracts. The data show particularly higher shares of rooftop potential on LMI rooftops in majority-Hispanic, majority-Black, and majority-American Indian census tracts. This fact lends support for policies and programs supporting expanding solar access to LMI households which focus on economic models to overcome the barrier of high upfront solar costs for resource-strapped households (O'Shaughnessy et al., 2020).

Several states and municipalities have been at the forefront of developing policies and mechanisms to expand solar to underrepresented households and communities, focused primarily on LMI households and often motivated by three primary objectives: reduce overall energy demand; reduce household energy burdens; and job creation (O'Shaughnessy et al., 2020; Reames, 2020). For instance, California's Single-family Affordable Solar Homes (SASH) program which began in 2009 and targets LMI households, also has special targeting for environmental justice communities overburdened by pollution (Reames, 2020). Washington, DC's Solar for All program launched in 2017 to provide solar electricity to 100,000 LMI households and reduce energy bills by 50%. In 2019, Illinois launched a Solar for All program to support both rooftop and community solar in low-income communities and communities of color. Including not only an income requirement but making an explicit connection between race/ethnicity and income in program design and targeting can facilitate addressing the gaps in targeting that result from only focusing on income (Clean Energy States Alliance, 2019).

This study finds that the majority of rooftop potential across census tracts regardless of racial and ethnic majority is on owner-occupied housing. However, the renter-occupied share of rooftop potential was higher in communities of color compared to all census tracts, majority-white census tracts, and no-majority census tracts. Particularly for majority-Hispanic, majority-American Indian, and majority-Black census tracts. The proportion of rooftop potential on renter-occupied homes requires special attention and programming designed to overcome the split-incentive dilemma. Therefore, while there remains great market potential to target and expand solar adoption for racial/ethnic minority homeowners, programs should be designed and targeted toward landlords of color and landlords with large rental property portfolios, located primarily in communities of color, to incentivize solar on rental homes.

While significant racial and ethnic disparities in solar adoption have been demonstrated, this study demonstrates that significantly less rooftop potential in communities of color is not a justification for the magnitude of adoption disparities. Compared to no-majority census tracts, when controlling for household income, Sunter et al. (2019) found majority-Black and majority-Hispanic census tracts had deployed 69 and 30% less solar, respectively, and 61 and 45% less solar, respectively, when controlling for homeownership. Controlling for both income and homeownership, compared to the rooftop potential in no-majority census tracts, this study found the rooftop potential was <2% lower for majority-Hispanic census tracts and <1% lower for majority-Black census tracts. Therefore, with relatively high rooftop potential on single-family homes in communities of color, interventions to overcome the limitations and barriers to adoption must center on racial equity while recognizing the interplay between race, income, and homeownership status. The clean energy transition will only be just and equitable with a recognition justice approach to the persistence of distributional disparities in technology adoption and an acknowledgment of the rooftop potential that exists in communities of color, often larger than would otherwise be assumed.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://dx.doi.org/10.7799/1432837.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2021.666411/full#supplementary-material

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A Mismatch in Future Narratives? A Comparative Analysis Between Energy Futures in Policy and of Citizens

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In the Netherlands, one of the goals of the energy transition is to expand the energy neutrality of houses up to 1.5 million houses until 2030. Citizens are expected to play an important role in this process, but the implementation is hampering, as citizens do not take up this role, for example, installing solar panels. Policy documents tend to anticipate futures changes from an economic rationale, which tends to align more clearly with the anticipated futures of higher educated, financially wealthy households. So, in a broader perspective, it is unclear how the future desires and expectations of citizens are represented in policy. Often, policies focus on the implementation of best-practices, in contrast, this study investigated in the potential mismatches between futures of citizens and environmental policies. As (policy) narratives of the future are performative, excluding certain stakeholders' perceptions might lead to energy injustice and could jeopardize the implementation of the energy transition. Indeed, expectations and desires of citizens seem not to be considered as they are based on different rationales (e.g., clean, green, safe living environment). This paper aims to analyse the future "narrative mismatches" (Ottinger, 2017) in the context of the energy transition in the Netherlands. Therefore, we combine a futures perspective, which distinguishes between expected, desired, and strategic future; and an energy justice perspective as we want to analyse how different issues of energy justice are recognized in these future narratives. Our research question is *"How do policy future narratives on energy relate to future narratives that are important to citizens' everyday life in the Netherlands?"* A narrative approach had been chosen to conduct a comparative analysis between a set of policy documents and the narratives of 30 local citizens. We identified several future narrative mismatches, which can be distinguished in two main types: (1) opposing mismatches, where policy narratives and narratives of citizens anticipate antagonistic futures, and (2) disconnected mismatches, where the mismatch emerges because narratives do not engage with each other and focus on different issues. These mismatches of anticipated futures might create challenges for the implementation of the energy transition characterized by just decision-making and a fair distribution of burdens and benefits.

Keywords: futures, energy, energy justice, narratives, policy, citizens

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INTRODUCTION

In the Netherlands, one of the goals of the energy transition is to increase the number of energy-neutral houses up to 1.5 million houses by 2030 and to have a full carbon-neutral system in the built environment by 2050 (Rijksoverheid, 2018). Although at first the impression might suggest that the energy transition is designable and straightforward in its implementation, the energy transition is initiated and influenced by a complex and messy combination of contradicting visions and ideas of the future. This shows in the hampering implementation of the policy of the energy transition in built environment in the Netherlands. The implementation has been difficult so far (Netherlands Court of Audit, 2020). The policies guiding this societal transformation are dominated by the expected and desired futures of policymakers. However, because adjustments in houses are needed, active involvement of citizens in the energy transition process is crucial. Citizens have different images and ideas of the future related to energy than policymakers (see Skjølsvold, 2014). These images might overlap, contradict, be ambiguous, oppose or affirm (Voros, 2003; Malone et al., 2017). Although it has been stressed that all actors are necessary to participate in the energy transition, in practice, this seems not to go easily, as not all citizens show interest or have the capability to participate. Therefore, it remains questionable whose futures are acknowledged and taken into account in the policies guiding energy transition processes and whether this will be a just process.

Narratives of citizens and other peripheral actors in the policy making process circulate less and hence, they will not, or barely, be taken into consideration. Yet, narratives, or stories, play a pivotal role in the process of creating energy futures, being the bridge between the past, the present, and the future (Holmes, 2009), also in the energy transition (Janda and Topouzi, 2015). Stories about the future are constitutive or performative (Borup et al., 2006) in the sense that they constrain and/or expand the range of possible futures while closing down others (Veenman, 2013; Beckert and Bronk, 2018). Soutar and Mitchell (2018) emphasize the importance of who is telling the narratives within the energy transition (p. 134): "the development of narratives of engagement is increasingly important for actors seeking to describe and prescribe futures in which they play key roles." Currently, the stories that matter in the creation of energy futures are mostly told by policymakers, front-line activists, scientists, and other highly educated.

This could lead to energy injustice, namely that not all citizens participate and, hence, can be provided with "safe, affordable, and sustainable energy" (McCauley et al., 2013, p. 1). Our thinking about energy justice is inspired by Bouzarovski and Petrova (2015) in three ways. First, they stress the importance of thinking in terms of energy services (e.g., cooking, washing, heating, cleaning). If citizens are deprived of these domestic energy services, they are prevented from participating in societal lifestyles, customs, and activities (Buzar, 2007). Second, they stress the importance of probabilistic energy vulnerability thinking. Households that are currently not considered to be energy service poor can become energy service poor in the future, and vice versa. Third, Walker and Day (2012) and Bouzarovski and Petrova (2015) argue that several factors influence whether households become energy service poor: low household income, high energy prices, energy efficiency, social practices of energy use, institutional factors, energy needs [e.g., elderly having a higher energy demand, (remaining) increase of persons working from home due to COVID-19]. Due to rising pricing of energy and governmental taxes to stimulate households to become self-sufficient, there is a group in society who cannot afford to make these investments, or are not the one in charge of making the investment, and pay literally the price of the energy transition.

The aim of this exploratory paper is to map future narratives of citizens and to analyse whether there are, what Ottinger (2017) calls, "narrative mismatches" between citizens and policy. These mismatches might create challenges in the implementation of a just energy transition, which may jeopardize the success of the energy transition in general. In contrast with most studies (DeCarolis et al., 2017; Woolcock, 2018; Blake et al., 2020) that focus on best-practices of environmental policies where the future narratives of citizens meet the futures described in policies, this study focusses on the mismatches between futures narratives of citizens and as described in policies. In situations of narrative mismatch, citizens may be "unable to mobilize information that could help to demonstrate the harms they suffer" (Ottinger, 2017, p. 42). Where Ottinger focuses particularly on the stories that give meaning to data, analyzing policy and communities, and stresses the importance of a further hermeneutic focus, and so this paper focuses on the future narratives expressed in policy documents and by citizens. We will analyse how both policy and citizens imagine and anticipate futures within the lived environment and related to energy transition processes, and how issues of energy justice are reflected in these future narratives. As a case study, we take the Netherlands. The Netherlands introduced a new governance structure called the Regional Energy Structure (RES), to lawfully include citizens through participation within the energy transition. This RES structure is built to downscale national policies and help municipalities to facilitate a custom neighborhood approach, specifically made for its inhabitants. Our corresponding research question is *"How do policy future narratives on energy relate to future narratives that are important to citizens' everyday life in the Netherlands?"*

This paper adds to the literature on futures and climate justice. In the literature on energy and futures, which is large and diverse, the focus is on different national socio-technical imaginaries (Jasanoff and Kim, 2013; Burke and Stephens, 2018), regional visions (Levenda et al., 2019), the use of scenarios (see for example Grunwald, 2011), etc. These are mainly policy futures, aiming to "making futures" (Inayatullah, 1993). In this paper, we are investigating the "use of futures" (Miller, 2012): future that are anticipated in future narratives (of citizens). This will be more elaborated in section Materials and Methods. The literature on energy justice focuses on the intersection between energy demands and poverty in different international case studies (e.g., Chester and Morris, 2011; Harrison and Popke, 2011; Petrova et al., 2013); the injustices arising from a globalized energy system (Sovacool et al., 2017), and conceptual contributions that combine insights from social justice and environmental justice (Walker and Day, 2012; Jenkins, 2018). In this paper, we do not analyse the unequal access to energy services by vulnerable groups, but focus on how issues of justice are anticipated in future narratives, which might eventually contribute to understanding the emergence of energy injustice. Although lots have been written on energy futures (see for example Heinonen et al., 2017; Ruotsalainen et al., 2017; Huh et al., 2019), also in combination with justice (Sovacool et al., 2019; Williams and Doyon, 2020), not often an explicit link between the two bodies of literature is made. This paper contributes to filling this gap by explicitly connecting these two strands of literature.

To answer the research question, section Materials and Methods a presents the theoretical framework that is used to analyse different kinds of futures in narratives. Section Results presents the methodological choices that are made in the research. Section Discussion and Conclusion gives an overview of the most important findings and finally section 5 discusses the findings and adds concluding remarks.

MATERIALS AND METHODS

Futures and Recognition, Procedure, Distributive Justice

Futures in the Energy Transition

Futures play an important role in the daily choices we make and in the narratives we tell. Not only are we in the process of "making futures" (Inayatullah, 1993) by aiming at visions such as the Energy roadmap 2050, we are also "using futures" (Miller, 2012). Apart from investigating the different futures that are told in the energy transition, it is crucial to see which futures are anticipated, as they shape actions and choices. Referring to Selin (2008): "the future is always active, even in the most mundane of decisions, expectations, and stories about the future are not always immediately obvious or easy to discern" (p. 1886). The "use of futures" refers to anticipation literature, being described as "*work below the threshold of consciousness (…) active within the system without the system itself being aware of them.*" (Miller and Poli, 2010, p. 12). How futures are used is the focus of this paper.

Futures studies have a long tradition in systematically studying the future in a broad sense, distinguishing between expected, probable, and preferable futures (Amara, 1981; Inayatullah, 2013). In this study we take this classic categorization to identify different types of futures that are anticipated. The first category of futures studies is the expected future, presenting one image of the future. Often, the expected future can be seen as the logical result of the past. It extends past and present patterns and trends into the future, implying a smooth transition between the past, present, and the future (Nowotny, 2010). In other words, the expected future often explores a "surprise-free future" (van Asselt et al., 2010). For this approach, past-based scientific knowledge and models are considered a reliable basis for making statements about the future. In the energy transition, expected futures are, for example, anticipated within the debate on security, in which the continuity of the extraplication of foreign dependence on energy and the turbulent international relations in the world (Groves, 2017) is assumed.

The second category is the possible future, dealing with multiple possible and plausible futures. Possible futures are often presented in a scenario study as a rich and detailed portrait of a plausible future world, or as future states of a system (Berrogi, 1997). A scenario is not an expected future but a plausible description of what *might* occur (Enserink et al., 2013). Considering possible futures, future images are never given as single scenarios, but they always come with two or more (Goodwin and Wright, 2010). Because multiple, alternative futures are considered to be possible, it is uncertain which trends develop, continue or stop, and which unexpected events might happen. In the energy transition, for example the Shared Social-Economic Pathways (SSP), which take different scenarios concerning regional rivalry, inequality, fossil-fueled development, and middle-of-the-road development into account (Riahi et al., 2017).

The third category of future studies is the preferred or desired future. In contrast to the first two approaches, expected and possible futures, the desired future favors normativeness instead of trying to be "neutral." It aims to develop a single image of a desirable future (utopia) and, from there, to reason backward in time in order to explore how this desirable future may be achieved. Within the energy transition, this type of future was for example anticipated in the development of grassroots initiatives, who anticipated a desired future of a CO_2 neutral energy use in 2050 (Oteman et al., 2017).

Besides these three types of futures, over time, critical futurists (Massini, 2007; Sardar, 2010) gained more attention. Critical futures "*emphasize that images of possible futures are not neutral but represent particular desires, values, cultural assumptions and worldviews*" (van Asselt et al., 2010). They analyse futures from a normative point of view, referring to pluralistic futures (Inayatullah, 2008), and stress the importance of taking alternative futures into consideration by acknowledging different worldviews that underlie each future. These researchers stress the point that dominant visions or narratives of the future serve as a guideline for (future) action. Without leaving room for alternative future narratives, dominant narratives limit the openness and hence colonize the future (Sardar, 2010). This view stresses the argument that ignoring narratives of citizens may not only jeopardize transition processes, but may also lead to (energy) injustice and vulnerability (Gupta et al., 2019, p. 30).

Energy Justice in Future Narratives

The literature on energy justice has the potential to advance the debate in critical futures and *vice versa*. Both focus on issues of injustice: the critical futurists stress the importance of considering alternative futures (e.g., of marginalized groups), and the literature on energy justice analyses how citizens might have an unequal access to energy services by analyzing three different dimensions: Justice of recognition, procedural, and distributive justice (Walker and Day, 2012; Jenkins et al., 2016). We analyse the three justice dimensions not in a classical manner (i.e., evaluating cases in terms of energy justice), but focus on how issues of justice are recognized in future narratives.

First, recognition justice focuses on (mis)recognition of or (dis)respect for particular *groups* (e.g., elderly, low-income households, ethnical minorities, gender, etc.) (Walker, 2012). Recognition justice acknowledges the rights, needs, desires of particular (vulnerable) groups (Walker and Day, 2012). For example, elderly or people suffering from illnesses might have a different demand for energy services, such as heating, than younger or healthy people. Similarly, low-income households or households with lower-level education might have different capacities to contribute to the energy transition. Whereas, wealthier households may have the financial capacities to invest in low-emission technology, low-income households might already have a smaller CO_2-footprint (see Lévay et al., 2019 for an analysis in Belgium), because they already adapted their behavior due to limited financial resources. That means groups are contributing differently to the problem (CO_2-emissions) but have also different capacities to change their behavior. Recognition justice stresses that social differences exist and are attached to both privilege and oppression. Hence, similar to the critical futures position, it calls for an acknowledgment of the divergent perspectives, aims, desires, and expectations present within a community. Stakeholders that are not even recognized to be affected cannot stress their concerns, hence their perspectives are unlikely to be considered during policy formulation and implementation (Young, 2000; Walker, 2019).

Second, procedural justice, in turn, evaluates the fairness of *decision-making process* (Walker and Day, 2012), focusing on the availability of appropriate, sufficient, and accurate information for all participants; the access to legal processes of appeal; and the extent that different participants' opinions, suggestions, and concerns are considered in the decision-making process (Walker, 2012; Simcock, 2016). Different forms of public participation can be distinguished based on the influence of the participants. Reed et al. (2018) distinguish a communication mode, which is a one-way flow of information from public authorities to stakeholders; a consultation mode, where stakeholder provide feedback to the plans of public authorities, and finally a co-productive mode, where goals and outcomes are jointly formulated. Procedural justice is closely linked to recognition justice (see also Simcock, 2016, see Schlosberg, 2001 for a discussion). A lack of recognition, or misrecognition (for example of different energy needs within a community) is considered to be part of the reason for unjust procedures and unjust distribution of burdens and benefits (see distributive justice below) (Young, 1990; Schlosberg, 2001; Miller, 2003).

Third, distributive justice describes the allocation, or fair distribution of, (future) *burdens and benefits*, stressing the importance to consider interacting distributional inequalities when talking about energy related justice (Walker, 2012; Walker and Day, 2012) and focusing on the re-distribution to minimize these negative consequences, for example, through subsidies (Jenkins et al., 2016). In the context of energy, distributive justice focuses often on the unequal distribution of the access to energy services, e.g., heating or cooling (Jenkins et al., 2016), the increased costs due to the energy transition (Jenkins et al., 2016), loss of jobs, nuisance during the (re)construction processes, or caused by new energy sources, e.g., windmills or heat pumps, etc. The distribution of burdens and benefits takes place on different levels: between communities or within communities, or for example, between different socio-economic or demographic groups.

Methods

Narrative Approach

In this exploratory paper, a narrative approach had been chosen to conduct a comparative analysis between a set of policy documents and the narratives of local citizens. Concerning the former, stories reflect discourses: "ensembles of ideas, concepts, and categories through which meaning is given to social and physical phenomena, and which is produced and reproduced through an identifiable set of practices" (Hajer, 1997, p. 44). In this context, we follow Soutar and Mitchell (2018, p. 133), arguing that to analyse policy making processes, "the 'narrative' concept offers rather more scope for understanding issues of societal engagement in energy systems" and "narratives can be understood as 'vehicles of meaning', which help us to make sense of the world, or in this case, the energy system" (see also Szarka, 2004; Tozer and Klenk, 2018). Hence, the different narratives in policies and from citizens can be more encompassing then only the energy transition. In order to collect narratives from the perspective of local citizens, this study made use of a biographic, narrative approach. Recently, there is the recognition of knowledge filtered through individual biographies, lived experience, the "embeddedness [of knowledge] in practice" and that this has drawn academic attention to the meaning of the position of the researcher (Gawlewicz, 2016). This method is concerned with understanding the cultural environment and social worlds through personal accounts and narratives; with life history or biographical interviews covering an individual's whole life; oral history approaches concentrating on specific events or periods.

We presented our findings, i.e., the mismatches we identified between policy narratives and narratives of citizens, in a workshop with policymakers and other stakeholders from the provincial and municipal levels. This workshop enabled us to validate and fine-tune our findings to increase the internal validity.

Studying Policy Documents

We analyzed 10 policy documents from a national, regional, and city level (see **Table 1**). Futures as described in policy documents indirectly create the framework in which citizens have to position their own futures. Our analysis included high level policy documents (like the National Climate Agreement) and more low level policy documents used for implementation (like regional and city policy documents) to understand how abstract guidelines are translated into neighborhood specific content. The comparison between these various levels of policy documents and the narratives of citizens can be made, as regardless of the source, all narratives are embedded in the same lived spaces. The policy documents were analyzed using qualitative content coding, combining both inductive and deductive approaches. The numbers in the results below are only a visualization of the qualitative interpretation of the data. By doing so, we

TABLE 1 | Policy documents analyzed.

#	Name	Year	Scale
1	**Nijmegen Heating vision** *(Dutch: Nijmegen Warmtevisie)*	2018	Local
2	**Anrhem Programme NEMIA 2020-2030** *(Dutch: Arnhem Programma NEMIA 2020-2030)*	2020	Local
3	**Arnhem's approach to a neighborhood orientated energy transition** *(Dutch: Arnhemse aanpak wijkgerichte energietransitie)*	2018	Local
4	**Nijmegen Application for Living lab natural gas-free Dukenburg** *(Dutch: Nijmegen Aanvraag Proeftuin aardgasvrij Dukenburg)*	2018	Local
5	**Nijmegen Sustainability Agenda 2011-2015** *(Dutch: Nijmegen Duurzaamheidsagenda 2011-2015)*	2011	Local
6	**Heating vision Nijmegen, in short** *(Dutch: Warmtevisie Nijmegen, in het kort)*	2018	Local
7	**Gelders Energy Agreement** *(Dutch: Gelders Energieakkoord)*	2017	Regional
8	**Implementation Gelders Energy Agreement** *(Dutch: Uitvoeringsplan Gelders Energieakkoord)*	2016	Regional
9	**Energy Saving Covenant Rental Sector** *(Dutch: Convenant Energiebesparing Huursector)*	2012	National
10	**National Climate Agreement** *(Dutch: Klimaatakkoord Nederland)*	2019	National

built on the already established analytical dimensions in the relevant literature in futures (expected, desired, and possible future) and energy justice (recognition, procedural, distributive justice). More specification according to the different themes in which these dimensions were placed, i.e., economy, environment, social issues, politics, and technology, were based upon existing literature (Veenman et al., forthcoming; Hielscher and Kivimaa, 2019).

During the different rounds of analysis, we added *strategic futures* as an extra category to the futures dimension, describing strategic actions to achieve a certain goal, for example *"Making more private home owners realize that global warming is urgent and asks for a fast energy transition. Urgency could be increased by indicating in which neighborhoods gasnetworks are outdated and so this transition could urge itself"* (GEA, execution, p 17). In this example, the future is a strategic act, namely increasing the awareness of homeowners by informing them about the quality of the gas network, rather than an desired or expected future. The final coding scheme with explanations can be found in Annex 1 (**Supplementary Material**).

In terms of process, by means of a pre-study, an indicative coding scheme was established based on analytical dimensions from prior literature. In practice this meant a list of keywords with short description presumed to be useful. The coding took place in three rounds. In the first round, we gathered key words for each of the different dimensions (expected, desired, plausible and strategic futures, and recognition justice, procedural justice, distributive justice burdens) for autocoding in Atlas t.i. These keywords were made together with experts, both in the field of futures and justice. In the second round, we checked the autocoding and by reading text around the codes, we refined the autocoding by adding some more keywords and deleting others. These two rounds each took several joint workshops. To safeguard reliability and validity of the generated coding scheme, the members of the coding team discussed the coding approach to align members' independently coded samples until any remaining differences in coding were resolved. Then, in the final round, each coder worked independently on checking all the auto-codes and one-by-one clarified and specified the autocoding.

Studying Citizen Narrative in Two Neighborhoods

For the citizens' narrative, a qualitative approach was chosen to analyse the narratives of citizens. Between June and Dec 2020 we maintained walk-along interviews (on 1.5 m distance due to the current Corona-measures) with 30 inhabitants in two neighborhoods in two middle-sized cities in the province of Gelderland, the Netherlands. The two cases were chosen in agreement with the municipalities, social housing corporation, and province and the main criteria was that no intervention regarding the energy transition of the neighborhood had taken place yet. Both middle large neighborhoods have between 2,000 (Neighborhood A) and 3,000 (Neighborhood B) inhabitants. In terms of housings types, both neighborhoods have 46% of social housing, but differ in percentage of house-owners and private renting (allecijfers.nl, 2020). The average income of the inhabitants in these two neighborhoods is relatively low, between 21.000 (B) and 25.000 (A) in 2020. However, the largest age category is between 25–45 in neighborhood A, and between 45–65 in neighborhood B. The respondents were recruited by flyering in every mailbox, addressing them directly on the streets and by snowballing. We created a broad scope of men, women, older, and younger persons, persons living in rental places and those who own property, persons with high and low income, vulnerable persons and persons with a migration background. This resulted in respondents with a great variety of characteristics. This variety is based on housing situation, 12 lived in social housing and 18 owned a property themselves. Gender, as there participated 17 men and 13 women. Age, 30–39 (1 respondent), 40–49 (13 respondents), 50–59 (11 respondents), 60–79 (3 respondents), 80–99 (2 respondents). But also in terms of education and job occupations, family situations. After 30 walk-a-long interviews for the purpose of this study, to explore the most dominant futures, these 30 narratives gave a representative overview of ideas and futures alive in these two neighborhoods.

Mobile methods, especially those that are based on walking through the neighborhood research participants during either routine daily activities or during unique events (Kusenbach, 2003), have a set of advantages compared to interviews or (digital) surveys that make them particularly useful to gain insight into neighborhood-based experiences and practices of marginalized groups (Anderson, 2004). During the walk, most questions started with "could you tell me more about your experiences of being an inhabitant of this neighborhood; your relation with neighbors; why you choose this neighborhood; etc.?" This interview strategy specifically encourages respondents to tell stories. Additionally, during the walk respondents decided on the route and could walk to specific areas related to events that happened in the past and take the interviewer back in their memory. The rest of the interview developed like a dialogue between two equal persons. In contrast with the systematic analysis of the policy documents, due to the richness of the stories of the citizens, these narratives were analyzed by using our analytical concepts on futures and energy justice as sensitizing concepts to filter and interpret the empirical material (Blumer, 1969). To emphasize and contextualize the narratives, the results refer to text fragments rather than codes.

RESULTS

Policy Documents

The policy documents show clear dominant narratives with considerable differences according to the desired, expected and strategic futures. Several justice issues emerge in these future narratives. Of course, the types of futures and justice issues are sometimes interrelated. Because of the small role that plausible futures played (Desired futures 832, Expected: 1.112, Plausible: 86, Strategic: 1441), this category is left out of the analysis. At the end of each analysis, a visual representation of the qualitative data is presented in a figure.

(Un)desired Future

Analyzing the desired future within the policy documents, the dominant narrative is, not surprisingly, the environmental future (see **Figure 1**), in particular the carbon free environment in 2050: "*This is one of the boundary conditions to fully generate carbon free energy in the future*" (Nijmegen warmtevisie, p. 24). This goes from the local scale: *"In the heat transition, the municipality council formulates a time path for neighborhoods to become gas free*" (Municipality of Arnhem, 2019, p. 9), to the regional scale: *In 2050, they [business park] all have to be carbon neutral* (Gelders Energie akkoord, 2017, p. 11), up to the national schale *the [Dutch] cabinet has one central goal in the "Klimaatakkoord": to reduce "greenhouse gases in the Netherlands with 49% compared to the levels of 1990."*

In this desired future narrative, issues of distributive justice are mainly discussed in terms of economic burdens: "*All sectors focus on cost-efficient measurements to make sure that the energy transition is affordable for society. The transition also needs to be affordable on an individual level*" (Rijksoverheid, 2018, p. 216). This is not only stressed on the national level, but also on the local

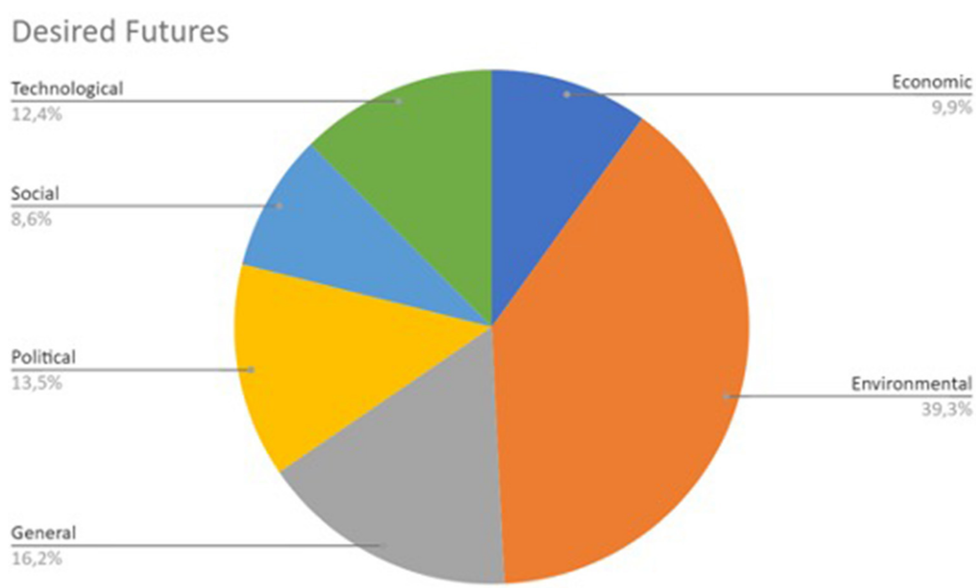

FIGURE 1 | Visualizing the different types of desired futures, and the topic: economic, environmental, social, political, general, and technology.

level: "*Affordability and reliability for the user are prioritised. The heating transition will cost money and shall not be free. However, for Nijmegenaren (people living in Nijmegen) the energy bill needs to be affordable at all times*" (Nijmegen, Warmtevisie, p. 8) and "*the starting point is that every Arnhemmer can keep up with the energy transition, and that the spread of societal costs is fair and sustainable*"(NEMIA, p. 9).

Energy poverty, in particular, is mostly considered as an undesirable future. Interestingly, it is only mentioned in the analyzed municipal policy documents (30 times). It is stated that "*the emergence of energy poverty is undesirable*" (Nijmegen, p. 8) or "*The energy transition must not in any way lead to (an increase of) energy poverty and debt problems, and preferably should be used as an instrument against energy poverty*" (Arnhem, p. 20). Hence, in Arnhem, a successful energy transition process is combined with social issues: "*Many Arnhemmers [persons who live in Arnhem] experience energy as a fixed burden that has to be paid every month and even might lead to energy poverty. To relate energy awareness and sustainable decision-making to themes that play a role in the daily lives of citizens, like poverty, loneliness, and health, it is more likely that things will change*" (Arnhem, p. 23).

Expected Future

In the expected future, the environment is less prominently anticipated. It strikes the attention that economic and technological futures are the most anticipated: *"the expectation is that in the future, innovative heat pumps will be on the market that can also efficiently heat houses,"* (Nijmegen warmte visie, p. 23). This holds for all governmental levels. The narrative concerning the economic expected future addresses that the energy transition should be cost-efficient *"Because just the sustainability in existing buildings requires an investment of over 20 billion euros over the coming 20 years"* (Gelders Energieakkoord Uitvoeringsplan, p. III). Also at the local level the expected economic future is central: *"Nijmegenaren will (...) will get the opportunity to make profitable investments"* (Nijmegen Warmtevisie, p. 8). In terms of distributive justice, this suggests that the policy narrative expects that the energy transition will offer benefits for all citizens.

Another strong narrative is the great optimism in what technology can do for the energy transition: "*a full electric public transport concession will be cost-increasing, but also significantly impact the city in terms of sustainability*" (NEMIA, p. 63). There are important expectations of technology that will make the desired environmental future possible, for example: "*For the neighborhoods that are planned to be gas-free before 2030, the potential energy sources and energy infrastructure should be known in 2021"* (Municipality of Arnhem, Arnhem, 2019, p. 9), or "*for the realization of the climate targets of 2030 and 2050, we see a great potential for wind energy at sea*" (Rijksoverheid, 2018, p. 159). This technological optimism is, as a narrative, combined with an economic perspective: "*Based on international agreements and developments, it could be said that a global hydrogen market will arise. The Netherlands has a good starting positioning to take a leading role in this*" (Rijksoverheid, 2018, p. 91). The technological futures together with the expected economic futures cover more than half all expected futures anticipated.

Despite these optimistic aspects, the expected future narratives, particularly on the local level, also anticipate greater economic burdens for citizens on the short-term (distributive justice). On the one hand, the economic burden is related to the energy itself: "*It is expected that the prices for energy and gas will increase seriously in the upcoming years*" (Arnhem, p. 2). On the other hand, it is also related to the technology that has to be installed: "*The costs to adjust a property is highly dependent on the type, year and if there have been previous investments, and additionally in what sense new investments could be combined with upcoming maintenance*" (Nijmegen warmtevisie, p. 56).

Strategic Future

In the strategic futures, the social futures appear as a clear narrative (**Figure 3**). The future success of the energy transition depends on citizens. Citizens *"have to get active and need to make their homes and lifestyles more sustainable*" (GEA, p. 22). Therefore, the local authorities adopt a so-called neighborhood approach: "*The aim of the neighborhood approach is to enter into dialogue with the residents of all neighborhoods in Arnhem about: What residents can do themselves to save energy, generate energy and prepare their homes for transition with small and larger measures*" (Arnhem AAN, p. 39). The strategic social future often goes hand in hand with the dominant environmental desired future and is visible at different scales. At the local scale the narrative is: "*To prepare a city for an era without gas, it is essential to reach out to all its inhabitants and to activate them to take action" (*Warmtevisie Nijmegen p.2). At the regional and national scale, it is stated for example that: "*The goal is that in 2025 more than 125.000 households are a member of an energy-coöperation"* (Gelders Energie akkoord, 2017, p. 13). Interestingly, these social issues that stress a central role for citizens have hardly been considered in the narratives on desired and expected futures (see **Figures 1**, **2**). It seems that the goals were already set, in which the social aspect is barely taken into account. Social issues, i.e., the involvement of various stakeholders and particularly citizens, seem to gain importance when it comes to actually implementing the energy transition. One might say they function as a means to an end.

The strategic future does not only stress the importance of citizens, but also implies *how* these citizens and other stakeholders should be involved in the neighborhood approach. In this approach, the economic expected future and the environment desired future can be seen: "*the energy transition is about citizens and their living environment, we involve inhabitants, both tenants and house owners, to participate in the development and realization phases*" (Nijmegen warmtevisie, p. 9), "*[w]e go into the neighborhoods, in which residents and other building owners are also involved*" (Nijmegen warmtevisie, p. 3), or "*we actively go into the neighborhoods to look for ways to save energy and find alternatives to natural gas, together with residents and businesses*" (NEMIA, p. 35). The government sees itself as "*a cooperating government focuses on conducting the dialogue. We take on the role of broker: facilitate, connect and share information. Together we tackle projects and enable initiatives by residents, companies and others*" (NEMIA, p. 24). From a procedural justice perspective, this suggests a participatory, even

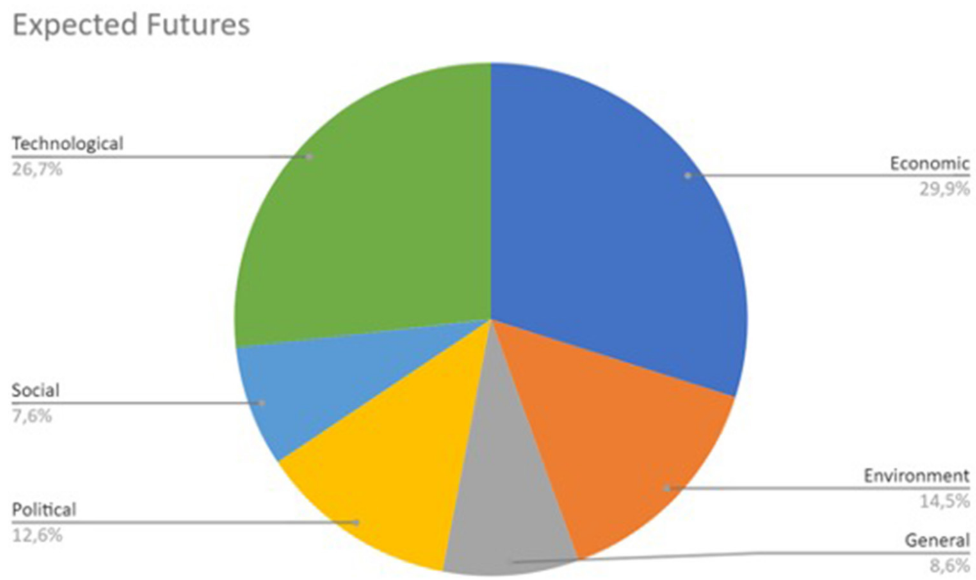

FIGURE 2 | Visualizing the different types of expected futures, and the topic: economic, environmental, social, political, general, and technology.

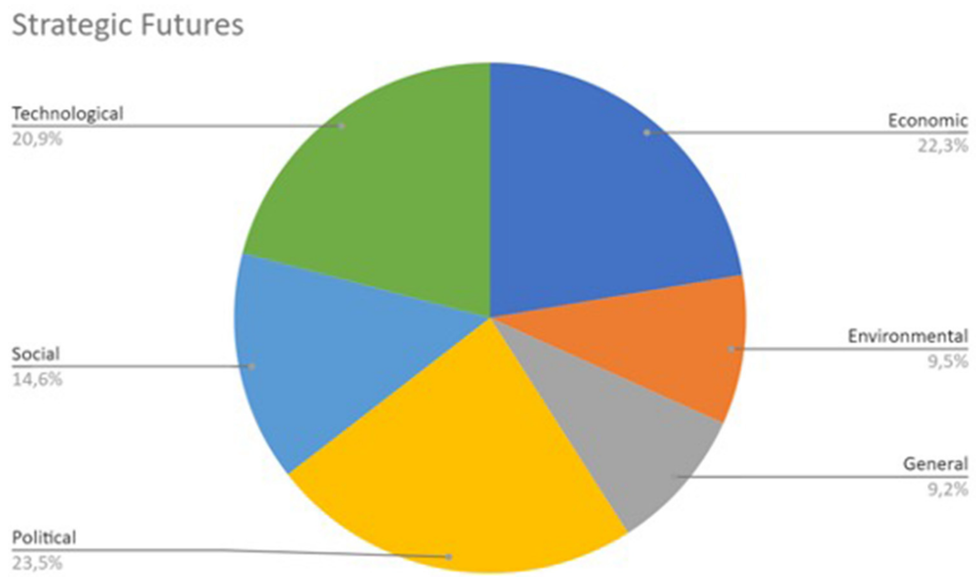

FIGURE 3 | Visualizing the different types of strategic futures and the topic: economic, environmental, social, political, general, and technology.

co-creative approach is envisioned in the policy documents, where citizens and local authorities cooperate on a relatively equal basis. The policy documents describe different possibilities on how to engage citizens, e.g., citizen representatives in project groups or information facilities in the neighborhoods. However, it is questionable who will be represented or who has access to these facilities. In the analyzed policy documents, it is not discussed how the governmental authorities aim to ensure an inclusive participation procedure. It also remains unclear how injustices between neighborhoods might be compensated.

The policy documents stress the importance of involving all citizens. From a climate justice perspective, this raises the question in how far the idiosyncrasies of citizens and neighborhoods are recognized. In this regard, there are three main aspects recognized that may be different within or between neighborhoods and citizens, yet mainly on the local level. First, the technical feasibility and economic viability to implement alternative sources of energy differs between neighborhoods. It is stated that: "*the alternatives for a boiler differ in cost-efficiency per neighborhood. For this reason, we choose a neighborhood-orientation*" (Nijmegen Warmtevisie, p. 9). Second, even though it is less prominently discussed, it is recognized that neighborhoods differ in their socio-cultural profile: *"Inhabitants have different priorities and concerns. During the energy transition it is important to include the different wishes and opportunities of all its inhabitants, to make sure all inhabitants can go through this transition in a fair and suiting manner without unwanted consequences for their personal situation"* (Arnhem AAN, p. 21). Details about the desired futures (wishes) and the opportunities (expected futures) are hence not mapped or discussed. Third, it is recognized that citizens have different capacities. For example, the limited practical capacities of tenants in comparison to property owners is recognized: "*Differently from house-owners, tenants do not have the freedom to choose how their property has been made suitable for the minimum requirement of an alternative heating source. In order to give landlords and social housing corporations a perspective for action and to protect tenants against high energy costs, the standard will therefore be mandatory in 2050 for homes intended for rental"* (Rijksoverheid, 2018, p. 20). Also the different financial capacities of citizens are to some degree recognized, also in combination with a danger of energy poverty: "*We have an explicit focus to make this transition possible Arnhemmers who are already struggling to pay their energy bills*" (NEMIA, p. 2 & see 4.1.1). Needless to say, the anticipation of the economic and environmental future leads to these issues.

Narratives of Citizens

Our analysis showed that the policy documents stress an important role for citizens in the energy transition process in terms of dominance in the strategic future. But how do citizens themselves experience responsibilities regarding the energy transition, and which futures do they anticipate?

(Un)desired Future: Quality of the Neighborhood

An issue that mobilizes people is a (un)desired future concerning the comfort of the neighborhood. The serious concerns of people we spoke to became explicitly clear when we asked them what they would wish for the future. We walked with a lady, Susan, a middle aged women living in social housing for almost 20 years as due to her circumstances she is not able to work. She takes care of a dog walking place and who feels responsible for the neighborhood. Due to various events in the past, she is not able to have a paid job any longer, but is very keen in investing her time in taking care of the neighborhood. As she walks her dogs twice a day and loves to be outdoors and get a fresh breath and some exercising, she knows exactly what is happening at every corner of the neighborhood. She speaks about the physical deterioration, or waste dumping, that becomes increasingly visible in the area, particularly in the streets with rental housing.

> *Those [people living in rental houses] let the gardens run wild. The stones are all loose. They put pieces of wood outside the garden and leave it there. Will come once, but that will never come. So all those children are going to carry it around. Are they going to make huts, and then you already have that rubbish lying among the bushes again. All of that sort of thing -Susan.*

The quote shows that she does not expect for physical deterioration to be improved soon or that this trend will change *"Will come once, but that will never come."* Living in the same neighborhood, almost everyone who walked with us shared their serious concerns regarding various aspects of deterioration of the area, an *un*desired future. Truus, an older lady of 80 years old who already lived in this neighborhood over 40 years in the property she bought together with her husband. Her husband died years ago, and now she has to manage live on her own. She addressed how this deterioration of the neighborhoods affects her quality of life in a negative manner:

> *Look at that neighbor. Look, I'm not going to ring the bell, he's only been living for 5 years. Apparently he thinks it's okay now. But I don't like it. I'm just tired of those leaves, that rubbish now and then. If I'm going to sell my house in a couple of years from now then someone will come and see that and think I should live here now? I just want this area to be clean, not perfect. But actually, I am just going to lose my enjoyment of living. I no longer enjoy living here because of the maintenance. - Truus*

The neighborhood where they are living is especially known due to its green and organic structure, in Dutch known as Cauliflower neighborhood. This also came to the fore during a walk with David. Wessel is 30 years old and works as a social worker elsewhere in the region. He lives in a flat he bought a couple of years ago, which is was former property of a social housing corporation:

> *However, because I love nature a lot, I do think that a lot of waste is dumped when I look around me like that. That is one of the areas for improvement in the neighborhood. This too (pointing at bushes): There are more trees here and there is more nature here, but if you look around you... Look, there is already a bicycle there. -David*

(Un)desired Future and the Energy Transition

In one of the neighborhoods, the social housing corporation redesigned a property into a carbon neutral house to create an example within the vulnerable neighborhood, not only to reach goals set in the Climate Agreement, but also to create social support and make citizens familiar with the energy transition.

> *Antje: You do have a house here. That also applies to social housing corporations. Energy neutral, I thought. It also has panels on it. And one street away from me, (...) there is a house that has been completely transformed. It's completely off the grid. Energy neutral, home of the future. That house has been empty for 1.5 or 2 years, because nobody wanted it. It was only available for a family, with 2 children. It was not allowed to use a TV upstairs. well you know, there were a number of requirements you had to meet.*
> *Interviewer: And those requirements were because it was energy neutral?*
> *Antje: Yes. because they wanted to do tests there every so often, because you had to be open that people from the contractors came to do tests.*

> *Interviewer: So was that a popular house then?*
> *Antje: No. Actually not, no.*

One would assume that this house would be popular among citizens with financial concerns, as the family living in this house would not have energy bills. However, according to Antje her experience, this house was not very popular among persons looking for rental housing. Antje is a middle aged single women, living in a social housing property herself as well. She lives from social payments, but in return she is highly engaged with everything that happens in and around the neighborhood. What becomes clear from this fragment is that the energy transition is not in the attention scope of citizens. The fact that living in this house required a behavioral change, which they are not ready for yet, made people preferring to live in houses linking to their perception of living comfort and higher bills.

Strategic Future: Responsibility

The undesired physical surroundings were, according to these people, caused by undesired behavior. Some see this as an individual responsibility, while others consider the responsibility to keep the neighborhood clean as a collective responsibility. Regarding the first, parents are appointed to teach their children, like Susan:

> *Because I don't want it to deteriorate so much. And look at my children, my son, he was in my car once and threw out a stick from a lollipop. Well, I put on the brakes, I went back, clean up! That's how I raised my children. Now those kids who drink, huppakee, they throw everything down like that - Susan*

Some used to have a very active social role, and prefer to share responsibilities within the neighborhood together. For example Willem, a retired men, who lived for 40 years in his neighborhood. For a very long time, he was one of the board members of the neighborhood association. Not driven by frustration, but driven by the idea that the quality of living:

> *I was able to buy a house very cheaply, so I always only needed part-time jobs for 60% and 80%. (...). That also left me free time, I was very active in the neighborhood in all possible ways; the entire redevelopment of the residential area is kind of done by me. These posts that are here, they would already have been removed ten times and every time I held it back, because cars need to be here, you understand that.* - Willem

There is also a downside of being one of the initiators within the neighborhood. Over time, it became clear that not everyone was always happy with Willem's good intentions. The first 20 years when he lived there, there were no parking lots and everyone just parked wherever there was free space. For example, as a result of his advocacy, inhabitants must apply for a parking permit at the municipality. Loes, a woman in her forties living in social housing and living now for 4 years in the same neighborhood as Willem, stressed the issues with the parking permits three times during our walk.

> *Well, it's a big annoyance, I yet need to write another letter. Look, here you can park freely, but the part where I live is mainly for permit holders... But if you walk around, I do that a lot, four times a day, I see that there is always space at license holder places, so I don't understand why those licenses are not issued.* - Loes

Moreover, it seems that the ones who take responsibility also carry burdens to create the desired future, in this case a comfortable living environment. Nevertheless, they are afraid these burdens will continue in the future:

> *But I have always thought in the interests of the neighborhood, for the great future ahead.... Then there was a meeting in my living room, but then there were neighbors who said: yes, there should be more trees in my street, but not in front of my window. Better lamp posts need to be made, but I don't want them to shine into me. There needs to be an extra barrier, but I don't want that in front of my door. (...). I had a dumpster right in front of my house for years, the new threshold has come right in front of my house, a lamppost shines into my living room. So I was the victim of everything (...). Then I pay the price, I have often worked very against my own interest, I took that with me.*- Willem

Due to feeling collectively responsible for his living environment and being willing to pay the price and mostly deal with the burdens, and where others had the benefits of his work. The burden might go as far that life itself gets difficulties losing your job:

> *Sometimes you have gotten so much on your plate that you yourself go under. Because then you are busy with so many things. I'm even busier with volunteering than with my boss.* – Susan

Strategic Future and Energy Transition

When walking with Fred, a single man in his early forties, living at the edge of the neighborhood, close to a park. Before he bought this house, he lived in various other properties in this same neighborhood or close by. He expressed his concerns regarding locals being part of the decision making regarding certain choices. As he lives on the edge between two neighborhoods, he observed a difference:

> *Yes, but you can also see in neighborhoods such as [name neighborhood], you know, there it is all fine. And people are aware, and you see in such neighborhoods that those neighborhood initiatives in the field of energy transition simply arise by themselves. But in the more working-class neighborhoods, things go completely wrong. - Fred*

Living on the wealthy side, he initiated a local green initiative, which succeeded. Over coffee the idea arose, with two neighbors, to set up a new facebook group for green initiatives. Within this initiative they tried to stimulate action to isolate their properties, instal solar panels etc. Their underlying idea was that early adopters with successful stories inspired others in the neighborhood to follow.

Expected Future Responsibility

As stated above, the expected future finds its origin in the undesired futures: the people do not expect their neighborhood to change. Their expected future, therefore, is a continuation of waste dump and lack of appreciation of green areas.

Two interrelated particular aspects of the expected future play a role in relation to justice. The first is linked to procedural justice and the willingness for citizens to take responsibility. The second is linked to recognition of justice and the fact that citizens do not feel heard or seen by the municipality. When they are taking their responsibility, they feel the municipality does not keep her promise:

> *And then I say, we can also collect the rubbish ourselves, and the municipality has to come and take it away. Well 'no,no, I am not going to do that, because you know beforehand that the municipality is not coming'* -Antje

Also later in the conversation, Antje tells us that they created a dog walking area and social meeting place in the neighborhood, but that had taken over 4 years, because they had to wait for responses from the municipality several times, which leads to distrust.

Furthermore, governmental institutions put a responsibility on the shoulders of citizens that come up with good ideas to improve the quality of the neighborhood. In the example used here, it took seven years to realize a dog playing field. The engaged citizens had a long breath and did not give up. After a while, conflicts emerged with their fellow neighbors. Like Antje, who is one of the volunteers appointed by the municipality to maintain the dog place:

> *Antje: Let me put it this way. we run the dog playground for 3 years. And in those 3 years we have been attacked, cursed, spat on by residents who disagree.*
> *Interviewer: Because due to the key [of the fenced dog playground]; you are also the contact person for and from the municipality to maintain it?*
> *Antje: Yes. Well it is because the dog playground is located in the middle of the neighborhood. you are restricted by certain rules.*
> *Interviewer: is that also to prevent it from becoming a hangout?*
> *Antje: Yes. Also. But also for nuisance.*

This example shows that local governments do not fully realize that giving inhabitants a key to a public space also causes serious social burdens. The transferred responsibilities of local governments toward inhabitants put pressure on the role of the inhabitants, who could be considered as privileged by other neighbors. The citation above even stresses how this one key is a reason for intimidating behavior between citizens in one neighborhood, in this case against those who have the key.

Expected Futures and the Energy Transition

When looking at energy transition processes, the economic expected futures play a role. Flat owner David expressed:

> *Last week I was approached by the municipality with the message that they want to generate electricity locally. But it doesn't make that much difference at all. I am still cheaper with my current energy supplier. That is also GreenChoice. That is not local, but relatively green electricity. On that part I choose eggs for money, because it shouldn't cost me more and more.- David*

As already became clear throughout earlier stories, David makes choices anticipating an economic expected future. He is really well-known about the nuts and bolts of his current situation, and financial aspects are frequently the main condition to change or remain a situation.

The technical future was mainly negatively anticipated in these efforts by the citizens in their stories. House owners are sometimes interested in improving their property with technical measurements. They attended (online) information evenings, replied to flyers, made phone calls with for example solar panel companies and even made serious calculations about the costs and benefits. Rogier lives with his family in a large municipal monument that he bought a couple of years ago. He knew the house was for sale, but also in poor maintenance conditions, as his brother and his wife are their neighbors. For technological development, the limitations are stressed rather than the potential. Rogier stresses for example:

> *There are hundreds of people who advertise, such as IKEA and the energy companies, who even want to rent out solar panels to you so that you don't have to make a big investment all at once. I think: bring it on, I will calculate what the benefit is for me and whether that actually makes sense. Where is it going now? I don't have a standard house. 'Ah, it's a monument. We will not start on that. ' 'I'll figure it out, I'll apply for that permit.' 'Okay. What kind of roof do you have? Oh, you have a cold insulated roof, we're not getting into that. The angle, not standard. If you had had a tiled or flat roof, it would have been fine. ' It's all 'desk so much' again. So as long as it's all standard... - Rogier*

Other people anticipated different expected futures. When speaking to Arnold, a man in his forties living in social housing, in the past he also had been approached to switch energy providers. In case he would switch to this provider, he got a sports shirt of his favorite football team for free, which made him switch. He was very happy in the beginning (also with the bills), though, after a couple of months when they recalculated his consumption, he had to additionally pay almost 1/3 of the original amount while he did nothing different than before. The next year, as soon as he could, he switched back to his previous energy provider and told me that he would never ever switch again due to this experience.

DISCUSSION AND CONCLUSION

The aim of this exploratory paper was to analyze and compare the future narratives in Dutch energy policy with the future narratives of citizens affected by the energy transition to identify potential mismatches, particularly with regards to how issues of justice were considered in these narratives. We identified two forms of mismatches: (1) opposing mismatches, where policy narratives and narratives of citizens anticipate antagonistic futures, and (2) disconnected mismatches, where the mismatch emerges because narratives do not engage with each other and focus on different issues. It should be taken into account that these are the *dominant* mismatches. The variety of narratives within communities are much more diverse and detailed than what can be covered in this paper. Hence, we identified several main mismatches (see **Table 2**) that could potentially contribute to hampering the implementation of the energy transition. These mismatches of anticipated futures are linked to justice issues. In the future, these mismatches might lead to negatively experienced consequences on both an individual as well collective level.

With regards to desired future, policy narratives focus strongly and optimistically on achieving national carbon neutrality until 2050, however, this narrative disconnects with future desires represented in citizens' narratives. Citizens' desires are more localized in scale, and broader and more comprehensive in scope, namely creating comfortable living environments (clean, green, safe). Opposing narrative can be seen according to the type of future: citizens' narratives appear to be more pessimistic, preventing undesired futures such as waste dump, less green, etc., then policy narratives, which are optimistic with a clear desire, carbon neutrality. Disconnected is the narrative on the content of the undesired futures. The undesired future represented in policy narratives on the municipal level is to prevent that the energy transition causes economic burdens and energy poverty for citizens. The main focus of citizens is on a clear, safe, and green living environment. This mismatch may cause issues for distributive justice in the future as citizens may experience and value the distribution of burdens and benefits in the context of the energy transition differently.

There are two, although related, opposing mismatches with regard to expected futures: policy narratives have an optimistic long-term perspective expecting that the energy transition will produce economic benefits due to cheaper energy sources, and that technological development will take place in the future that will enable/facilitate the energy transition. However, citizens do not expect that technological development will enable the energy transition as they are faced in their daily practices with the difficulties of implementing low-carbon measures. Similarly, they sometimes also expect an extra economic burden of investing in low-carbon energy sources. Hence, policy future narratives and citizens' future narratives show an opposing mismatch when it comes to the expected distribution of burdens and benefits, which may lead to distributive justice issues in the future. This opposing mismatch is critical as citizens are clearly recognized in policy narratives as an essential actor and driver to implement the energy transition. Hence, most citizens anticipate different desired and expected futures and hence, consider different potential long-term benefits.

According to the strategic future, we see an important and active role of *individual* citizens in the policy document. The motivation of the citizens derives from a translation of the policy goals (carbon neutral, cost efficient). In other words, citizens are expected to participate because they too want to reach these goals. However, although citizens' might take individual responsibility (e.g., changing their everyday lifestyles or implementing carbon low technology), yet striving for another desired future, a clean and safe neighborhood. Carbon neutrality is not a dominant issue that comes to the fore in the citizens' narratives. Policy does not present a narrative that clearly links the energy transition to the desired future narratives of neighborhoods. However, as became clear in the narrative regarding the dog walking place, this transferred responsibility of local governments toward the shoulders of active citizens negatively affects the position of

TABLE 2 | Overview of mismatches between future narratives in policy and citizens.

Anticipated future	Narrative mismatch	Policy narratives	Citizens' narrative
(Un)desired	Disconnected (issues of distributive justice)	Carbon neutrality, cost efficient (national-wide, specific)	Focus is broader on neighborhood as a whole (localized, broad-comprehensive)
	Disconnected (issues of distributive justice)	Preventing economic burdens and energy poverty (local)	Creating clean, safe, and green living environment
	Opposing (issues of recognition justice)	Focus dominantly on desired futures (optimistic)	Focus dominantly on undesired futures (pessimistic)
Expected	Opposing	Technologic (mainly optimistic, long-term)	Technologic and economic (pessimistic, short-term)
	Opposing (issues of distributive justice)	Economical benefits	Economic benefits and burdens, no changes in the neighborhood concerning waste dump and green. Fear of conflict
Strategic	Disconnected (issues of recognition justice)	Individually: Direct translation of abstract goals to individual goals (economic, environmental)	Individually: Responsibility for their desired future (clean/green local environment)
	Opposing (issues of procedural justice)	Collective: neighborhood approach: active participatory and co-creative with citizens	Collective: citizens fear conflict when they take the lead in collective approaches (expected future) Citizens hesitate to trust governmental institutions in being supportive to facilitate local initiatives (expected future).

these citizens within the neighborhood, which may cause issues with regards to procedural justice or recognition justice as active citizens might be disrespected within their own community.

Another opposing mismatch in strategic futures is at the collective level. The policy documents argue that a collective neighborhood approach should be adopted to implement the energy transition. This approach should be based on participatory and co-creative decision-making. However, this narrative is an opposing mismatch with the narratives of citizens in two ways. First, the narratives of citizens demonstrate that taking responsibilities for collective neighborhood initiatives can be a quite challenging task. Not only because the people taking the initiative feel like carrying the burden, but also because collective neighborhood approaches sometimes result in controversy or even conflict among neighbors as other neighbors do not accept how costs and benefits are distributed. Second, citizens' narratives stressed the negative experiences they had with the municipality in the past. They explained that their concerns were not taken seriously, that the procedures were bureaucratic and that it took a lot of time and energy. This decreases the willingness of citizens to lead or participate in these collective initiatives. This indicates that future issues of procedural justice in the form of non-participation might be caused by past experiences of misrecognition. In the literature on energy justice, little attention is being paid to conflicts among citizens stemming from the participatory approaches to implement the energy transition.

A final observation is that the policy documents recognize an important role for citizens in the energy transition process. Hereby, policy documents recognize that neighborhoods and citizens differ in terms of economic and cultural characteristics, however, this recognition justice remains still abstract and is—for now—hardly translated into strategic considerations. The dominant future policy narrative with its focus on economic future considers mainly the position of higher educated citizens, but does not recognize the position of lower educated citizens, socially-deprived households or households of a different cultural background. Our analysis of citizens' narratives clearly stresses the diversity and idiosyncrasy of citizens with regards to their future narratives. This diversity is not only based on statistical socio-economic characteristics (e.g., tenant/property owner, income, education), but also on their experiences in the neighborhood. From an energy justice perspective, it raises the question whether citizens have the capabilities to take on these responsibilities (see also Walker and Day, 2012).

Notably, these mismatches present analytical conclusions based on exploratory research, but focus on the dominant, broadly shared futures. That means they might be differently applicable for each (group of) citizen(s). Further research could be done to specify between (groups of) citizens and narratives, and/or at the relation between matching—and—mismatching and opposing narratives.

Theoretically, this paper combined the literature on future-making with the literature on energy justice. For future studies, the justice literature provides concrete aspects to consider when focusing on worldviews or perspectives. We observed that the policy documents apparently paid relatively little attention to the futures anticipated by other actors in the energy transition. Critical futurists might argue that alternative futures are not considered in the policy futures. The literature on energy justice helps us to pinpoint the mismatches more clearly. For the literature on energy justice, the current justice literature tends to focus on the fairness of decision-making procedures, the fair distribution of burdens and benefits, or the respectful recognition of groups' particular idiosyncrasies, which are often analyzed in ex-post analyses paying little attention to futures. That is a missed opportunity for two main reasons. First, policies are based on particular anticipated futures. Hence, excluding certain groups' future narratives increases the danger of reproducing injustices. Not acknowledging or (mis)recognizing alternative expected and desired futures of vulnerable groups may contribute to the creation or reproduction of existing injustices (cf. critical futurists). In this paper, we have not analyzed the societal consequences of particular future narratives, hence, we cannot prove in how far the exclusion of certain citizens' future narratives actually (re)produces injustices. However, what our analysis has shown is that there are several disconnected and opposing mismatches between the future narratives in policy documents and those present among citizens.

Our analysis also indicates more practical insights for policymakers. An ex-ante evaluation of future narratives dominant in policymaking could prevent reproducing injustices in policies. This can be done by policymakers paying more attention to developing multiple future narratives on desired futures that links the individual desired futures of citizens more clearly to the energy transition. In order to do so, our method proved that (one-to-one) walk-alongs work. Attitudes are less offensive when citizens experience that they are literally seen and their voices are heard, in contrast, with digital surveys of which they are never sure what happens with the outcome. Not only can they collect citizens' futures, the walks can also improve the relationship between citizens and policy to listen and learn from each other's futures. This approach may help to integrate or the narratives, which leads to a more societal support to implement the energy transition.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

By using an online text editor we were able to write together and have discussions about the arguments made in this article real time and contributed all equally to this article. SV and MK raised the funding, were SH conducted the interviews. All authors contributed to the article and approved the submitted version.

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Energy Transition and Sustainable Road Transportation in Turkey: Multiple Policy Challenges for Inclusive Change

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This paper aims to explore energy insecurity in Turkey at the intersection of environmental sustainability, human security and justice vis-à-vis growing energy demand coupled with greenhouse gas emissions coming from the transport sector. High dependence on fossil fuel imports creates bottlenecks for the economy and require urgent shift to renewable energy sources. Prospects for renewable energy transition are analyzed based on focusing on total final energy consumption by energy and transport sector as well as greenhouse gas emissions. In order to propose holistic clarifications to the triangular problem of high fossil fuel dependence, energy demand increase and greenhouse gas mitigation, sustainable energy transition in road transport is put forward. It is justified based on the share of greenhouse gas emissions originating from road transport sector and high taxation levels that create extra burden on private consumers. Energy transition is conceptualized with the theoretical offerings of sustainability transition literature that point out to socio-technical processes, hence the societal, technological as well as external structural contexts of change. Upon this background, this policy and practice review outlines the current policy instruments in order to highlight the mismatch between policy and practices for just energy transition in conjunction with sustainable mobility in Turkey.

Keywords: energy transition, renewable energy, sustainable mobility, electric vehicles, greenhouse gas emission, road transport

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INTRODUCTION

Energy balance of Turkey demonstrates importance of hydrocarbon fuels, particularly coal, natural gas and oil products within the national energy mix (Eurostat, 2020). Fossil fuels have been increasing their share within the total primary energy supply of Turkey. Oil (30%), natural gas (30%), and coal (28%) own the biggest share in total primary energy supply, whereas the share of renewables has been increasing over time but accounted to only about 12% in 2018 (IEA, 2019a).

Turkey has great dependence on fossil imports and its energy demand is set to increase in the future. It is among the world's rapidly developing power markets with its dynamic population, increasing energy demand as a result of continuous economic growth and large-scale urbanization occurred within the last decades (Bilgen et al., 2008). Turkey intends to decrease its energy vulnerability through use of indigenous sources, namely coal as well as nuclear energy development (Richert, 2015). Although, there is great potential for renewable energy deployment there are a number of obstacles that impede their full utilization. Turkey does not have a consistent mitigation strategy and hesitates to ratify Paris Agreement (Alkan et al., 2018). Nevertheless, there are further inconsistencies apparent in Turkey's energy policies. Turkish government aims to improve the renewable energy share within its electricity generation and to meet 10% of its increasing energy demand of the transport sector from renewable sources through a series of policy initiatives. However, there is continuous support for coal use given to producers as well as consumers in need which contradict the political will for renewable energy development and greenhouse gas mitigation (Republic of Turkey, 2012; Republic of Turkey's Voluntary National Review, 2019).

Energy sector is responsible of about 72% of greenhouse gas emissions in Turkey and transport sector alone emits 21% of greenhouse gas emissions as of 2019. GHG emissions of energy sector has raised by 172% over the period of 1990–2017 which signals for alarming need to shift to renewable sources (Republic of Turkey Ministry of Environment Urbanization, 2019). As a result of high dependence on oil in transport sector, the greatest proportion of emissions are derived from the road transport, which more than tripled in 1990–2017 (UNFCCC, 2018, as cited in Climate Action Tracker Report, 2019). On the other hand, energy demand of the transport sector is expected to increase along with the GDP per capita (Saygin et al., 2019). Turkey's UN Climate Change Conference of Parties (COP21) commitments under the current Nationally Determined Contributions and with regards to the 21% reductions of business as usual (BAU) emissions are found to be very optimistic and lacking credible policy outcomes (Işeri and Günay, 2017; Kat et al., 2018). Therefore, it is argued that transformation of the transport sector through integration of domestic renewable sources can decrease energy dependence as well as greenhouse gas emissions of Turkey.

Energy vulnerability has repercussions on a variety of issues including poverty that create inequalities. Energy security means, firstly, securing access to energy by the poorest rural regions and secondly, uninterrupted access to it by different sectors of economy (Kuik et al., 2011; Månsson et al., 2014). The term energy poverty is commonly regarded as access to modern energy services.

Definition of energy access by the IEA encompasses stable and affordable access to electricity and cooking fuels that are environmentally sustainable instead of reliance on traditional sources of biomass, wood or dung (Birol, 2014). It must be stressed that access to modern energy services is not restricted to basic human needs, but also involves productive and modern uses as well as mobility to ensure development, considering their interactive relationship (Sovacool et al., 2012). Mobility as another key energy service implies varied transportation options with adequate infrastructure and fuel sources at cost-effective prices (Woodcock et al., 2007, as cited in Sovacool et al., 2012).

Physical accessibility to electricity does not appear to be a problem in the case of Turkey, where number of people without access to electricity fell from 6 million in 1990s to zero as of 2016 (The World Bank, 2020). Energy poverty in Turkey implies the problems of affordability for basic energy services including electricity, heating and transport. Although there are different ways to calculate energy poverty, one way of looking at it is by measuring the portion of income that is allocated for access to energy services, where 10–15% of a family's monthly or yearly earnings spent on energy services marks the household as energy poor (Dutta, 2011, as cited in Sovacool, 2014). Selçuk et al. (2019) conclude in light of the 2017 data that about 25% of households were computed as energy poor even though that number decreased over time with respect to 2003 levels; and 50% of the lowest income households were regarded as energy poor in Turkey. Despite the fact that energy is an invaluable source that is vital for the conduct of modern daily lives whether it is for cooking, keeping homes warm in winter, cool in summer; working and studying; or producing a variety of goods and services, its affordability seems problematic for low-income Turkish households (Bilgen et al., 2008; Emeç et al., 2015).

According to OECD's Taxing Energy Use Country Note (OECD, 2019a,b) coal and coke for industrial or residential use are not being taxed in Turkey, but neither are renewables. Indeed, coal subsidies granted to poor families for heating greatly hampers transition to cleaner alternatives and has direct effects on air pollution as well as health conditions. Turkish government provides social contribution in the form of coal subsidies for households whose income per person is less than one third of the net average income, and for heating at minimum amount of 500 kg provided once each year in winter. There are further inconsistencies in Turkish energy and climate policies. Transport sector requires an in-depth look for energy sustainability and within the context of energy vulnerability in Turkey, as it holds great share of energy demand and greenhouse gas emissions in the country. Transport poverty is reflected in the share of expenditures for transportation in Turkish households' budget as well as high price components for gasoline and diesel. Transportation expenditures has been increasing its share within the Turkish households' budget over the period of 2009–2018 and reached to 18.3% of the total yearly expenditures in 2018 [Turkish Statistical Institute (TurkStat), 2018]. It is possible to make a correlation between energy/fuel poverty and transport affordability which infers vulnerability to fuel price raises. Difficulty in affording transport costs imply transport poverty, although it is often neglected in the policy discourses as well as in energy poverty literature (Mattioli et al., 2018).

High fuel prices may impede individuals' liberty of mobility and even create further obstacles in terms of socio-economic exclusions; thus, transport poverty may translate into failure of meeting one's personal and diverse transport needs (Berry et al., 2016). Indeed, measurement of transport affordability is rather difficult and complex through mere assessment of the share of household budget as it may be an individual phenomenon rather than the problem of the entire household, even though it is usually accepted that households' transport expenditures exceed that of energy (Mattioli et al., 2018). Mattioli et al. (2018) identifies prices, income and energy efficiency, that includes among all the others, vehicle efficiency as the prominent drivers of fuel poverty with regards to transport affordability.

Turkey has one of the highest levels of gasoline prices in the world which partially stems from the high share of taxes as the government have aimed at increasing its tax revenue since 1999 (Biresselioglu et al., 2014). The high taxation rates imposed on the transport sector could be with the purpose of covering high externalities or higher inelasticity of fuel demands which in return exacerbate revenue increase purposes as energy tax rate levels in Turkey are not optimal due to lack of carbon pricing and fuel efficiency standards for vehicles (Bardazzi and Pazienza, 2014; Bali and Yayli, 2019). Although CO_2 labeling of new vehicles had been introduced in 2009, absence of mandatory CO_2 regulations for manufacturers and tax components hampers the required incentive to change user behavior (Mock, 2016). Inevitably, fuel and vehicle prices in Turkey fail to reflect the environmental costs. On the contrary, high gasoline prices has resulted in a shift to more polluting LPG and diesel used vehicles (Saygin et al., 2019).

Therefore, it is argued that electrification of transport systems in Turkey can provide multiple benefits for energy system changes on different grounds. Firstly, it can reduce greenhouse gas emissions to the benefit of climate change mitigation. Secondly, provided that it will be integrated with electricity supply from local renewable sources it can promote renewable energy deployment and increase energy security (Yergin, 2006; Valentine, 2011). Thirdly, it can help to reduce transport poverty and related inequalities in Turkey. However, large-scale development of electrified vehicles requires cost competitive solutions that can enable equitable diffusion to reduce transport poverty. Indeed, there are various obstacles to be addressed which include choosing the best policy mechanisms that shall offer incentives for suppliers and consumers. A combination of public subsidies in the form of tax incentives; guarantees to reduce financing and other risks; leases as well as R&D spending for sectoral efficiency targets are fundamental in scaling up investments.

Geographically and territorially speaking there is great consensus on the huge opportunities for deployment and full utilization of renewable energy in Turkey (Biresselioglu, 2012; Sekercioglu and Yilmaz, 2012; Mete and Heffron, 2015; Karakosta et al., 2016). However, even if clean energy resources are available, development of incentives through right policy tools for large scale deployment remain as a critical issue to be addressed. So far, the urgent need for meeting increased energy demand and insufficient funding for renewable energy development have led to prioritization of projects with low capital cost over short timeframes in Turkey; but it resulted in more dependence on natural gas imports and environmentally unfriendly options (Sirin and Ege, 2012; Röhrkasten et al., 2016).

Inevitably, Turkey's high energy dependence on fossil fuels and prospective increase in its energy demand create multiple bottlenecks for energy security in geopolitical, environmental and socio-economic terms. Energy as a vital source for conduct of modern daily lives shall be made available and affordable for everyone without compromising the needs of future generations. Having clean alternatives is essential to protect energy vulnerabilities of consumers at the face of price increases or supply disruptions. Review of related policy mixes, namely policy instruments that shall interact to orient attention among public and private actors can help achieving the overarching policy objectives (Kern et al., 2019). Acknowledging the increasing energy demand coming from road transport sector, Turkish government has put various targets under legislative actions and political commitments. This study aims to outline the existing policy framework for energy transition in Turkey and with a particular focus on sustainability transition of the road transport sector. This policy and practice review is organized as follows: analytical grounds of sustainability transition are introduced to underline the pre-requisites of just energy transition and its assessment methods. A qualitative research through in-depth review of public and international reports, policy papers, legislative acts is conducted to assess the most effective policy tools for decarbonising the road sector while drawing parallels with the best practices in the world. The study concludes with a review of key findings and actionable recommendations for just energy transition in order to point out to the existing policy gaps.

ASSESSMENT OF POLICY OPTIONS AND IMPLICATIONS WITHIN THE ANALYTICAL FRAMEWORK OF SUSTAINABILITY TRANSITION

Required environmentally friendly technologies for full utilization of sustainable energy resources are not always cost-efficient, which in return result in trade-offs in government's policy outcomes in the domestic framework. In line with this view, some scholars studied the historical evidences of energy transitions with an attempt to provide future insights. It is concluded that a new energy source with its technologies can become competent over incumbents upon the condition that its services are cheaper than those alternatives (Fouquet and Pearson, 2012). Indeed, the transitions take a very long time and are rather complex processes. Early examples of transition to coal as a result of increase in the price of wood in Great Britain provided a strong incentive in diverting consumers' energy choices at the wake of Industrial Revolution (Allen, 2012).

The role of policy processes upon influencing the extent of sustainability transitions is a widely contested topic in the literature (Meadowcroft, 2011; Lockwood et al., 2016; Roberts et al., 2018; Köhler et al., 2019). The interplay between political factors and economic, technological, and social links are widely conceptualized within the framework of socio-technical systems transitions. Sustainability transitions remain highly political, as regulatory frameworks and distribution of social revenues often require state intervention or governance reform, considering that changes can only be achieved through political processes (Meadowcroft, 2011; Lockwood et al., 2016). According to Meadowcroft (2011), political engagement is taken as a pre-requisite for building coalitions and constructing power centers among different actors.

Socio-technical transitions consist of the socio-technical landscapes and niche innovations that continuously interact with each other (Kuzemko et al., 2016). Moreover, socio-technical transitions of energy regimes infer path dependencies for the adoption of technological innovations, which in return require long-standing commitments to research and development practices. It feeds back to the importance of external structural context of the landscape level, hence the governance with adaptive capacity for the creation of knowledge, supply of necessary resources and formation of markets that will ensure spill-over effects (Smith et al., 2005). In addition to tools used for the social acceptance of renewable energy innovations, Mallett (2007) points out to the role of technology cooperation, whereby adaptation takes place via diffusion and acceptance of new equipment, practices as well as know-how among variety of factors including private sector, civil society and local governments. Overall, it is possible to include different variables consisting of technology, regulation, infrastructure, user practices, cultural meaning as well as maintenance and supply networks for transitions occurring at the intersection of technological niche, socio-technical regime and socio-technical landscape (Geels, 2005).

In the past, security of supply and climate change have been at the center of energy transition narratives. Current discussions are incorporating policy mixes that reshape green deal proposals through social innovation and digital revolution, whereby different social groups play an active role in their reproduction (Bloomfield and Steward, 2020). However, there is relatively limited attention paid to normative impacts of sustainability transitions that incorporate ethical considerations for equity and justice implications (Köhler et al., 2019). Societal transformations will determine the new configuration of wealth distribution, new opportunities and assigned privileges specific to certain social groups (Bennett et al., 2019). Climate mitigation policies may lead to exacerbation of inequalities particularly for the most vulnerable groups including low-income households, migrants, or ethnic minorities (Markkanen and Anger-Kraavi, 2019). Given the intrinsic relation between access to energy services and human development, there is urgent need to treat sustainability transitions with a bottom-up approach that incorporates human values of justice and equity rather than analysis of merely political processes or technological niches.

Considering that transitions hold the potential to exacerbate existing vulnerabilities of people, incorporating a justice dimension to sustainability transitions is imperative (Bennett et al., 2019). Conflictual lines between sustainability and social justice issues are often addressed within the specific domains of energy, and transport inequality. Indeed, ensuring access to affordable, reliable, and modern energy sources enables socio-economic development as energy is the key input for conduct of daily life. However, inequalities in accessibility and affordability of key energy services including mobility persist (Simcock and Mullen, 2016; Mattioli et al., 2018). Adoption of new technology and innovation for energy transition may constitute important barriers that can generate further exclusions. On the other hand, sustainable transport systems that rely predominantly on private vehicles compromise mobility justice (Mullen and Marsden, 2015).

Consequently, transformative and structural societal change requires addressing the existing inequalities to contribute toward more comprehensive policy making at multi-levels of governance frameworks. Exploration and anticipation of ethical implications in the framework of sustainability transitions can contribute to ex-ante mitigation policies in order to prevent further exclusionary policy action from early stages. Indeed, adoption of a bottom-up approach that treats sustainability transition as a prospective problem rather than the ultimate solution necessitates consideration of the most vulnerable segments of society. Novelty of such contributions will be identification of community-based solutions that include normative values of social justice on the path toward zero-carbon and more inclusive societies. Bridging the gap between top–down policy making and societal frameworks is essential if we really want to build better futures.

Development of Renewable Energy Policies in Turkey

Turkey's national energy policy has aimed at decreasing its import dependence and enhancing energy security through diversifying its energy imports, ensuring integration among its regional markets, scaling up its domestic energy production with coal, lignite, nuclear energy and renewables as well as improving energy efficiency (OECD, 2019a,b). Despite significant policy changes of the past, it is worth questioning why the past efforts resulted in so little change in terms of successful sustainability transition.

Remarkable renewable energy potential of Turkey has not been fully utilized yet and insufficient number of measures have been adopted in line with privatization efforts since the 1980s (Bilgen et al., 2008). Although acknowledging the significance of political drivers for change as provided by the theoretical contribution of sustainability transition, there are number of multi-level challenges including adoption of new scientific knowledge that is necessary to achieve practice changes. Therefore, explanation of the existing mismatch between policies and practices in Turkey will be key to identify the recurring shortcomings for further development of renewable energy innovations including those required for electrification of the transport sector.

Reduction of capital costs at the early stage of new renewable energy technologies require supplementary fiscal support mechanisms for them to have economies of scale whether through tax exemptions, specified feed in tariffs, or market guarantees (Apak and Atay, 2013). Since 2001, Turkish government has been giving importance to full liberalization of its internal energy market (Mete and Heffron, 2015). Power plants installed by renewable energy have been integrated into the distribution system with various efficiency targets. The legal basis aimed at scaling up the investments of renewable energy sources within electricity generation was enacted in 2005 through "Law No. 5346 on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy."

Turkey aims at increasing the share of renewables in its total primary energy supply with a target to produce 30% of its electricity from renewable energy sources by 2023. However, electricity demand from local coal reserves amounted to 37% of the total generation in 2019, which signal major setback in achieving clean and sustainable energy use[1].

[1] *Turkish Electricity Transmission Corporation, Electricity Generation—Transmission Statistics of Turkey.*

"Energy Efficiency Law No. 5627" was also introduced in 2007 with the ultimate purpose of enhancing efficiency of energy sources in order to prevent energy waste, promote environmental protection as well as remove the extra burden of energy costs weighing on the economy[2]. Indeed, advancements of energy efficiency may lead to reduction of energy consumption levels and costs borne by different economic sectors through technological promotion. More concrete energy efficiency targets were later reinforced to provide a guideline for transport sector and decrease its energy density (Republic of Turkey, 2012-2023).

In accordance with the Law No. 5346, feed-in-tariffs were put forward with purchase guarantees for electricity generated from renewable sources[3]. However, investments of renewable energy technologies did not improve due to high technology costs that were not covered by the proposed tariff levels in 2005–2010. Therefore, the existing legislation was amended in 2010 with "Law No. 6094" that introduced new incentive mechanisms with higher feed-in-tariff rates in order to attract more investors[4]. Turkey has already achieved its 2023 target of 30% electricity generation from the renewables partially stemming from the introduced feed-in-tariffs for investment support (OECD, 2019a,b). Accordingly, the Renewable Energy Resources Support Mechanism was established to determine the guaranteed purchase tariff rates for electricity generation from different renewable energy resources. The new feed-in tariff program incorporated use of diverse technologies and bonus promotions for utilization of local equipment with the aim of boosting the national industry. Use of nationally manufactured equipment during the installation phase enables price subsidy per product for a maximum of 5 years. Additional incentives are provided for R&D activities of domestic renewable energy development. However, the designated timeframe of this support scheme is restricted to facilities commissioned until December 2020. The funding of investments cannot exceed 10 years which has been perceived as one of the most discouraging factors for projects with longer life cycles (Varlik and Yilmaz, 2017).

Existing targets set to reinforce electricity generation from renewable energy sources comprise of 34.500 total installed power capacity in hydro (53% increase compared to current level), 20.000 MW in wind (625% increase), more than 1.000 MW in geothermal (223% increase), 5.000 MW in solar and 1.000 MW in biomass (346% increase) to be achieved throughout 2013–2023. Investors have the option to select among the fixed feed-in tariffs or make sales directly at the power market (Mete and Heffron, 2015). The investors face the challenge of making the most cost-effective investment decisions. For instance, ambitious target set to increase wind power capacity is deemed to be pretty challenging to attain, mainly due to lack of access to adequate financial resources.

[2]Law No.5627 (2007). *Energy Efficiency Law*. Available online at: https://www.resmigazete.gov.tr/eskiler/2007/05/20070502-2.htm

[3]Law No.5346 (2005). *Law on Utilization of Renewable Energy Sources for the Purpose of Generating Electrical Energy*. Available online at: https://www.mevzuat.gov.tr/MevzuatMetin/1.5.5346.pdf

[4]Law No.6094 (2010). *Amending the Renewable Energy Law*. Available online at: https://resmigazete.gov.tr/eskiler/2011/01/20110108-3.htm

Low feed-in-tariff rates along with bureaucratic obstacles for licensing are regarded to hamper instead of incentivising renewable energy investments in Turkey (Mete and Heffron, 2015; Richert, 2015). Livingston (2018) concludes that continual weakness of Turkish lira and challenging macroeconomic conditions provide further financial limitations for renewable energy development (Livingston, 2018; Mahmud and Sirin, 2018).

Establishment of a conducive political and economic environment to renewable energy investments is one of the greatest obstacles to overcome in Turkey. Financial barriers persist against the government's plans to increase renewable energy output (Beck and Martinot, 2004; Kalehsar, 2019, p. 13). Limited financing is exacerbated by lack of alternative sources including for energy efficiency investments (Taranto and Dinçel, 2019). Solar energy target at 5,000 MW is also deemed very ambitious despite the fact that solar PV technologies enabled decrease in investment costs. In contrast to great availability of solar power utilization in Turkey the main barrier in deployment of PV technologies is related to the power limit of 600 MW that has been imposed through "Law No. 5346 on Utilization of Renewable Energy Resources for the Purpose of Generating Electrical Energy." Biomass sources are widely used in Turkey despite high tariff rates, but their advancement is linked to access to raw materials and their relative technology. On the other hand, investments of geothermal energy and hydro power are widely considered feasible for electricity generation.

Another important policy mechanism was established through Renewable Energy Resource Areas that enabled land use fee incentives with a discount rate of 85% applied to lease and permission fees including for treasury owned or state properties with great potential for renewable energy facilities during the first 10 years of projects comprising of the investment and operational phases[5]. Despite existing incentives, the main obstacles that hinder renewable energy deployment in Turkey include insufficient tariffs, unsuitable network connections, difficulties in storage and transfer, inadequacy of research and development funds, high cost of technologies as well as the limitations that investors have to face in sustainable financing (Varlik and Yilmaz, 2017). Acknowledging the stringent factors on public financing mechanisms, Uyar (2017) finds the solution in promotion of energy efficiency targets through utilization of effective technologies such as smart grid and energy storage in industry, buildings as well as in transport sector.

National Renewable Energy Action Plan (Republic of Turkey Ministry of Energy and Natural Resources, 2014a) became one of the main pillars of Turkey's energy policies in alignment with the European Union (EU)'s Directive 2009/28/EC on promotion of the use of energy from renewable sources. It introduced key strategies for increased share of renewables within the electricity generation, enhanced technological and industrial deployment of renewable energy sources taking into account mitigation efforts for climate change until 2023. Energy efficiency audits

[5]Regulation No. 29852 (2016). *Renewable Energy Resource Areas*. Available online at: https://resmigazete.gov.tr/eskiler/2016/10/20161009-1.htm

and energy management systems became obliged for certain industrial enterprises.

Use of renewable energy in the buildings and full utilization of renewable sources in transportation to achieve 10% share have been among the main objectives with the target of implementing European Union's directives (National Renewable Energy Action Plan, 2014-Republic of Turkey Ministry of Energy and Natural Resources, 2014).

Sectoral Targets for Transport Under National Energy Efficiency Action Plan

Share of road transport in energy demand exceeds 90% in Turkey where passenger cars and freight transport play a major role (Saygin et al., 2019). Turkish government have adopted a strong focus of achieving transition in transport sector although the existing policy frames are still at an infant stage.

Policy mechanisms that introduced mandatory biofuel use with the tax exemptions has been a step forward. Legislative measures aimed at increasing the use of renewable energy and enabling progressive integration of biofuels in the transport sector include bioethanol obligation and tax exemptions (National Renewable Energy Action Plan, 2014-Republic of Turkey Ministry of Energy and Natural Resources, 2014). Mandatory bioethanol content in gasoline for road fuel/petroleum produced from domestic products and supplied to the market was set with a target of 2% since January 2013, and 3% as of 2014 in accordance with the decisions of Energy Market Regulatory Authority.

Energy Market Regulatory Authority also mandated special consumption tax exemptions for use of 2% bioethanol, that have been produced from domestic products and mixed with petroleum. National Energy Efficiency Action Plan, 2018-Republic of Turkey Ministry of Energy and Natural Resources (2018) puts industry, technology and transportation at its focal point for promotion of best practices and know-how in energy efficiency and environmentally friendly energy usage. Energy efficiency has been among the key objectives of Turkey's energy policies due to energy intensity of the industries as well as the transport sector.

Achieving sustainable energy transition and energy efficiency in transport sector, particularly in line with the weight of road transport which is a major consumer of petroleum products are among the government's policy priorities (National Energy Efficiency Action Plan, 2018-Republic of Turkey Ministry of Energy and Natural Resources, 2018). Energy supply security, environmental pollution, and related health problems as well as degradation of biodiversity because of inefficient practices held in transport sector are underlined with this regard.

Energy consumption by transport sector has been growing and it is estimated to keep increasing in the near future considering high dependence on oil and petroleum imports in transportation. Therefore, National Climate Change Action Plan 2017–2023 sets forth determined targets to reduce old vehicle models and support alternative fuel options with enhanced energy efficiency over the period of 2017–2023 (Climate Action Tracker, 2019). In this perspective, raised points include rebalancing the distribution of different modes of transport through development of combined utilization in passenger and freight transport (National Energy Efficiency Action Plan, 2018-Republic of Turkey Ministry of Energy and Natural Resources, 2018).

The role of road transportation is aimed to be diminished through expanded and modernized railway networks as well as frequent use of maritime transport within the public transportation systems. Reduction of the weight of road transportation to below 60% for the freight and below 72% for the passenger transport are intended targets by 2023.

Acknowledging the need for shift to sustainable transport systems, Turkey has been aiming to plan suitable infrastructures with integrated modes of transport while lowering the vehicles' unit fuel consumption levels. Strategical purposes to be achieved by 2023 include abatement of per unit fossil fuel consumption from motorized vehicles, increasing the role of public transportation including on the highways and sea transport in order to decrease the fuel intensity in urban transport systems (Republic of Turkey, 2012-2023). Significance of technological advancements along with extended financial tools are underlined to achieve these targets. Energy efficiency in transportation is particularly encouraged with integration of smart management systems and competent infrastructure. Determined activities are set forth in line with the EU regulations on CO_2 emission standards to be able to reduce fossil fuel use in motorized vehicles (Republic of Turkey, 2012-2023)[6].

Accordingly, fuel cell and hybrid electrical vehicles with smaller motor size are strongly promoted with legislation of an accompanying bill to be developed in accordance with the implementation of environmental taxes of vehicles in the EU and other OECD members. Use of biofuels and synthetic fuels are also aimed to be encouraged in transport systems with excise tax discounts as long as their domestic productions are not detriment to the national agricultural sector. Policy measures for the achievement of promoting use of renewable energy sources related to transport sector encompass biofuels obligations and tax exemptions (National Renewable Energy Action Plan, 2014-Republic of Turkey Ministry of Energy and Natural Resources, 2014).

Guidelines described under the subsequent National Energy Efficiency Action Plan are in line with the Energy Efficiency Strategy targets to promote sustainable and energy efficient transport systems in Turkey. The priority areas identified to improve energy efficiency of vehicles are advancement of research development on alternative fuels and their technologies, build-up of bicycle transport options and elimination of passenger cars to curtail the traffic congestion.

The market outlook for electric vehicles is positive as there are several initiatives that already took place with forward looking targets to be achieved until 2030. Accordingly, pilot projects for

[6]*Regulation (EU) 2019/631 of the European Parliament and of the Council of 17 April 2019 setting CO2 emission performance standards for new passenger cars and for new light commercial vehicles. & Regulation (EU) 2019/1242 of the European Parliament and of the Council of 20 June 2019 setting CO2 emission performance standards for new heavy-duty vehicles.*

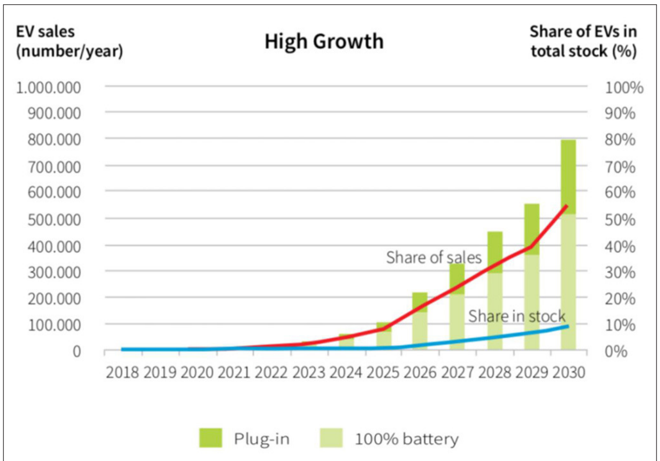

FIGURE 1 | Total number of electric vehicle car estimations until 2030 in Turkey. Source: Shura Energy Transition Center, Transport Sector Transformation: Integrating Electric Vehicles into Turkey's Distribution Grids, 2019.

distribution grids have been designated in multiple areas in line with a high growth scenario that foresee 65% of vehicle sales to be made for electric vehicles including battery and plug-in hybrids in the **Figure 1**. Turkey has recently ventured on producing its own zero emission electric passenger car, TOGG which will be launched in 2022.

It is expected to be chargeable in varied charging stations and at a rapid speed in less than half an hour. The expected surge in the share of electric vehicles can be observed in the below graph although such projections do not include non-passenger light duty vehicles with commercial objectives at the moment.

Tax incentives are commonly prioritized for encouragement of energy efficient and low emission vehicles such as electric, hybrid, hydrogen or natural gas fired ones in the world, and particularly in the European Union. In line with such developments, Turkey attempted to introduce some incentives to promote electric and hybrid vehicles. Special excise tax law has also been enacted to provide tax exceptions for electric and hybrid vehicles in Turkey[7]. However vehicle taxations system is calculated upon the age and motor power of vehicles.

The special excise tax has been criticized to promote shift to older second-hand models with higher emissions, as older cars have less motor vehicle taxes (Senzeybek and Mock, 2019). Differentiated taxation mechanisms shall be evaluated in conformity with fuel consumption as well as CO_2 emissions of vehicles. Establishment of a database that records CO_2 emissions of every vehicle at the market shall enable reinforcement of planned tax system.

Assessment of prominent policies for renewable energy development and decarbonisation efforts of fossil fuel dependent road transport systems provide a guideline for future implications. Despite current considerations for decarbonisation of energy and transport systems, there are multiple challenges to be addressed.

[7] *Law No.197 Motor Vehicle Taxes.*

Main arguments that hamper renewable energy development in Turkey are centered around inadequacy of fiscal incentives, whereas lack of regulatory standards for CO_2 emissions and clean alternatives are the major stumbling blocks to build sustainable road transport systems.

ACTIONABLE RECOMMENDATIONS

Political nature of transition processes necessitates facilitating regulatory frameworks that shall have the adequate capabilities to address technical, administrative as well as justice aspects of systemic change. Presented findings in the previous section provide a direction for effective policy making in energy and transport sectors to reformulate the existing policy frameworks in line with carbon-free and equitable energy transition pathways. Building on the argument that there is potential for improvement, the following section integrates these recommendations with the alternative innovative and cost-effective solutions for decarbonisation of road transport systems. Accordingly, actionable policy recommendations are summarized in a table followed by presentation of the findings.

Environmental Performance Review of Turkey by the (OECD, 2019a,b) calls for a reform of the vehicle and fuel taxation system with emission criterions while fossil fuel tax exemptions for industrial and residential use shall be eliminated. It is argued that reducing the emissions from transport sector can enhance environmental quality with mitigated air pollution while electric mobility can ensure decarbonisation of the power sector (Saygin et al., 2019). Therefore, it is possible to assume that large scale implementation of electrified transport options provides a series of benefits in the form of energy savings, but also for prospective renewable energy deployment.

It is important to stress that low-emission vehicles (electric or hybrid vehicles) are currently not affordable by low-income individuals and effectiveness of governments' incentive policies in contributing to equity is controversial unless their mass production is ensured to reduce costs (Mullen and Marsden, 2016, as cited in Mattioli et al., 2018). Alternative ways to advance sustainable mobility such as bicycle and pedestrian transport options, promotion of green transport in urban and regional systems should be addressed to reduce inequalities. Traffic density is another major problem of the road transport in most cities which in return exacerbate the air pollution.

Implementation of control systems through smart parking spaces at high fees in urban areas and enhanced public transport with better infrastructure are among the alternative practices to prevent increased congestion (WRI Turkey Sustainable Cities, 2018). Introducing new mobility procedures while supporting more sustainable modes of transport through car-sharing with the use of advanced technologies are among the considered policies for decarbonising the road sector in Turkey. However, strong policy planning objectives do not match with the required technology production capacity (Varlik and Yilmaz, 2017).

Environmental Performance Review of Turkey by the (OECD, 2019a,b) points out to the need for increased volumes of eco-innovation policies and spending on R&D activities accompanied with more support to national innovators which would inevitably fortify the domestic markets on the path toward green growth.

Innovative and Cost-Competitive Solutions for Sustainable Road Transport in Turkey

In Turkey, energy use problems exacerbated by the technological incapacity of current transport systems dominated by mostly old and inefficient vehicles that lack any fuel standards lead to unnecessary fuel use and highly wasted consumption levels with detrimental impact on the environment (Szyliowicz, 2004, p. 30). Even though transport sector is considered difficult to decarbonise due to many reasons that include restricted presence of alternatives, there are a number of proposed solutions[8] within the current policy agendas of countries (Lehtveer et al., 2019). Upon this background, it is imperative to draw an outline of the external landscape developments and technological niches that have impact over the dynamics of road transportation system.

Clean and low-carbon transport solutions are intertwined with technological advancements. In other words, electric and hybrid vehicles, hydrogen cars or efficient combustion engines incorporate innovative results (Apak and Atay, 2013). Vehicles that work with electricity provided through on or off-grid and supplied with battery packs are called electric vehicles, even though different electrification options exist in alignment with diverse battery durations (IRENA, 2013). According to the International Energy Agency (IEA), batteries and electrolysers are suitable technologies for mass manufacturing of electric vehicles, although they are currently at different stages of development. On the other hand, costs of lithium-ion batteries, that are essential technological advancements for electrified transport options, have recently been decreased due to widespread production. Electrolysers also hold the capacity for further cost reductions. Moreover, batteries can be used in the power sector with integration of different renewable energy sources in electricity generation which make lithium-ion batteries feasible to use in the energy systems apart from their utilization in transportation.

In line with such technological developments and prospective decline in production costs, governments have been introducing policies targeted at promotion of sustainable transport options with increased attention to electric cars in various countries. International Energy Agency describes achievement of adequate manufacture capacity of batteries as crucial for sustainable electrification in the road transport which will hold a fundamental role in future markets. Currently, global manufacturing capacity of batteries is largely led by China which has about 70% of all volumes, whereas the United States shares 13% and the European Union 4%. Europe is the global leader in production of electrolysers that are used for fuel cell passenger cars (IEA, 2020). The major obstacle in promotion of use of electrical vehicles is the costs of lithium-ion batteries, apart from the pre-requisite of mass standardization and manufacturing (European Commission, 2017).

Support mechanisms by governments through various incentives to boost manufacturing of battery and electrolyser products in order to reduce costs may alter the national attitudes and convey a substantial message for domestic automotive industry. It can steer the shift toward electrified vehicles along with prospective creation of new jobs and employment opportunities.

Introduction of specified standards on low-carbon fuels, subsidies for purchase of electric cars as well as facilitated tax credits are alternative methods to encourage their demand.

Another important barrier in broad use of electric vehicles is the complementary need for suitable public infrastructures in the form of public charging stations which may be challenging to develop in the short run. Indeed, electrification of medium-long haul and heavy freight vehicles confronts more obstacles in terms of battery use at adequate ranges.

Large-scale adoption of electric vehicles depends upon supplementary charging infrastructures and in a variety of locations (IRENA, 2013). There are a number of viable solutions in line with different charging rates, such as normal, medium or high-level power charging points that may be available at home, work or public parking areas, and require peculiar investments to access the network at ranged costs. As a result, costs may vary and appear non-incremental if charging stations are at home, whereas costs for those that are placed at workplace parking areas may differ depending on availability of infrastructures and distance from the electricity distribution network. Interestingly, IRENA (2013) points out that diffused use of electric vehicles does not necessarily require mass installment of public charging stations at the initial stage and instead displays an exponential increase. Moreover, since access to private parking spaces at homes or workplaces is an issue in developing countries, public charging stations attract more attention for investments (Saygin et al., 2019). It is positively relevant in planning of future charging station deployments in Turkey which shall be taken into consideration together with the peculiarities of its urban areas.

Use of hydrogen also provides great opportunity if met with the necessary stimulus packages and policy actions aimed at benefiting from large scale manufacturing of battery and electrolysers, although they remain as capital intensive investments. Hydrogen can be utilized for decarbonisation of various sectors comprising of long-haul transport and help to reduce air pollution. International Energy Agency (IEA) stresses that is not only light and easy to store, but also does not generate pollutants and GHGs, which means that hydrogen can play a fundamental role in sustainable energy transition when used in various sectors. Support policies for investments in technology of hydrogen have been scaling up along with the rising demand, while policy incentives are being centered around transport sector in which current mechanisms are targeting mostly passenger cars, vehicle refueling stations and buses in a number of countries (IEA Report on the Future on Hydrogen, 2019-IEA, 2019). However, hydrogen can be produced from a range of sources such as renewables, coal, natural gas, oil as well as nuclear energy. It is possible to

[8] Directive 2009/28/EC of the European Parliament and of the Council (2009). Promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. http://data.europa.eu/eli/dir/2009/28/oj

transform hydrogen into transport fuels for different vehicles or electricity for power generation at home or industries (Lehtveer et al., 2019).

Hydrogen demand has been on the rise since some time, but its production is largely dependent on fuel costs as the biggest price component which creates further obstacles. As a result, hydrogen is vastly produced from fossil fuels, in major part from natural gas and coal due to lower production costs at the current level. Varied costs of hydrogen production by production source reveals that its use for low-carbon energy transition remains to be an issue for cost competitiveness. Because hydrogen production mostly relies on coal and natural gas at the moment[9]. However, it may change with further reductions in the cost of renewable energy productions. An additional alternative for sustainable road transportation may be use of electro fuels that are essentially carbon-based and generated from renewable electricity along with CO_2 from biomass. Electro fuels are feasible for a wide range of transport methods and in conformity with the combustion engine, which means that big scale infrastructure investments are not necessary (Lehtveer et al., 2019). However, the most fundamental input that determines electro fuel costs are electrolysers and price of electricity that shall provide cost-effective solutions in transport sector.

Biofuels produced from biomass are also largely utilized for decarbonisation of transport sector and to substitute fossil fuels without the necessity for large scale investments in infrastructure. Biofuels can be used in road and rail transport as an alternative to electrification, however sustainable use of biofuels for conservation of adequate food production and livestock is an important issue to be addressed[10]. Furthermore, costs of biofuels are affected by volatile price levels of feedstocks. Total production costs for liquid biofuels including ethanol and biodiesel are largely based on prices of feed crops (IRENA, 2013). Due to such limits, biofuels can be utilized in specific sectors that are particularly deemed difficult to decarbonise (Lehtveer et al., 2019). In terms of biofuels use in Turkey, the degree they can grant an alternative solution to fossil fuel sources are questionable in terms of sustainable and extended use of biomass for production of biofuels.

In light of varied and rapidly changing technological advancements that offer prospective breakthroughs it is imperative to mention the current state of sustainability attempts in Turkish transport sector. Share of hybrid and electric vehicles is currently lower than 0.1%, but it is expected to increase in the near future that shall reach about 2.5 million electric vehicles by 2030 according to the high growth scenario (Saygin et al., 2019). Although there are some initiatives aimed at progress toward electrification of the transport sector as evident in several policy implementations such as tax benefits to electric and hybrid vehicles as mentioned earlier, additional policy designs should be considered including through differentiated taxation mechanisms that shall take into account vehicle fuel consumptions and emission levels. Since electric and hybrid cars are expected to take up their share in Turkey, further considerations include compatible infrastructural installments.

National benchmarks relating to electric vehicle charging do not exist yet, mostly because of limited degree of installments at current level. However, Energy Market Regulatory Authority introduced the draft regulation on connection to the distribution system for charging of electric vehicles[11]. Although it is possible to assert that there are some steps taken toward low carbon transition of the transport systems in Turkey, there is still much room for improvement in terms of technological growth, compatible policy practices as well as equity implications. Despite availability of various low emission alternatives to fossil fuels, their cost competitiveness remains an issue to be tackled for large-scale adoption of sustainable transport solutions also at the global scale. It remains as a challenge to be tackled in Turkey and largely relies on international advancements on international battery technologies that shall introduce cost reductions.

Global market uptake of electric vehicles is estimated to increase as more than half of passenger vehicles sold will be electrified by 2040 (BloombergNEF, 2020). Despite expected cost reductions in batteries, another thing that may reduce their competitiveness is the volatile oil prices which would significantly alter economics of zero-emission vehicles. Apart from the essential technological advancements, policy mechanisms that offer a variety of incentives through subsidies in taxation, purchase bonus or elimination schemes are vital to reduce the high initial capital costs of not only the renewable energy investments, but also zero-emission vehicles.

Against the backdrop of analyzed policy mixes along with rapid technical improvements a myriad of inferences can be made to target development of renewable energy and sustainable transport in Turkey. The results of this policy review can be considered as merely a first step toward systematizing national renewable energy policies based on preliminary investigations of sustainable energy transition and decarbonised road transport systems with connotations of equality.

Considering such shortcomings, actionable policy recommendations across dual policy issues of socio-technical system change of energy and road transport in Turkey are summarized in the **Figures 2**, **3**.

DISCUSSION: CAN TURKEY PROMOTE SUSTAINABLE AND INCLUSIVE ROAD TRANSPORT SYSTEMS IN THE NEAR FUTURE?

Introducing the required affirmative legal and regulatory measures to signal for behavioral change in consumer habits and provide for cost effective clean alternatives are

[9]IEA, *Hydrogen production costs by productionsource, 2018*, IEA, Paris.

[10]Directive 2009/30/EC of the European Parliament and of the Council (2009). *Amending Directive 98/70/EC as Regards the Specification Of Petrol, Diesel and Gasoil and Introducing a Mechanism to Monitor and Reduce Greenhouse Gas Emissions and Amending Council Directive 1999/32/EC as Regards the Specification of Fuel Used by Inland Waterway Vessels and Repealing Directive 93/12/EEC.* Available online at: http://data.europa.eu/eli/dir/2009/30/oj

[11] Energy Market Regulatory Authority (2011), Draft Text of Procedures and Principles Regarding Electric Vehicles Charging Station.

Policy Issue.1: Current legislative framework concerning renewable energy development in Turkey lacks the capacity to incentivize further investments. Deployment of renewable energy sources are hampered by inadequate funding opportunities and restricted technology transfer. Dependence on fossil fuels fostered by government's continuous support to power generation from coal and nuclear results in great vulnerability for climate change and energy security vis-à-vis growing national energy demand.

Objective: Projected increase in Turkey's energy demand should be met from utilization of great renewable energy potential of the country. It is imperative not only for energy independence but also to reduce GHG emissions originating from energy sector. Energy transition policies of Turkey shall incorporate a justice perspective in order to prevent exacerbation of existing inequalities.

Pre-condition: Turkey must ratify Paris Agreement. Having a longer-term energy transition framework embedded in a forward-looking agenda with comprehensive sectoral transformation outlook that considers social injustices and distributional implications of mitigation policies is mandatory.

Possible Actions

- Legislative and regulatory framework concerning renewable energy development as well as energy efficiency mechanisms should be re-evaluated with stable and diversified financing options.
- Comprehensive incentive mechanisms to address multiple risks of investments should be introduced for renewable energy projects. Ensuring grid integration of electricity produced from renewable energy in urban and rural areas is essential to ensure spatial energy justice.
- Challenges in adoption of technological innovations shall be addressed with longer term commitments to research and development activities while providing persistent support to national innovators.
- Turkish government must stop encouraging electricity generation from coal power. Accordingly, coal subsidies to energy poor households shall be eliminated. Fossil fuel tax exemptions for industrial and residential use shall be replaced with renewable energy incentives.
- Energy transition policies shall address energy justice through equitable access to clean resources without putting extra burden on the most vulnerable sections of the society. Accessibility and affordability of modern energy services can be promoted through policies such as tax exemptions, subsidies, grants, and other redistributive mechanisms.

FIGURE 2 | Actionable Policy Recommendations for Renewable Energy Transition in Turkey.

among the most important parameters for sustainable transition of mobility systems in Turkey. Policy measures that include mandatory CO_2 standards, CO_2 based vehicle taxation and improved CO_2 labeling schemes[12] that shall include quantitative information on estimated running costs can provide leverage effect (Mock, 2016). One of the greatest novelties to be introduced with innovative, clean and cost-effective solutions in transport systems is

[12]Directive 1999/94/EC of the European Parliament and of the Council (1999). *Relating to the Availability of Consumer Information on Fuel Economy and CO2 Emissions in Respect of the Marketing of New Passenger Cars*. Available online at: http://data.europa.eu/eli/dir/1999/94/2008-12-11

Policy Issue.2: Transport is responsible for 21% of GHG emissions in Turkey. Road transport is fossil fuel dependent and particularly difficult to decarbonize due to restrictive presence of alternatives. High fuel prices and current tax scheme result in use of less environment friendly vehicles in Turkey.

Objective: Reduction of soaring energy need from fossil fuel dependent road transport systems, where current demand exceeds 90%. Addressing increasing energy need of passenger and freight transport is necessary to curb GHGs and provide clean alternatives.

Pre-condition: Electrification of road transport systems, investments in complementary infrastructure and clean fuel alternatives shall be coupled with political and economic incentives to signal for behavioural change. Reliance on merely private low emission vehicles can widen the existing socio-economic inequalities.

Possible Actions

- Path-dependence of technological and infrastructural obstacles should be addressed to create investment opportunities for building of electrified road transport systems to deliver the 10% target of renewable sources utilization in transportation.
- Bottlenecks concerning digitalization, adoption of technological innovations as well as necessary research and development practices require closer cooperation among national and international stakeholders. Turkish government should foster political engagement for construction of such coalitions at different levels of socio-technical landscapes.
- Vehicle taxation system has to be reformed in order to prevent use of older vehicles which emit more GHGs. Additional policy mechanisms including carbon pricing, fuel efficiency standards, mandatory CO2 regulations for manufacturers of commercial and passenger vehicles should be introduced.
- Zero to low emission vehicles shall be incentivized through tax reductions or subsidies, but it does not solve the problems of congestion or air pollution in cities. Electric and hybrid vehicles can perpetuate existing inequalities and create new distributional injustices.
- Justice implications of accessibility and affordability of decarbonised mobility systems infer better planning in urban areas through establishment of smart cities and promotion of clean alternative such as widely electrified public transport systems, cycling, walking or shared riding options to prevent further exclusionary policies.

FIGURE 3 | Actionable Policy Recommendations for Decarbonization of Road Based Transport in Turkey.

the multiple gains to the benefit of different stakeholders including energy companies, investors, manufacturers as well as service providers.

Transformation of the transport sector shall create positive effects on multiplied value chains with the possibility to enhance economic growth in a sustainable manner while creating new job opportunities. As Turkey is one of the most important manufacturers and exporter of vehicle and vehicle parts in the world; the automotive sector constitutes an essential part of the economy (Mock, 2016). Against this backdrop and in line with the global market shifts in the automotive sector that is increasingly adopting sustainable solutions with the latest technological advancements, Turkey has made some progress in catching up with such trends. Nevertheless, current policies appear as limited in scope.

Growing population of Turkey matched with the swift urbanization trend implies significant benchmarks for the build-up of necessary infrastructure aimed at larger-scale deployment of electric vehicles that shall meet the diverse needs of different end-users. Aggregate acceptance of electric vehicles also depends on presence of complementary infrastructure to ensure interoperability and harmonization of standards. The market report on transport sector transformation prepared by Shura Energy Transition Center (Saygin et al., 2019) therefore assumes the home charging stations to lag behind the public ones by 2030, while the public ones will be spatially restricted to shopping malls, main highways and gas stations. In fact, current eight pilot regions represent 35% of the national energy consumption and 33% of the total population with a variety of residential, industrial and commercial customer portfolios. The model predicts a yearly 5% increase in total demand of electricity during 2018–2030 on distribution grid of the pilot regions that is based on differentiated charging venues and patterns including peak hours. Such increase in energy demand in pilot regions is planned to be met through additional renewable energy integration to the system that will be generated from solar and wind power whose baseline is very limited at the current state and by local lignite sources to some extent.

Evidently, it is significant to meet increased energy demand of electrified transport systems from domestic renewable energy sources to provide multiple offerings to national energy security and GHG emissions. Energy generation from renewable resources necessitate incentivising renewable energy investments and spatial assessment of their grid integration. Incorporation of technological solutions can provide supplementary leverage effects.

The study conducted by Shura Energy Transition Center (Saygin et al., 2019) includes energy storage through battery systems and estimate its positive impact together with renewable energy use to relieve the distribution grid except for peak hours and at the absence of any incentive mechanisms. For instance, alternative solutions that will enable investment cuts and prevent the peak loads on the grid are being developed in Germany, which leads sustainable energy transition under Energiewende. It includes smart charging practices such as integration to an optimisation mobile application in order to estimate the most cost-effective charging times (Agora Energiewende, 2019). However, one important point to draw attention is that the modeling of distribution grids of each pilot regions in Shura Energy Transition Centre's study takes GDP per capita into account, development coefficient and other socio-economic indicators including the education level in chosen cities as the multiplication factor to project the number of electric vehicles and required charging points. Therefore, a positive correlation is estimated between higher GDP and development standards for expected portion of the population that will likely use electric vehicles (Saygin et al., 2019). Evidently, such projections neglect poorer households and imply multiple externalities for equitable transition.

Analysis of electric vehicle uptake through a justice lens implies that despite its environmental benefits, EV use can be exclusionary and create further distributional injustices (Jenkins et al., 2018).

Accordingly, climate mitigation policies shall be approached with their potential consequences on inequality. Policy actions aimed at low carbon energy transitions should incorporate practices of acceptance, mobilization, and empowerment to address justice (McCauley et al., 2019). Markkanen and Anger-Kraavi (2019) conceptualizes maximized positive social co-benefits whereby policy design, implementation and mitigation action are inclusive. Acknowledging that the notion of social justice is intrinsically non-separable from environmental sustainability, social and spatial vulnerabilities are compounded at the juncture of gender, race, and indigeneity. Therefore, policy measures for energy transition should not be detriment to the most vulnerable people. These include adoption of alternative measures in planning of local mobility systems to promote walking, cycling and use of public transport rather than solely relying on private low emission vehicles (Mullen and Marsden, 2015). It is important to stress that market-based instruments such as environmental taxes can create economic burdens and increase existing vulnerabilities of low-income households. Bardazzi and Pazienza (2014) makes a comparison on use of market-based instruments for design of energy policies in Turkey and the EU whereby a price signal is sent to consumers with the attempt of achieving behavioral change for fuel substitution; however, it appears controversial in terms of justice implications.

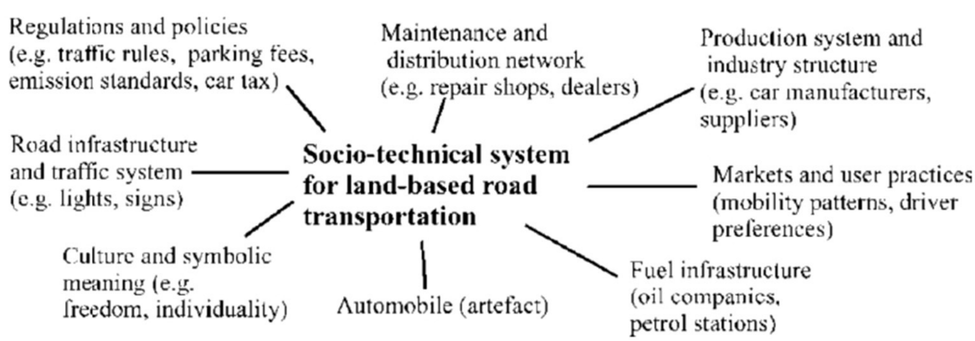

FIGURE 4 | Socio-technical system transition in the context of modern road transportation. Source: Geels (2005).

Indeed, policy instruments aimed at shift to clean energy should primarily consider the energy poor in the society (Berry et al., 2016).

On the other hand, transition management at multi-level governance frameworks can facilitate transition toward just and low carbon energy systems by multi-stakeholder engagement.

Indeed, socio-technical transitions occur through multi-actor processes among different social groups as it is highlighted in **Figure 4** (Geels, 2005). Socio-technical system transition for sustainable road transportation can be achieved through a combination of command-and-control schemes and market-based instruments incorporating car labeling, emission standards and taxation tools to encourage low emission mobility among passenger and freight vehicle users as well as car manufacturers. Mobility patterns, role of culture, user practices also play a key role in transition processes.

Relationship among different social groups such as policy makers, market regulators, automotive manufacturers, energy companies, innovators, investors, and users that interplay at various levels is key in attaining inclusive socio-technical regime transition of land-based road transportation. For instance, public procurement practices by municipalities can serve as a strong tool to establish markets for low emission alternatives. Further incentives can be implemented by regional governances on top of government subsidies although, it implies careful examination of characteristics of each city or town (Heinrich Böll Stiftung, 2012).

CONCLUSION

Some degree of political will is demonstrated by Turkish government to decrease its energy dependence, step up its climate change action namely through enhanced energy efficiency and shift to renewable sources including in transport sector. However, persistent policy gaps exist.

As a result of this policy and practice review, it is concluded that there are mainly four issues relating to sustainability of transport systems integrated with renewable energy use in Turkey.

Firstly, the current policy framework de-incentivizes renewable energy use through support of fossil fuel and coal subsidies provided to different consumers; secondly current vehicle and fuel taxation system and CO_2 standards hamper behavioral change which led consumers to opt for less environment friendly options; thirdly, there is need for advanced technology cooperation to develop innovative and cost competitive clean alternatives. Lastly, justice implications of energy transitions shall be embedded in ex-ante mitigation policies in order to prevent exacerbation of existing socio-economic inequalities.

Upgrading the regulatory and policy framework as well as increasing public awareness is much needed to overcome the persisting challenges of renewable energy use and sustainable transport in an inclusive fashion. The existing Turkish policy agenda for climate change is not only weak in terms of its pledge but also short-sighted. Turkish government's reluctance to ratify Paris Agreement further reiterates its unwillingness toward mitigation efforts. Turkey urgently needs a forward-looking climate mitigation strategy that incorporates necessary measures to prevent adverse effects of transition processes on people who are disproportionately more vulnerable at the face of climate change. Ensuring accessibility and affordability of key energy services, including mobility is imperative in order to address justice implications of sustainability transitions. Policies such as tax exemptions, subsidies, grants, or other redistributive mechanisms can provide equitable and affordable means of access to clean energy and decarbonised transport solutions without putting extra burden on the most vulnerable sections of the society. However, promotion of non-car modes of transportation is also important. Design of clean mobility options that provide alternative solutions through electrified public transport systems, development of urban spaces with walking, cycling and shared riding possibilities can contribute to just transition pathways toward sustainable transport systems.

AUTHOR CONTRIBUTIONS

The author confirms being the sole contributor of this work and has approved it for publication.

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Investigating Energy Justice in Demand-Side Low-Carbon Innovations in Ontario

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The diffusion of low-carbon innovations, including innovative products and services, is required to accelerate a low-carbon energy transition. These innovations also have the potential to alleviate and perpetuate existing social inequities, calling into question their "justness." Energy justice is a useful analytical tool for framing justice questions related to energy. In this paper, we ask whether demand-side low-carbon energy innovations are meeting energy justice criteria. To address this question, this study develops four indicators from existing energy justice frameworks and applies them to a range of demand-side innovations offered to energy users in Ontario. The indicators are used to assess innovation availability, affordability, information, and involvement. Innovations were identified using surveys and desk research across Ontario's energy technology innovation system (ETIS). One hundred twenty-two innovations are analyzed for these four indicators, and according to intended innovation users and innovation providers. Findings suggest that three of the four indicators—availability, affordability and information are broadly being addressed, while involvement was more difficult to establish. However, the ETIS may be perpetuating inequities through an over emphasis of innovations for particular energy users, such as private businesses, alongside under-emphasis on potentially marginalized actors, such as low-income households and renters. Furthermore, government-delivered, publicly owned or regulated innovation providers place a greater emphasis on energy justice, including the provision of innovations for marginalized actors. This study aids our understanding of energy justice in low-carbon energy innovations and is critical given that in the context of funding cuts to public services, there may be an increased reliance on decentralized actors. The consideration of justice gaps that emerge through such decentralization should not be overlooked. Our findings suggest that within Ontario's ETIS, who provides innovations matters. Given the insights presented in this study, this research approach and the developed indicators could be applied to other contexts and socio-technical systems. The application of energy justice indicators, derived from existing scholarship, therefore presents an important opportunity to address current and understudied practical energy challenges.

Keywords: energy policy, low-carbon innovations, public services and governance, energy justice, low-carbon energy transitions

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INTRODUCTION

Low-carbon energy innovations, referring to novel products or services that result in lower-carbon emissions compared to established technologies (Wilson, 2018), have the potential to enable low-carbon energy transitions. Beneficially, low-carbon energy innovations (hereafter referred to as innovations) can alleviate social injustices and thus contribute to equitable energy transitioning; conversely, innovations can also perpetuate social injustices (Sovacool et al., 2019a). As such, it is critical to understand the relationship between innovations and justice, and more specifically the impact of innovations on justice concerns. In order to understand this relationship, wide consideration across the socio-technical energy system can be advantageous wherein a range of innovations, the various types of innovation users, and the various types of innovation providers are considered. Such understanding is critical given current and evolving relationships between innovation users and providers (Wolsink, 2012); increasing reliance on non-state actors in the provision of innovations and social welfare (Williams et al., 2014; Hillman et al., 2018); and the current proliferation of innovations (Karakaya et al., 2014). Research here has the potential for mitigating against emerging, as well as addressing existing, justice issues.

The justice dimensions of energy transitioning—inclusive of justice aspects "showing up" in the innovations involved in energy transitions—are increasingly important (Sovacool et al., 2019a). Specifically, over the last decade, energy justice has emerged as a concept exploring the intersection of justice, equity, and fairness in energy activities (Jenkins, 2018). Energy justice has been conceptualized in multiple ways—composed of three overarching tenets (distributive, recognition, and procedural justice) or as principles connected to energy-related decisions (e.g., availability, affordability, good governance, and due process; Sovacool and Dworkin, 2015). Through such emergent frameworks, energy justice has developed into a useful analytical tool for framing justice questions, where scholars can *apply* energy justice concepts, rather than merely discuss them (Jenkins, 2018). Accordingly, within energy justice scholarship, the use of indicators has been argued as promising for measuring energy justice (Sovacool and Dworkin, 2015), and for assisting decision makers with evidence-based research.

The overarching aim of this research is to investigate energy justice in low-carbon energy innovations. In this paper, we ask: Are demand-side low-carbon innovations meeting energy justice criteria? This research draws on energy justice literature and adapts justice conceptualizations to inform the study of energy justice in innovations. In particular, four energy justice principles, i.e., availability, affordability, good governance, and due process are operationalized to establish indicators to quantitatively measure the presence or absence of availability, affordability, information, and involvement, respectively, in 122 low-carbon, demand-side innovations intended for energy users in Ontario, Canada. Energy users include, for example, individuals, households, organizations, and businesses, whereas the innovation providers include governments, utilities, non-profit organizations, and private businesses. By examining the presence or absence of energy justice in innovations, we are able to study relationships between energy users, energy providers, and the "justness" of the innovations. That is, we examine which innovations are just, which actors are providing just innovations, and which actors are receiving just innovations. This research also provides insight into distributional (i.e., by investigating how benefits such as affordability and availability are distributed to various energy users), recognition (i.e., by identifying whether potentially marginalized actors are excluded from such benefits) and procedural (i.e., by investigating who gains access to information and involvement processes) justice concerns. Further, this paper demonstrates how energy justice indicators can be derived from existing scholarly frameworks and applied to critical, current, and understudied practical challenges.

Section Introduction of this paper begins with a review of literature—section Energy Justice outlines the two frameworks employed for the development of energy justice indicators; section Innovations and Justice provides a brief overview of innovations literature, introduces the Energy Technology Innovation System (ETIS), and outlines the importance of considering the relationship between innovation users and providers from a justice perspective; and lastly, section Research Context outlines the research context of Ontario, Canada, including the four broad types of innovation providers in Ontario, and why a justice assessment is important in the Ontario context. Section Materials and Methods describes the research materials and methods, including the identification of innovations assessed in this study and the development and coding of energy justice indicators. Finally, the results are provided in section Results and discussed in section Discussion, along with a reflection on the development and application of energy justice indicators and potential limitations of the study.

Energy Justice

Energy justice has emerged primarily as an academically developed concept, where understandings of justice are applied to critical energy issues, such as energy poverty and energy security, by interdisciplinary justice scholars (Jenkins, 2018). This research employs two primary frameworks to guide study of energy justice in innovations, including in the development of energy justice indicators.

The first framework is comprised of energy justice tenets and was initially presented by McCauley et al. (2013). The authors propose energy justice as a new research agenda, one that shares the same basic philosophy with environmental and climate justice scholarship (Baasch, 2020). Here energy justice is noted to be conceptually distinct because of its particular focus on energy and its consequent aim to provide safe, affordable and sustainable energy. This triumvirate of tenets advanced by McCauley et al. include interlinked and overlapping justice themes that "have emerged in justice literature for energy policy" (p. 2) and include: (1) distributional justice, which recognizes the unequal distribution of costs and benefits; (2) recognition justice, which is concerned with the fair consideration and representation of people in vulnerable circumstances, where such vulnerability may be worsened through a given process; and (3) procedural justice, concerning the ability of all groups to participate in, and impact, decision-making (McCauley et al., 2013; Sovacool et al., 2019b). Since its introduction, scholars have advanced modifications to the tenets. A later contribution from Jenkins et al. (2016) emphasizes the order of these tenets, i.e., the "what, who and how," while other scholars have added additional justice tenets, including cosmopolitan justice, which is a universal approach centered on the protection of all human beings (e.g., global externalities; Sovacool et al., 2019a) and restorative justice, which focuses on the response to injustices through reparation of harm done rather than punishment (Heffron and McCauley, 2017).

The second framework for understanding energy justice has been advanced by Sovacool and co-authors. Sovacool and Dworkin (2015), first developed an energy justice framework by connecting energy policy and technology concerns with eight philosophical concepts from classical theorists and modern thinkers, including, for example, Kantian ethics, utilitarianism, and libertarianism. The overarching concepts—virtue, utility, human rights, procedural justice, welfare, freedom, posterity, and responsibility—inform the development of a principles-based account of energy justice: availability, affordability, due process, good governance, sustainability, intra-generational equity, inter-generational equity, and responsibility. The order of these principles is not based on importance, rather, it starts with the "simplest and most accepted ones" before moving toward the "more controversial and complex" (p. 439). Sovacool et al. (2017) add two additional principles—resistance and intersectionality—which follow an exploration of non-Western justice theorists, thereby addressing a critique levied against energy justice theory as being derived from Western, European, and American thinkers, with the exclusion of scholarship from the Global South (McCauley et al., 2018).

The continued evolution of these frameworks reflects the fluid nature of justice considerations across time, place and perspective, where what is seen to be "just" varies to such an extent that developing a *static categorization* may not be achievable, nor even desirable. However, while conceptualizing energy justice remains a challenge, the frameworks and categorizations emerging within energy justice literature provide a useful tool for analyzing particular contexts and challenges (Sovacool and Dworkin, 2015), particularly in areas of research where justice considerations have largely been absent.

In order to develop the indicators in this study, our research draws primarily from Sovacool and coauthors' energy justice principles. However, in keeping with Sovacool and Dworkin (2015), who emphasize the mesh of energy justice tenets inherent in their framework of principles, our indicators provide insights for both theoretical frameworks. Our study draws from the principles: availability, affordability, due process and good governance. These principles were selected for two reasons: first, these four principles, when considered across various end-users within an innovation system, provide insight into the three main tenets associated with energy and environmental justice: distributional, recognition, and procedural justice (McCauley et al., 2013; Baasch, 2020). Specifically, by considering these indicators in relation to the various types of energy users in a socio-technical system, we can gain an understanding of how benefits, such as availability and affordability are distributed; whether potentially marginalized actors are being excluded from such benefits, i.e., recognition (Sovacool et al., 2019b); and who gains access to information and involvement processes, which are components of procedural justice (Sovacool and Dworkin, 2015). Secondly, these indicators were selected based on the availability of data, given that the methods outlined in section Materials and Methods do not allow for consideration of all principles—for example, resistance would not be able to be assessed given the available dataset. It should be noted, however, that due to the fluidity of justice principles outlined above, a complete representation of justice likely would not be possible, even with the inclusion of all principles or tenets.

Innovations and Justice

Eco innovations, a term that is used synonymously with low-carbon, green, sustainable, and environmental innovations, are defined as the "creation or implementation of new, or significantly improved, products, processes, marketing methods, organizational structures, and institutional arrangements which lead to environmental improvements compared to relevant alternatives" (OECD, 2009 as cited in Karakaya et al., 2014, p. 394). These innovations not only have the potential to contribute to low-carbon energy transitions, they also have the potential to contribute to equitable transitions by positively affecting users. This can be seen in the case of innovations for addressing energy poverty. Energy poverty—broadly referring to the inability of households to meet their energy needs, including households in industrialized nations (Bouzarovski et al., 2012; Bednar and Reames, 2020)—has been shown to fall disproportionately on low-income and racialized communities (Drehobl et al., 2020). Depending on their implementation, innovations here have the potential to address energy poverty through, for example, enabling retrofits for communities to reduce their spending on energy (Bednar and Reames, 2020). Nonetheless, if justice considerations are not a priority in the design and diffusion of innovations, innovations may exasperate injustices. For example, regressive funding arrangements raise average shelter costs while only addressing energy affordability for a small portion of vulnerable households, thereby worsening increasing overall costs for many low-income households (Gillard et al., 2017). Another example involves energy literacy, where critical knowledge gaps in communities are associated with the inability to participate in energy decision-making processes, such as voting or public meetings (Bozuwa, 2019). Innovations have the potential to contribute to knowledge-building through, for example, educational training for members of renewable energy cooperatives (Johnson and Lewis, 2017). Conversely, such innovations may also exasperate injustices when knowledge-building initiatives are unavailable to marginalized actors—for example, renewable energy cooperatives have historically seen an underrepresentation of low-income, racialized communities (Johnson and Lewis, 2017), and women (Fraune, 2015).

Within sustainability transitions theory, the Energy Technology Innovation System (ETIS) is a framework that describes a systems perspective of innovation, including innovation emergence and diffusion, as well as the various actors, networks and institutions involved in innovation processes (Sims Gallagher et al., 2012; Grubler and Wilson, 2013). This framework, which has already been employed in the Canadian context by Jordaan et al. (2017), is used in this study to identify Ontario demand-side low-carbon innovations. The ETIS is noted to have different structures in different contexts; in other words, dynamic relationships exist between innovation users and innovation providers and these vary in different contexts (Sims Gallagher et al., 2012). This is relevant to our research because the specific actors (i.e., innovation users and providers) involved within a given ETIS can impact the justice aspects of innovations.

From a justice perspective, there are multiple reasons why the type of innovation provider is important for energy users. For example, Reames (2016) notes that energy users' (e.g., households') lack of trust in particular types of providers may be a barrier to innovation uptake in communities that have historical or socioeconomic reasons for social exclusion (e.g., low-income or otherwise marginalized communities). Lacey-Barnacle and Bird (2018) considered the role of providers—specifically, intermediary organizations[1]—from an energy justice perspective, arguing that intermediaries have the potential to act as a "critical bridge" by engaging marginalized communities and otherwise excluded community groups. However, they also note that the ability of intermediaries to address key justice concerns is highly dependent on funding support through multiple levels of government, which is hampered during times of austerity. The increasing reliance on providers that are not government-owned or heavily regulated has also been criticized on the basis that it represents a form of "roll-back neoliberalism" occurring alongside significant funding cuts to critical public services (Williams et al., 2014). In this context, there can be unwillingness to critically consider possible justice gaps emerging out of decentralized and localized actor involvement in traditionally government-led energy initiatives (Catney et al., 2014). Furthermore, as energy transitions continue to advance, the participation of energy users in low-carbon demand-side innovations requires engagement with new information, relationships, and transactions. Hence, participation in these options requires current relationships between consumers and conventional energy providers to change and new relationships to emerge (Wolsink, 2012). Moreover, such changes have the added potential to contribute to just paths by increasing the likelihood of various types of actors (including those that are marginalized) being acknowledged and included in key developments, as well as gaining from them.

The 2019 research agenda of the Sustainability Transition Research Network (STRN) emphasizes the irreducible impact of transitions on notions of equity and justice, while noting that attention drawn to this impact has been limited (Köhler et al., 2019). They have advanced a call for research "engaging explicitly with ethical considerations that arise from sustainability transitions" (p. 16). Recently, Sovacool et al. (2019a) explored the relationship between justice and low-carbon innovations by assessing energy justice in four innovations: energy services contracting, electric vehicles, solar photovoltaic panels, and low-carbon heating. These innovations were examined according to four justice principles: affordability, sustainability, equity, and respect. Their investigation reveals that innovations may carry opportunities to alleviate injustices while simultaneously contributing to another type of injustice. For example, electric vehicles reduce carbon emissions, air pollution and fuel usage, but are not equally accessible to all people due to cost and charging barriers. A further study from Sovacool et al. (2019b) employs a tenet-based framework (including distributive, procedural, cosmopolitan and recognition justice) and identified 120 distinct injustices associated with four European low-carbon transitions, including nuclear power, smart meters, electric vehicles and solar energy. As energy transitions continue to advance, with a more diverse array of actors involved than in traditional energy systems (Brisbois, 2020), the relationship between innovation users and innovation providers will be critical to understand from an energy justice perspective. Thus, the current research contributes to literature by investigating potential justice gaps that may emerge in evolving relationships between innovation users and providers in a given socio-technical context, by specifically taking into account different innovation user and provider dynamics.

Research Context

The research context is Ontario, Canada's most populous province of ∼14.6 million, and where energy sectors (natural gas and electricity) are predominantly provincially regulated. Ontario's energy system—a "hybrid" approach—encompasses both central planning and market competition (OEB, 2020). The electricity system, in particular, began a shift toward centralized planning and management in 2003 (Ontario Ministry of Energy, 2017), with conservation programs centrally managed by the Independent Electricity System Operator (IESO). Over the study timeframe, climate change policy comprised a patchwork of federal and provincial policy frameworks and actions that consisted mainly of sector specific programs. With respect to innovation, Ontario's Innovation Agenda (Ontario, 2008), advanced by the provincial government, articulates a strategy to develop energy technology, among other areas of innovation. Ontario's Innovation Agenda also supports social enterprises, a collective term for a range of organizations seeking market-based solutions for social problems (Hillman et al., 2018), and which have long been involved in climate change and energy policies and services (Gliedt and Parker, 2014).

Given the context-specific nature of the aforementioned dynamic relationships between innovation users and providers within the ETIS, the following subsections detail key trends in Ontario regarding innovation providers, as well as the relationships between providers and users, over the study timeline. Within Ontario's ETIS, four main types of providers of low-carbon innovations are: (1) governments, (2) utilities, (3) non-profit organizations, and (4) private businesses. Innovation users may include, for example, households

[1] Intermediary organizations are typically defined by the functions they perform—for example, demand articulation, network building, capacity building, innovation process management, knowledge brokering, and institutional support (Hannon et al., 2014). In the ETIS, innovation intermediaries (Gliedt et al., 2018) are important actors in the development and delivery of demand-side innovations.

(including renters and low-income households, individuals, non-profit organizations, and public sector institutions. The following section details the role of innovation providers in their support for these types of energy users in the Ontario context.

Governments

Environmental and climate change policy was subject to stops and starts at both the federal and provincial levels. Generally, Liberal governments have committed to either international or regional climate change agreements or markets and targets, while Conservative governments have refused to participate in such agreements or markets. Many municipalities have taken leadership on climate change mitigation and action through networks such as the Federation of Canadian Municipalities and International Council for Local Environmental Initiatives Canada.

All levels of government (federal, provincial, and municipal) have been involved in providing innovations. For example, programs for energy users, such as the EnerGuide for Houses and ecoEnergy programs were designed by Natural Resources Canada from 1998 to 2012 to encourage homeowners to reduce their GHG emissions via home energy efficiency retrofit investments (Hoicka et al., 2014). Ontario's provincial government put forward the Green Energy and Green Economy Act (GEGEA), which established Canada's first feed-in-tariff program, and the 2016 Climate Change Mitigation and Low-carbon Economy Act established the country's second provincial cap and trade program, the proceeds from which funded numerous other innovations to address energy and climate change. Municipal governments have also offered programs, such as the Home Energy Loan Program for energy efficiency retrofits from the City of Toronto. Ontario has also seen the uptake of municipal energy plans funded by the Government of Ontario's Municipal Energy Plan Program (Wyse and Hoicka, 2019). Furthermore, through the Municipal Act, Ontario gave municipalities new greenhouse gas emission reporting responsibilities and powers to use local improvement charges to assist financing of energy projects through municipal tax bills (Ministry of Municipal Affairs and Housing, 2012).

Utilities

Over the study timeframe, there were 80 local electricity distributors operating in Ontario, all licensed by the Ontario Energy Board (OEB)—of these, 77 are also regulated by the OEB (Ontario Distribution Sector Review Panel, 2012). These utilities serve energy users directly, and electricity distribution lines have been predominantly owned and managed by municipalities for over a century (Ontario Distribution Sector Review Panel, 2012). Ontario had three major natural gas distribution utilities (now merged into two) that serve natural gas customers and also regulated by the OEB (2012). A large majority of Ontarians (roughly 95%) bought electricity and natural gas from utilities, with these utilities not being permitted to make a profit from the sale of electricity or natural gas (OEB, 2020). Conservation programs available during the study timeframe were provincially regulated and rolled out by utilities. Natural gas utilities began offering demand-side management programs in the mid-1990s (IndEco Navigant Consulting, 2017). Following the push for electricity conservation in 2005, conservation programs were delivered by local electricity distribution companies. One policy, implemented by utilities starting in 2004, was a ministerial directive to implement smart meters across the province by 2010 to provide real-time information on electricity usage to manage responses to time variant energy prices (Ontario Minister of Energy, 2004). The installation of smart meters in 4.8 million homes cost the province roughly $1.9 billion (Crawley, 2014). Lastly, 100 Indigenous community energy plans also received funding from the IESO's Indigenous Community Energy Plan program (Wyse and Hoicka, 2019), which was announced in conjunction with the Municipal Energy Plan Program in the province's Long-Term Energy Plan (Ministry of Energy, 2013).

Non-profit Organizations

Non-profit organizations have played a critical role in filling the gaps created by provincial government cost-cutting (Brouard et al., 2015). For example, non-profit organizations such as Green Communities Canada and the Residential Energy Efficiency Project were deeply involved in the delivery of the federal EnerGuide for Houses and ecoEnergy programs (Hoicka et al., 2014). Further, the GEGEA that created the feed-in-tariff program with benefits for community-based groups created opportunities for social enterprises in the energy sector. Support for the non-profit sector in Ontario has included numerous networks and funding agencies. However, Brouard et al. (2015) note that "the dominant formulation of social enterprise in Ontario, especially from the point of view of funding bodies, is one that focuses on individual entrepreneurs creating successful businesses that have, as an element, a broadly construed social purpose (e.g., employment or environmental need)" (p. 65).

Private Businesses

Ontario's Innovation Agenda (Ontario, 2008) articulated the desire to develop innovation. Further, the agenda developed networks to encourage researchers, entrepreneurs, and businesses with a streamlined approach of client-based services to commercialize innovations (Hepburn, 2013). One prominent example was the Green Button Initiative. This program was developed by the province's innovation hub (MaRS) in order to encourage "standardized and secure access to smart meter data (that) would leverage the province's global-leading investment in the smart grid and would open up the sector to innovative solutions for energy conservation" (Bordeaux and Vesta, 2015). It had the goal of having third party service providers enter the market to provide services that encourage behavior change among customers.

Energy Users and Justice Concerns in Ontario Context

Ontario is also an important context to investigate due to the presence of numerous energy justice concerns for energy users. Concerning the distribution of costs for households, for example, while Ontario's energy poverty rate has been estimated to be roughly 7% (Canada Energy Regulator, 2017), energy poverty is experienced more frequently by Ontario's rural energy users (Scott, 2016) as well as racialized and Indigenous peoples (CUSP, 2019). Further, low-income households, which are far more likely to experience and be harmed by energy poverty, are estimated to be 14.4% of Ontario's population (Statistics Canada, 2017). Low-income households are more likely to be renters (Canadian Rental Housing Index, 2018), and face a higher risk of missing electricity payments—for example, in 2015, 60,000 Ontario homes had their power shut off for failing to make payments (Habitat for Humanity Halton-Mississauga, 2018). Given such challenges, it may be unsurprising that electricity prices have been a flashpoint within Ontario's politics (e.g., Bowes, 2016; O'Shea, 2016). Problems with meaningful community involvement have also been documented in Ontario. For example, the GEGEA has been criticized on the grounds that centralized, top-down development processes have perpetuated procedural injustices, where communities have been excluded from decision-making processes, contributing to deepened feelings of disempowerment and marginalization (McRobert et al., 2016; Walker and Baxter, 2017). Further, the IESO's Indigenous Community Energy Plan program was argued to employ an overly top-down approach lacking meaningful participation and consideration of "local needs, values and resources" (Rakshit et al., 2018, p. 21).

MATERIALS AND METHODS

This section outlines the materials and methods used in this research. The unit of analysis is the demand-side low-carbon innovation. One hundred and twenty-two innovations were identified using two methods, described in detail in section Identification of Innovations. The innovations were then assessed according to an energy justice framework detailed in section Development and Coding of Energy Justice Indicators.

Identification of Innovations

The methods involved in the identification of innovations are outlined here and a more detailed description is available in the Hoicka et al. (2021). In Hoicka et al. (2021), which focuses on understanding the potential of low-carbon innovations aimed at the demand-side (i.e., end users) to impact socio-technical system change, the ETIS framework was employed to identify low-carbon innovations. Within the ETIS, a policy domain can be used to identify a regime boundary within which governments and institutions deploy policies (Matti et al., 2017). The policy domains that are typically investigated by ETIS studies include energy, environmental, science, technology and innovation, and industrial policy, but they vary by ETIS and are context dependent, defined by the institutions in a particular context. Innovations offered during the 2003–2018 timeframe comprise the scope of this research. In June 2018, a conservative provincial government was elected and many policies were reversed or rescinded; innovations post-election are therefore not considered. The ETIS policy domains specific to the Ontario context that influence the diffusion of low-carbon innovations for the demand-side were: climate change; energy; industrial and science, technology, innovation; and social enterprise and social innovation.

Innovations were identified using a combination of two approaches:

- Desk research was conducted to identify institutions (across federal, provincial and municipal scales) and their associated legislations, plans, strategies, and policy frameworks; actors and networks; and the aspirational demand-side innovations identified in these documents. This research also identified experts across the four policy domains who were sent a survey.
- Two surveys were used. A first survey was sent to identified experts belonging to the four policy domains including individuals belonging to intermediaries (i.e., accelerator and incubator centers); municipal, provincial or federal governments; regulators and system operators; universities and research institutes; utilities; non-profit organizations; consultants and other private businesses. Participants were asked to identify innovations available to Ontario's energy users that have the potential to make an important contribution to a transition to a low-carbon energy system. A second survey was next sent to the providers of innovations themselves and the identified innovations.

The scope of the current analysis is based on data resulting from the first survey, wherein 475 surveys were sent to individuals with 135 responding and resulting in the identification of 90 innovations relevant to this analysis; 32 innovations relevant to this analysis were additionally identified solely through desk research.

Development and Coding of Energy Justice Indicators

A dataset of innovations was developed wherein each innovation was coded according to publicly available sources, such as innovation websites and government policy documents. Innovations were then coded according to our framework for assessing energy justice, which draws from Sovacool and coauthors framework for understanding energy justice (Sovacool and Dworkin, 2015; Sovacool et al., 2016, 2019a). Four indicators—availability, affordability, information, and involvement—were developed in relation to four corresponding energy justice principles (see **Table 1**). As is outlined in section Energy Justice, the particular principles were selected due to their applicability to the three main tenets of energy justice (McCauley et al., 2013), as well as the characteristics of the available data. The research employed binary coding, rather than a scaled approach, given the innovations research and the survey from the outset did not set out or have the particular objective of examining the justice components or using a justice framework for examining Ontario's innovations. Therefore, each innovation in our sample was coded for the "presence" or "absence" of availability, affordability, information, and involvement—our measures of energy justice. Thus, each energy justice indicator was measured as a binary 1–0 outcome for each type of innovation user. **Table 2** provides examples of coded text for each energy justice indicator. Coding of justice

TABLE 1 | Energy justice indicators.

Indicator	Coding approach for assessing indicator	Principle	Definition of principle
Availability	This indicator assesses whether the innovation aims to improve provision of supply, infrastructure, energy efficiency, conservation, transportation, storage, and/or distribution of energy. This includes, for example, the availability of energy efficiency technologies or electric vehicle infrastructure. This does not include, for example, information about the provision of supply, infrastructure, energy efficiency, conservation, transportation, storage, and/or distribution of energy.	Availability	Broadly, availability draws from the idea that "people deserve sufficient energy resources of high quality" (Sovacool et al., 2016). Sovacool and Dworkin (2015) emphasize concerns related to supply and reliability, as well as technological innovations enhancing conservation, transportation, storage, and distribution of energy, including investment in such factors.
Affordability	This indicator assesses whether the innovation aims to reduce cost/improve affordability of supply, infrastructure, conservation, transportation, storage, and/or distribution of energy for each user type. This includes, for example, improved affordability through financial incentives.	Affordability	Affordability draws from the idea that "the provision of energy services should not become a financial burden for consumers, especially the poor" (Sovacool et al., 2016). Furthermore, affordability concerns energy bills that do not overly burden consumers, as well as stable and equitable prices (Sovacool and Dworkin, 2015).
Information	This indicator assesses whether or not the innovation aims to provide "active" information about supply, infrastructure, conservation, transportation, storage, and/or distribution of energy for each user type. This includes, for example, proactive provision, information resulting from energy audits, capacity-building initiatives, or lobbying. The indicator does not incorporate "passive" information, such as general information provided on publicly available websites; however, this is discussed as an element of transparency in the discussion section.	Good governance	Sovacool and Dworkin (2015) identify "good governance" as a principle of energy justice, where access to information about energy and the environment is a central element of "good governance."
Involvement	This indicator assesses whether or not each type of actor was involved (through engagement and consultation efforts) in the development of the innovation.	Due Process	Due process, for the purposes of this research, draws primarily from the idea that "communities must be involved in deciding about projects that will affect them" (Sovacool and Dworkin, 2015).

TABLE 2 | Examples of coded text for each indicator.

Indicator	Fragment of coded text	Coding approach
Availability	"Participation is easy, and includes the installation of a switch that allows us to send a signal to either your electric water heater to temporarily delay the heating of water or central air conditioner to temporarily cycle on and off the compressor in your unit. As an added incentive, you will receive your choice of a FREE in-home display (IHD) that will allow you to monitor your energy consumption" (Community Conservation Manager, 2018).	Given the provision of energy efficiency technologies to energy users, this innovation was coded as addressing the availability indicator for the eligible types of energy users.
Affordability	"Homeowners can get a low-interest loan of up to $75,000 to cover the cost of home energy improvements" (Toronto, 2017).	Given the aim to overcome cost barriers for energy efficiency, this innovation was coded as addressing the affordability indicator for the eligible types of energy users.
Information	"This includes activities such as awareness campaigns, material and course development, and education workshops. These projects help equip communities and organizations with knowledge and training, creating opportunities for them participate in Ontario's energy sector" (IESO, 2017).	Given the provision of active information (i.e., educational workshops) about energy activities, this innovation was coded as addressing the information indicator for the eligible types of energy users.
Involvement	"The list of invitees included architects, engineers, developers, builders, environmental groups, and property owners, and/or managers (particularly of large amounts of property in Toronto, such as the Toronto District School Board)" (Toronto, 2006).	Given the involvement of the identified actors in consultation efforts, this innovation was coded as addressing the involvement indicator for private businesses, non-profit organizations, and institutions.

indicators was completed by the first author, with support from co-authors.

By developing energy justice indicators derived from existing scholarly frameworks, we provide a method for measuring energy justice, in consideration of various innovation users and innovation providers (see **Table 3**). This measurement can contribute to understanding energy justice in low-carbon energy innovations, within a given socio-technical system, and thus demonstrate how energy justice can be applied to critical, current, and understudied practical challenges.

RESULTS

This study assessed 122 demand-side innovations available to Ontario's energy users, which we have categorized according to the aim of the innovations. The aim of the innovation refers to the specific contribution to low-carbon energy transitions advanced by the given innovation (e.g., the advancement of battery storage; see **Table 4**). An example is provided to demonstrate how each specific aim may be advanced by an innovation.

TABLE 3 | Various actors involved within the Ontario ETIS innovation system.

Actor category	Actor types assessed	Assessment approach
Innovation users[a]	(1) Governments (including federal, provincial and municipal), (2) homeowners, (3) low-income households, (4) renters, (5) Indigenous communities[b] (including First Nation and Métis communities), (6) individuals (including targeted members of the public that are not explicitly included in other subcategories such as homeowners or renters), (7) public sector institutions (including school boards, universities, colleges, libraries, and hospitals)[c], (8) non-profit organizations, (9) private businesses (including industry, consultants and other private businesses), and (10) utilities (including natural gas, electricity utilities, and planning authority).	The presence or lack of presence of each energy justice indicator was coded for each type of innovation user. One innovation may be intended for multiple types of energy users.
Innovation providers	(1) Governments (including federal, province of Ontario and municipal), (2) non-profit organizations, (3) private businesses, and (4) utilities (including natural gas distributors, electricity distribution companies, and the planning authority).	Each innovation was coded according to what type of actor provided the innovation. One innovation may be provided by multiple types of actors (e.g., one innovation may be provided by a partnership between a business and a non-profit organization).

[a] *These categories emerged from the data, rather than being pre-determined, and correspond with the documented users of a given innovation.*
[b] *It should be noted here that results concerning Indigenous communities should be considered with caution. It was difficult to engage networks that served Indigenous communities, particularly in the cases when served by private business or non-profit sectors (government and utility programs have more publicly available information). Due to the system boundary, remote communities were not addressed by this research.*
[c] *While many of these public sector institutions operate with a not-for-profit model, for the purpose of the user type assessment, these were coded as distinct categories. The government of Ontario notes differences between public sector institutions and non-profit organizations, including their organizational mandate, sources of revenue and staffing levels (Government of Ontario, 2019), which warrant distinct consideration from a justice standpoint.*

Of the 122 innovations analyzed, 36 were provided by governments (federal, provincial or municipal), 38 by non-profit organizations, 28 by private businesses (including industry and industry associations), and 47 by utilities (including electricity and natural gas utilities and the provincial system operator and planning authority). Reference populations, i.e., the larger group, to which an analytic sample is being compared (Schmidt and Pardo, 2014), for these innovation providers are as follows: 444 municipal governments, 1 provincial government, 1 federal government, 59,605 non-profit organizations, 1,063,756 private businesses, and 77 utilities (Hoicka et al., 2021).

Presence of Energy Justice in Low-Carbon Energy Innovations

This section concerns whether the 122 demand-side low-carbon energy innovations are meeting energy justice criteria. Almost all (98%) of the innovations demonstrated presence of either:

(1) Aiming to improve *availability* of supply, infrastructure, energy efficiency, conservation, transportation, storage, and/or distribution of energy;
(2) Aiming to reduce cost/improve *affordability* of supply, infrastructure, energy efficiency, conservation, transportation, storage, and/or distribution of energy for energy users;
(3) Aiming to provide targeted *information* about supply, infrastructure, conservation, transportation, storage, and/or distribution of energy to energy users; or
(4) *Involving* various actor types through engagement and consultation in the development of the innovation.

Further, each innovation demonstrated between 0 and 4 of the energy justice indicators and, on average, each innovation in this sample demonstrated 2 of the energy justice indicators. A chi-square test of independence was conducted to examine the differences between the presence of justice indicators in the Ontario innovations and significant differences were found ($\chi^2 = 186.86$, $df = 6$, $p < 0.05$). As shown in **Table 5**, information provisioning was present in 63% of the innovations, compared to availability in 59%, affordability in 56%, and involvement in 40% of the innovations. Thus, the data show moderate majorities for information, availability and affordability. Involvement was "unknown" for 54% of the innovations, in contrast with 3% unknown for all other energy justice indicators.

Presence of Energy Justice Across Innovation Users

This section concerns how the 122 demand-side low-carbon energy innovations are meeting energy justice criteria *in relation to the targeted innovation users*. Results demonstrate that availability, affordability, information, and involvement of the demand-side innovations vary according to which energy user type is on the receiving end of the innovations. In particular, innovation availability, affordability, information, and involvement were present most frequently in the innovations provided to private businesses. Conversely, innovation availability, affordability, information, and involvement were present less for low-income households, renters and Indigenous communities. The relationship between the presence of justice in innovations and user type was not tested given that cell counts for some cells were 0.

Presence of Energy Justice Across Various Innovation Providers and Users

This section first concerns how the 122 demand-side low-carbon energy innovations are meeting energy justice criteria *in relation to the provider of the innovation*. Of the innovations

TABLE 4 | Description of innovations in the sample.

Aim of the innovations	Description	# of innovations[a]	Example innovation
Battery storage	These serve to balance supply and demand within energy systems, and ease the points of congestion (IESO, 2021a).	6	Community energy storage
Demand-side management	The modification of consumer demand for natural gas or electricity through various methods such as financial incentives, education, and other programs (OEB, 2008).	28	Culture of conservation—unplug your stuff campaign
District energy	Networks that involve "multi-building heating and cooling, in which heat and/or cold is distributed by circulating either hot water or low-pressure steam through underground piping" (Rezaie and Rosen, 2012, p. 3)	1	Combined heat and power (CHP) incentives
Electric vehicles	Any vehicle that is partially or entirely powered by electricity and plugs in to recharge (Ministry of Transportation, 2009).	9	Electric vehicle suitability assessments
Electric vehicle charging stations	Charging stations for electric vehicles (e.g., at home, at work or at public charging stations; Ministry of Transportation, 2009).	3	Electric vehicle chargers grant programs
Energy efficiency	"The ratio of useful energy output/energy input, usually defined as a percentage. The more efficient a device is, the less energy is lost, which allows less energy to be used to produce an energy service" (Hoicka and MacArthur, 2021). While energy efficiency may be a component of an energy demand reduction strategy, it is coded as conceptually distinct within this study.	68	Financing of energy efficiency retrofits through local improvement charges
Local energy plans	A process to develop "strategic vision documents that outline the energy goals of a local context or community" (Wyse and Hoicka, 2019)	7	Capacity-building for smart energy communities
Microgrids	A small grid with generation, consumption, and sometimes storage that can operate in a grid-connected and "isolated" mode (Palensky and Kupzog, 2013)	2	Micro-grid demonstration project
Natural gas infrastructure	Infrastructure that supports the transportation of natural gas through pipelines to local utilities (OEB, 2012).	1	Natural gas grant program
New construction	The building of new and substantially renovated buildings (Cadmus, Econoler and Apex Analytics, 2018).	7	Energy efficiency incentives for new construction
Program design	The design of specific programs that contribute to, for example, energy efficiency, or demand-side management.	1	Energy efficiency consultancy
Public/shared/alternative transportation	Includes public, shared, and sustainable transportation services.	7	Community bike sharing services
Renewable energy (location not specified)	Energy derived from natural processes that are replenished at a rate that is equal to or faster than the rate at which they are consumed (Government of Canada, 2017).	19	Energy efficiency retrofits for rooftop (PV) solar
Renewable energy (onsite)	Renewable energy that is generated on-site.	10	Institutional research laboratories
Renewable energy (offsite)	Renewable energy that is generated off-site.	4	Green electricity retailer
Retrofits/installations	These may involve, for example, improving or replacing lighting fixtures, ventilation systems or windows and doors, or adding insulation (Government of Canada, 2019).	33	Deep energy retrofit program
Smart meters	These allow for the implementation of time-of-use rates, and for customers to manage their electricity consumption (IESO, 2021b).	6	Residential energy data and analytics
Submetering	This allows a landlord, property management firm, etc. to bill tenants for individually measured electricity use (Navigant Consulting, 2016).	1	Commercial building metering and submetering

[a]*An innovation may feature one or more aims; therefore, the total number of innovations in this table is >122 demand-side innovations.*

assessed in this study, utilities are found to be the most frequent provider of innovations (38%), followed by non-profits (31%), governments (30%), and then private businesses (23%). **Table 6** displays how availability, affordability, information, and involvement of the innovations vary according to the different types of innovation providers. Energy justice, according to our indicators, is being addressed in different proportions according to the type of innovation provider. Notably, many of the innovations provided by governments and utilities demonstrate availability, affordability, information and involvement, whereas innovations provided by non-profits and businesses see considerably more variation—for non-profit-led innovations, information provisioning was present in 89% of the innovations, compared to <40% for availability,

TABLE 5 | The extent to which innovations demonstrate four indicators of energy justice ($n = 488$).

			Availability	Affordability	Information	Involvement
Innovations	Yes	Count	72	68	77	49
		%	59%	56%	63%	40%
	No	Count	46	50	41	7
		%	38%	41%	37%	6%
	Unknown	Count	4	4	4	66
		%	3%	3%	3%	54%
	Total	Count	122	122	122	122
		%	100%	100%	100%	100%

TABLE 6 | Frequencies of justice indicators by provider type.

			Availability	Affordability	Information	Involvement
Energy justice of innovations provided by governments ($n = 144$)	Yes	Count	27	26	20	19
		%	75%	72%	55%	53%
	No	Count	9	10	16	0
		%	25%	28%	44%	0%
	Unknown	Count	0	0	0	17
		%	0%	0%	0%	47%
	Total	Count	36	36	36	36
		%	100%	100%	100%	100%
Energy justice of innovations provided by utilities ($n = 188$)	Yes	Count	31	31	23	30
		%	66%	66%	49%	64%
	No	Count	12	12	20	6
		%	26%	26%	43%	13%
	Unknown	Count	4	4	4	11
		%	9%	9%	9%	23%
	Total	Count	47	47	47	47
		%	100%	100%	100%	100%
Energy justice of innovations provided by non-profits ($n = 152$)	Yes	Count	15	12	34	10
		%	39%	32%	89%	26%
	No	Count	23	26	4	0
		%	61%	68%	11%	0%
	Unknown	Count	0	0	0	28
		%	0%	0%	0%	74%
	Total	Count	38	38	38	38
		%	100%	100%	100%	100%
Energy justice of innovations provided by private businesses ($n = 112$)	Yes	Count	18	13	19	8
		%	64%	46%	67%	29%
	No	Count	10	15	9	2
		%	36%	54%	32%	7%
	Unknown	Count	0	0	0	18
		%	0%	0%	0%	64%
	Total	Count	28	28	28	28
		%	100%	100%	100%	100%

affordability, and involvement; and for business-led innovations, information was present for 67% of innovations, availability for 67%, affordability for 46%, and involvement for 29%. A chi-square test of independence was conducted to analyze the frequencies for utilities and significant differences were found ($\chi^2 = 15.87$, $df = 6$, $p < 0.05$). Due to low expected

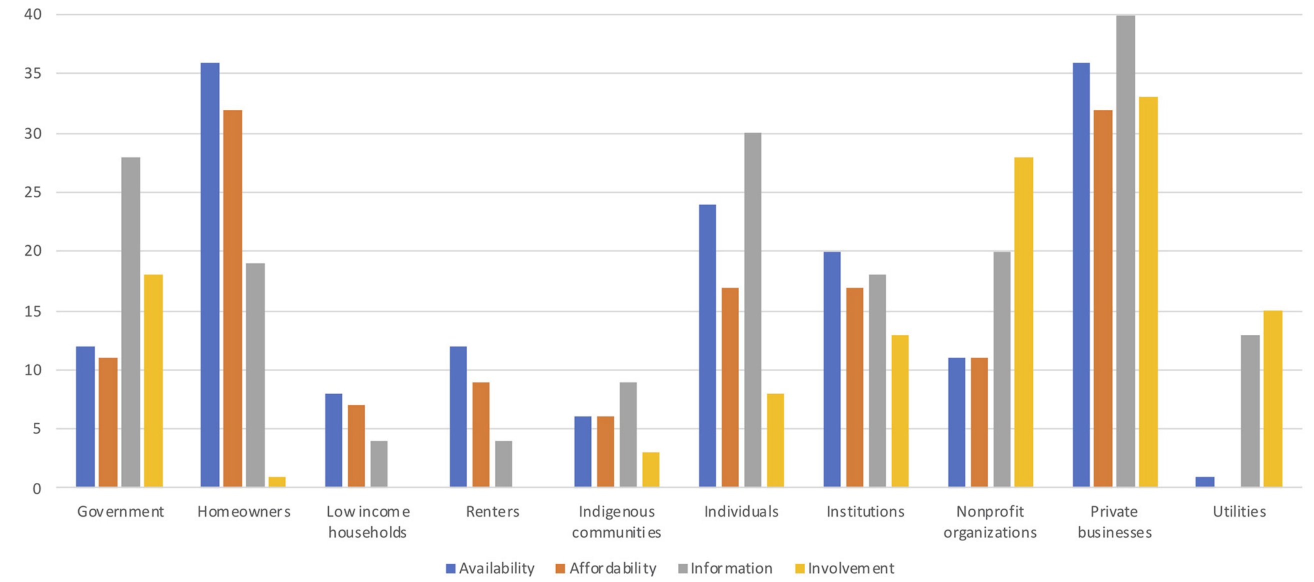

FIGURE 1 | Frequencies of energy justice indicators across innovations by user type.

frequencies[2], this test was not performed for governments, non-profit organizations or private businesses.

Figure 1 displays the combined results for all types of innovation providers according to each type of innovation user. The following crosstabulation (**Table 7**) and corresponding clustered bar charts (**Figures 2–5**) display each type of innovation provider according to each type of innovation user, in order to demonstrate the provision of innovations by provider type for each user type. The table and charts are complementary to each other, where the table displays the relationship between innovation providers and users, with energy justice indicators collapsed. The clustered bar charts display the relationship between innovation providers and users, taking into account each of the energy justice indicators. The total count in the following tables and figures refer to the total possible outcomes, i.e., the number of innovations offered by each type of provider, across the four energy justice indicators, for each type of user. For example, 36 government-provided innovations, across 4 energy justice indicators, for 10 types of innovation providers = 1,440 total possible outcomes.

The results show that while similar patterns are present across all innovation providers, the presence of energy justice is demonstrated most frequently in the innovations provided to private businesses (between 26 and 32% of innovations), and least frequently in the innovations provided to low-income households (between 0 and 7%), renters (between 2 and 10%), and Indigenous communities (between 1 and 7%), no matter the provider type. However, innovations provided by governments and utilities demonstrate the highest presence of energy justice for low-income households (7 and 6%, respectively), while utilities demonstrate the highest presence for renters (10%) and Indigenous communities (7%). Innovations provided by private businesses demonstrate the lowest presence of energy justice for these types (0, 2, and 1%, respectively). A chi-square test was conducted to examine the differences between the presence of justice indicators and significant differences were found for each innovation provider: governments ($\chi^2 = 73.80$, $df = 18$, $p < 0.05$); utilities ($\chi^2 = 103.86$, $df = 18$, $p < 0.05$); non-profits ($\chi^2 = 72.45$, $df = 18$, $p < 0.05$); and private businesses ($\chi^2 = 92.00$, $df = 18$, $p < 0.05$).

Concerning information, where innovations provided by non-profits and private businesses demonstrated the highest presence overall, innovations provided by private businesses demonstrate the highest presence *for* private business innovation users; and innovations provided by non-profits demonstrate the highest presence for private business and individuals.

Finally, utilizing data provided in **Tables 7**, **8** presents the *combined* frequencies of the presence of energy justice for innovation users across the four types of innovation providers, thereby accounting for all users and allowing for a direct comparison of providers. For example, from **Table 7**, governments provided innovations to 10 different user types, each accounting for 144 innovations and therefore a total of 1,440 innovations across all users, as reflected in **Table 8**. The combined frequencies included in this table thus lead to a higher number of possible outcomes for each innovation, resulting in higher percentage of "No" for all provider types. Results demonstrate that innovations provided by governments (14.58%) and utilities (14.26%) incorporate significantly more justice elements (across users) compared to the innovations provided by non-profits (12.43%) and private businesses (11.42%); ($\chi^2 = 29.69$, $df = 6$, $p < 0.05$).

[2]"In contingency tables with more than one degree of freedom it is inappropriate if more than about one fifth of the cells have expected values <5 or any cell an expected value of <1" (Swinscow, 1997, n.p.).

TABLE 7 | Crosstabulation of the presence of energy justice[a] across innovation users by provider type.

			Government	Homeowner	Low-income households	Renter	Indigenous communities	Individuals	Institutions	Non-profit	Private businesses	Utilities
Energy justice of innovations provided by governments $n = 1,440$	Yes	Count	26	34	10	6	7	31	24	22	38	12
		%	18%	24%	7%	4%	5%	22%	17%	15%	26%	8%
	No	Count	101	91	117	110	120	96	103	105	89	115
		%	70%	63%	81%	76%	83%	67%	72%	73%	62%	80%
	Unknown	Count	17	19	17	28	17	17	17	17	17	17
		%	12%	13%	12%	19%	12%	12%	12%	12%	12%	12%
	Total	Count	144	144	144	144	144	144	144	144	144	144
		%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Energy justice of innovations provided by utilities $n = 1,880$	Yes	Count	25	45	12	19	14	24	23	31	60	15
		%	13%	24%	6%	10%	7%	13%	12%	16%	32%	8%
	No	Count	140	110	147	131	151	141	142	134	105	150
		%	74%	58%	78%	70%	80%	75%	76%	71%	56%	80%
	Unknown	Count	23	33	29	38	23	23	23	23	23	23
		%	12%	18%	15%	20%	12%	12%	12%	12%	12%	12%
	Total	Count	188	188	188	188	188	188	188	188	188	188
		%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Energy justice of innovations provided by non-profits $n = 1,520$	Yes	Count	22	21	5	8	9	27	17	29	41	10
		%	14%	14%	3%	5%	6%	18%	11%	19%	27%	7%
	No	Count	102	103	119	112	115	97	107	95	83	114
		%	67%	68%	78%	74%	76%	64%	70%	63%	55%	75%
	Unknown	Count	28	28	28	32	28	28	28	28	28	28
		%	18%	18%	18%	21%	18%	18%	18%	18%	18%	18%
	Total	Count	152	152	152	152	152	152	152	152	152	152
		%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Energy justice of innovations provided by businesses $n = 1,120$	Yes	Count	19	18	0	2	1	11	21	9	34	13
		%	17%	16%	0%	2%	1%	10%	18%	8%	30%	12%
	No	Count	75	76	94	89	93	83	73	85	60	81
		%	67%	68%	84%	79%	83%	74%	65%	75%	54%	72%
	Unknown	Count	18	18	18	21	18	18	18	18	18	18
		%	16%	19%	16%	16%	16%	16%	16%	16%	16%	16%
	Total	Count	112	112	112	112	112	112	112	112	112	112
		%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

[a]*Energy justice here is the combined score.*

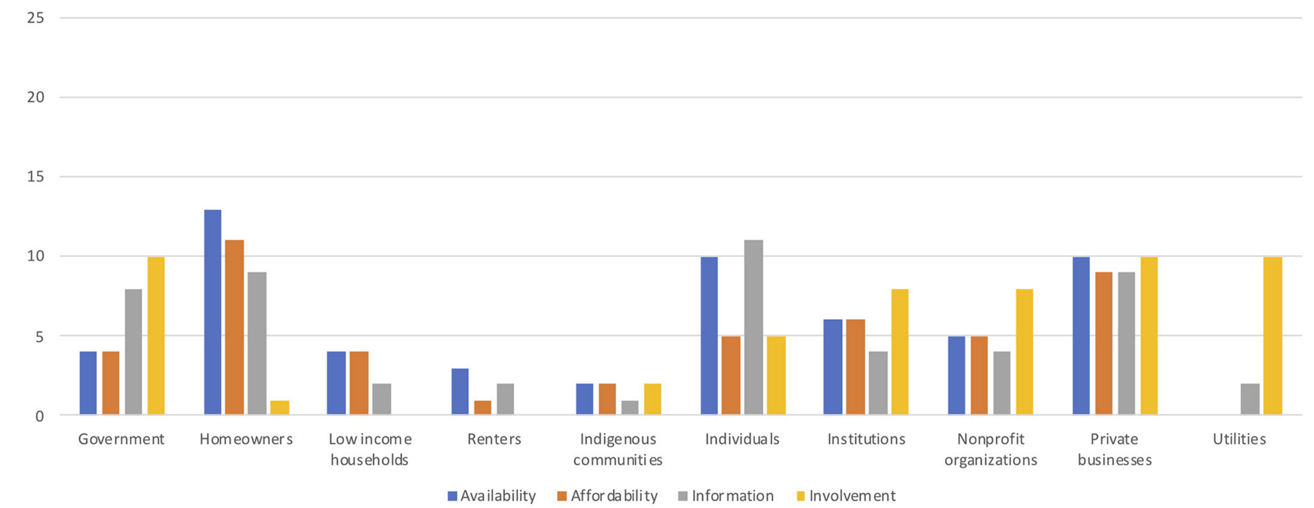

FIGURE 2 | Energy justice of government provided innovations according to user type ($n = 1,440$).

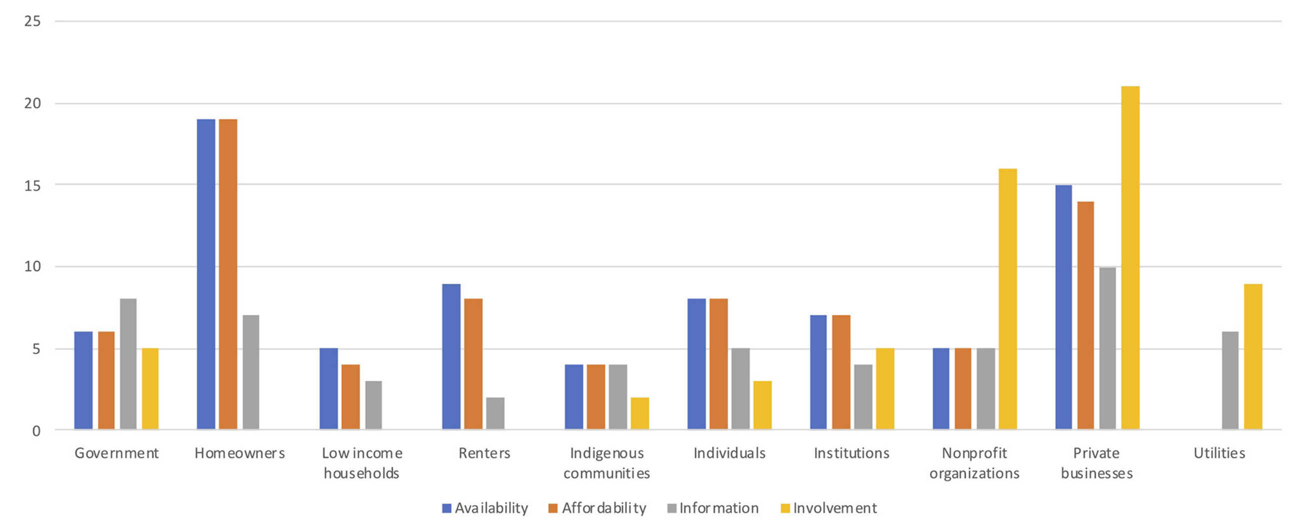

FIGURE 3 | Energy justice of utility provided innovations according to user type ($n = 1,880$).

DISCUSSION

In order to address whether demand-side low-carbon energy innovations within Ontario's ETIS meet energy justice criteria, we employed indicators to measure energy justice across a range of innovations—the scope of which pertains to innovations identified specifically through Survey 1 and desk research from Hoicka et al. (2021)—provided to energy users. By applying indicators in this way, and by considering the relationship between the innovation user and innovation provider, our research identified potential justice gaps in the Ontario context. Thus, we contribute to literature by demonstrating how energy justice indicators can be derived from existing energy justice scholarship in order to better understand the relationships between innovation providers and innovation users within a given socio-technical system. The following section proceeds by first connecting our results to existing scholarship, including conversations about a Green New Deal in Canada; second, a reflection is provided on the design and application of indicators to measure energy justice generally, and in this particular context; last, some limitations of this study are discussed.

Energy Justice in Ontario's ETIS

Based on Survey 1 and desk research data, our results suggest that availability, affordability, and information are broadly being addressed within Ontario's ETIS, with a particular

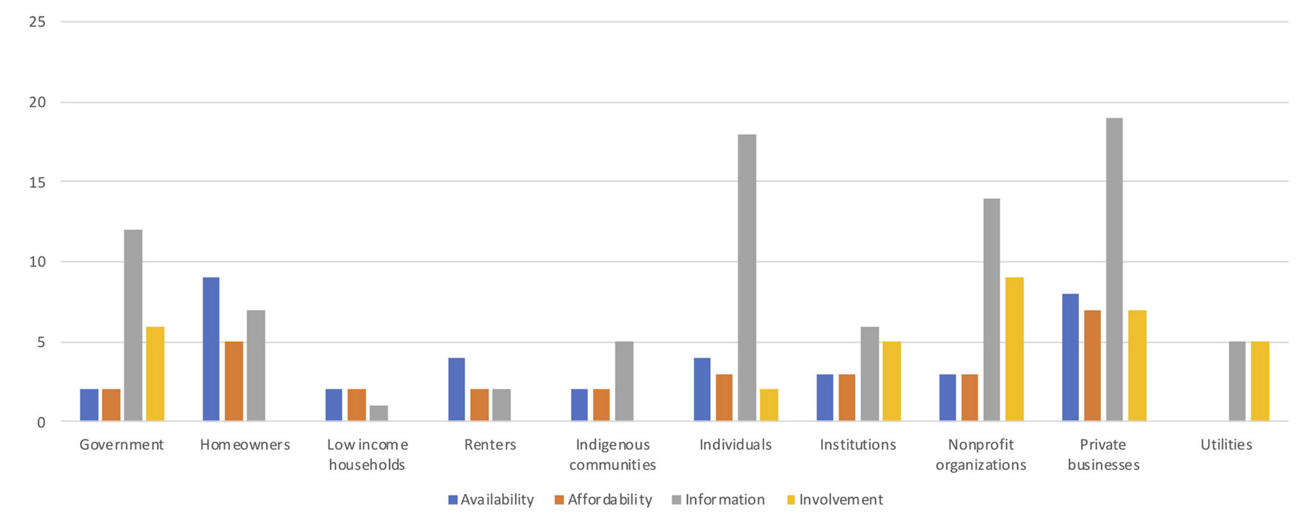

FIGURE 4 | Energy justice of non-profit organization provided innovations according to user type ($n = 1{,}520$).

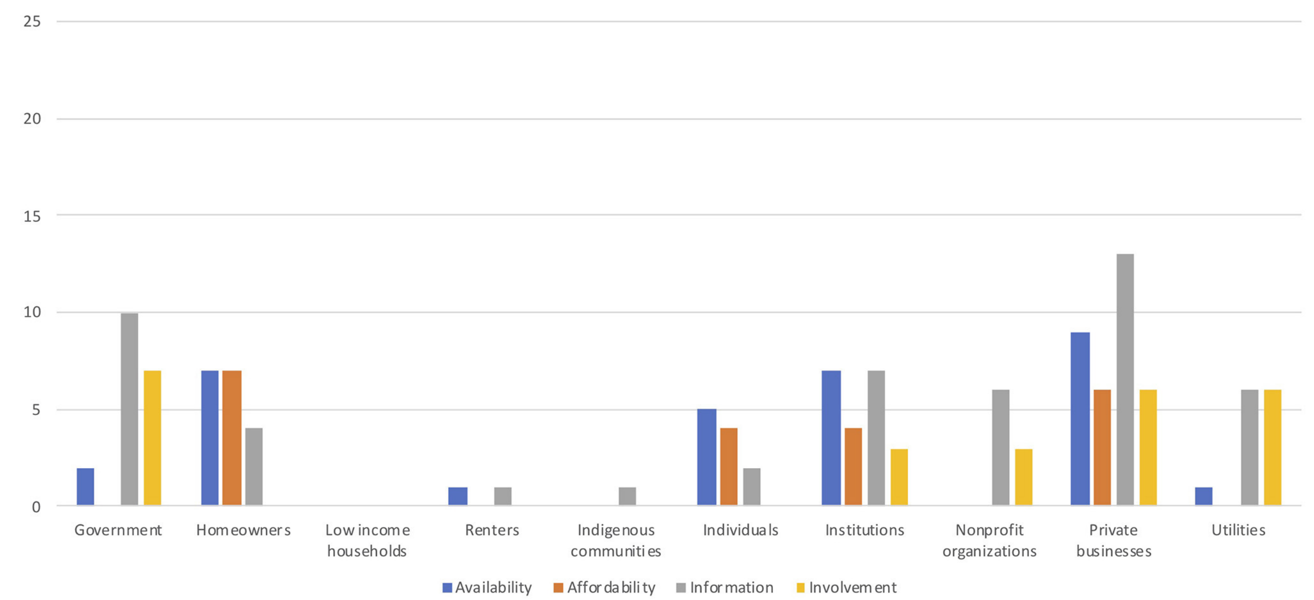

FIGURE 5 | Energy justice of private business provided innovations according to user type ($n = 1{,}120$).

emphasis on information. However, it should be noted that while the availability, affordability, and information indicators each demonstrated a majority "yes," these are not substantial majorities; thus, there remains opportunities for improvement in these areas. While a low presence of involvement was demonstrated overall, it is important to note that involvement was unknown for the majority of the innovations. Thus, it is unclear whether the results reveal low involvement, or merely reflect a lack of transparency surrounding involvement. However, a lack of transparency is nonetheless a concern, especially considering that procedural justice concerns have been raised in the Ontario context (Walker and Baxter, 2017; Rakshit et al., 2018).

Concerning the innovation users, our research finds that the ETIS may perpetuate inequities through an under-emphasis on potentially marginalized actors. In particular, the lack of innovations addressing affordability and availability for low-income households and renters is a significant justice gap. Furthermore, these same types of actors were also very rarely stated to be included within involvement processes. Even the most represented indicator overall, information, was not found to specifically target people in vulnerable circumstances, including

TABLE 8 | Combined frequencies across provider types.

			Governments	Utilities	Non-profits	Private businesses
Energy justice of innovations ($n = 5{,}960$)	Yes	Count	210	268	189	128
		%	14.58%	14.26%	12.43%	11.42%
	No	Count	1,047	1,351	1,047	809
		%	72.71%	71.86%	68.88%	72.22%
	Unknown	Count	183	261	284	183
		%	12.71%	13.88%	18.68%	16.34%
	Total	Count	1,440	1,880	1,520	1,120
		%	100%	100%	100%	100%

low-income households and renters. Given that knowledge-gaps pertaining to energy are associated with the inability to meaningfully participate in energy decision-making (Bozuwa, 2019), it seems critical that people in vulnerable circumstances are targeted with active information (e.g., energy audits or capacity-building initiatives), rather than merely having passive information on public websites.

Last, and perhaps most critical, concerning the relationship between the innovation provider and innovation user, we found that the type of innovation provider has potentially an important role in justice implications. Specifically, in the Ontario context, innovation providers that are governments, or some combination of publicly owned or heavily regulated, place a greater emphasis on justice when providing innovations, including the provision of innovations for people in vulnerable circumstances. These findings contribute to growing scholarship that considers the evolving relationships between innovation users and providers, including concerns about privatization and funding cuts to public services (Williams et al., 2014). Given that social enterprises (e.g., private businesses and non-profit organizations) operate within the "third sector" of the economy, often where market or governmental failures exist in the provision of social welfare (Hillman et al., 2018), it is critical that any increased reliance on such actors does not exasperate justice concerns for people in vulnerable circumstances. Further, while non-profit organizations are argued to have filled the gaps of provincial government cost-cutting (Brouard et al., 2015), our analysis suggests that non-profit organizations are more likely to address knowledge gaps (i.e., through the provision of information) than any of the other indicators featured in our analysis. While information is an important component of procedural justice in that it can result in higher knowledge levels, there is debate as to the effectiveness of information, on its own, in changing behavior (Abrahamse et al., 2005). Given that the dominant formulation of funding for social enterprises in Ontario is one that focuses on the development of successful business ventures (Brouard et al., 2015) it is possible, due to lack of funding, that many non-profit organizations have limited capacity to address other energy justice indicators. Lastly, although social enterprises are increasingly key drivers of social progress (Hillman et al., 2018), the profit-motive present within social enterprises in Ontario context may disincentivize the provision of innovations to potentially vulnerable groups (i.e., those that are less likely to pay directly for innovations).

Notably, these findings reflect similar concerns regarding public services and social justice within ongoing conversations about a Green New Deal (GND) in Canada. In May 2019, the Coalition for a GND was formed, which provided a platform for discussions from townhalls across 150 communities, involving roughly 7,000 people. These participatory townhalls produced a range of "green lines" for a Canadian GND that emphasized the importance of a legally binding climate target in line with 1.5C, public investment in renewable energy infrastructure, subsidies for greener technology, full access to quality public service, centering of marginalized communities and affordable energy-efficient housing (The Pact for a Green New Deal, 2019). Our finding, that government delivered, publicly owned or regulated innovation providers may more frequently address energy justice—conceptualized here as availability, affordability, information, and involvement—for marginalized communities, is therefore an important contribution to these ongoing conversations.

Reflection on the Development and Application of Energy Justice Indicators

Our research demonstrates how energy justice indicators can be derived from existing energy justice scholarship and applied to critical, current and understudied practical challenges. Such an approach contributes to literature because it provides a tool for researchers to measure energy justice within a given sociotechnical context. This approach is also important for policymakers, given that measurement can assist in the development of evidence-based decision-making.

Given the important findings within the Ontario context, our study suggests that the development and application of energy justice indicators could be applied to other socio-technical systems to identify potential justice gaps. For example, such an approach could be incorporated into energy planning initiatives within a given locality (e.g., regional energy planning or local energy plans) in order to inform future program design and implementation. Depending on the particular challenges in a given context, the development of more or different indicators, e.g., derived from other energy justice principles, as well as different types of actors, may provide a more appropriate measure of energy justice. Furthermore, funders and program designers that are concerned with social justice may wish to employ a similar approach to ensure funding is addressing energy justice concerns, especially for people in vulnerable circumstances.

Limitations

In keeping with Sovacool and Dworkin's (2015) warning that there are limitations and difficulties associated with quantifying complex justice concerns, some limitations emerged throughout the development of our study. We found that indictors provide a useful, but limited, measure of justice—for example, our involvement indicator measured who is involved within consultation efforts, but did not consider the degree to which they were involved, nor whether any concerns actors raised were overcome. This limitation is made more noteworthy due to the use of binary indicators, which are limited in their ability to capture nuance. While binary indicators provide an achievable scope for the study of 122 innovations, a more in-depth study involving a smaller sample of innovations may allow for a "deeper dive" with interviews and literature reviews for individual innovations. Thus, our research highlights the importance of complementary qualitative research, which can strengthen our understanding with investigations of particular innovations and activities within a socio-technical system.

Further limitations also arise with our reliance on publicly available data, which draws heavily on data from innovation providers. As such, there may be some limitations in our study's ability to reveal injustices if data were misrepresented on public-facing websites and documents. Furthermore, certain characteristics related to justice were absent from consideration given their absence in publicly available data. For example, this research method was largely unable to assess racial justice, despite environmental racism being prevalent and understudied in the Canadian context (Waldron, 2018). Such a gap is significant, and again highlights the importance of complementary qualitative research. Lastly, it was difficult to engage networks serving Indigenous communities, so innovations for these communities have potentially been overlooked, particularly those provided by private business and non-profit organizations offering innovations. The results in relation to Indigenous communities should therefore be viewed with caution.

CONCLUSION

Globally, and in Ontario, the diffusion of low-carbon innovations is ongoing. Although innovations offer a range of social and environmental benefits, there is no guarantee that benefits will be distributed justly. Innovations are emerging in the context of increased decentralization and oftentimes within the context of neoliberalism, including privatization and public service cuts. Given the evolving relationships between innovation users and innovation providers, as well as increased reliance on providers such as private businesses and non-profit organizations in the provision of social welfare, investigating energy justice in low-carbon energy innovations is critical to mitigate against emerging, as well as address existing, justice issues. To that end, our study presents a valuable strategy to develop and apply energy justice indicators to investigate the gaps across a given socio-technical system, including the consideration of innovations, innovation users and innovation providers, and the relationships between them.

The findings of our study are now particularly relevant in Ontario due to the political shift which occurred at the end of the study timeline. In 2018, Ontario's Conservative party successfully campaigned on a promise to repeal significant provincial policy initiatives, including the GEGEA and the provincial cap and trade regulation that was funding the diffusion of low-carbon innovations. Hundreds of community renewable energy projects were canceled (Sharp, 2019). Considering this rollback of public investment and subsidies for a low-carbon energy transition, low-carbon innovations and climate change action, our study raises questions as to whether new justice gaps are being created. Commitments to energy justice reflect broader moral beliefs concerning social justice that, if agreed upon, ought to motivate corrective action (Galvin, 2019). It is therefore critical that these actors understand what justice gaps may emerge from the increased reliance on innovations they provide, in order for them to design and offer innovations accordingly.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

SW: research conception and design, data analysis, interpretation, literature review, and writing. RD: writing, research design, and support with analysis and interpretation of results. CH: critical conceptual, writing support, and principal investigator of the larger project this study draws from. YZ: assistance with data collection, data analysis, and strong organizational support. M-LM: assistance with data collection and data analysis. All authors contributed to the article and approved the submitted version.

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Indigenizing Climate Policy in Canada: A Critical Examination of the Pan-Canadian Framework and the ZéN RoadMap

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Climate policies and plans can lead to disproportionate impacts and benefits across different kinds of communities, serving to reinforce, and even exacerbate existing structural inequities and injustices. This is the case in Canada where, we argue, climate policy and planning is reproducing settler-colonial relations, violating Indigenous rights, and systematically excluding Indigenous Peoples from policy making. We conducted a critical policy analysis on two climate plans in Canada: the Pan Canadian Framework on Clean Growth and Climate Change (Pan-Canadian Framework), a federal government-led, top-down plan for reducing emissions; and the Québec ZéN (zero émissions nette, or net-zero emissions) Roadmap, a province-wide, bottom-up energy transition plan developed by civil society and environmental groups in Quebec. Our analysis found that, despite aspirational references to Indigenous Peoples and their inclusion, both the Pan-Canadian Framework and the ZéN Roadmap failed to uphold the right to self-determination and to free, prior, and informed consent, conflicting with commitments to reconciliation and a "Nation-to-Nation" relationship. Recognizing these limitations, we identify six components for an Indigenous-led climate policy agenda. These not including clear calls to action that climate policy must: prioritize the land and emphasize the need to rebalance our relationships with Mother Earth; position Indigenous Nations as Nations with the inherent right to self-determination; prioritize Indigenous knowledge systems; and advance climate-solutions that are interconnected, interdependent, and multi-dimensional. While this supports the emerging literature on Indigenous-led climate solutions, we stress that these calls offer a starting point, but additional work led by Indigenous Peoples and Nations is required to breathe life into a true *Indigenous*-led climate policy.

Keywords: climate policy and planning, indigenous self-determination, settler colonialism, Canada, decolonization

INTRODUCTION

"In the introduction [to the ZéN Roadmap], they say 'Indigenous people have warned us against this for centuries and environmentalists too'... Indigenous people haven't just been warning, they have been living it for decades. It is impacted their wellbeing, their health... we've surpassed this dangerous threshold in northern Canada. The way its painted in this Roadmap, it is like 'oh in the possible distant future'. No, this is concrete. It's actually happening. It's actually taking place now" (E#6).

There is mounting support that Indigenous knowledge systems are key to combating the climate crisis (IPCC, 2014). Indeed, Indigenous Peoples have been sounding the "climate" alarm bells for several decades. Drawing on their Elders and knowledge keepers, as well as their reciprocal relationship with the natural world, Indigenous Peoples have been consistently raising their voices based on changing species migrations, water levels, and weather patterns, and, when necessary, putting their bodies and spirits on the line in the face of unrelenting extraction (Gedicks, 1994, 2001; Green and Raygorodetsky, 2010; Temper et al., 2020). Scientific evidence is now catching up: we are facing an obvious and rapidly accelerating global climate crisis. Global temperatures have increased by more than 1.1°C since the late-nineteenth century due to human influences on the climate system [Haustein et al., 2017; see also Environmental Change Institute (2013)]; at the current rate of warming, we could exceed 1.5°C in a little more than a decade, and 2°C by mid-century. A report released in April 2019 by Environment and Climate Change Canada, shows Canada is warming at twice the global rate, with the Canadian Arctic in particular warming at more than three times the global rate (Bush and Lemmen, 2019).

In light of this existential threat, a growing number of governments—federal, territorial, provincial, and municipal—are declaring climate emergencies, proposing new policies, and plans. The Pan-Canadian Framework on Clean Growth and Climate Change ("Pan-Canadian Framework" or "PCF") is one such plan: a beam of "sunny ways" creeping into Canadian climate policy following the election of a majority Justin Trudeau government. This period came to a grinding halt in 2018 when a federal House of Commons climate emergency declaration was immediately—coincidentally or serendipitously—followed by an announcement of the (re)approval of the Trans Mountain pipeline (a pipeline to transport bitumen oil from the Alberta tar sands to the British Columbia coast for export). Furthermore, it became evident that despite the policies contained with the Pan-Canadian Framework, Canada was at minimum 77 megatons from meeting its 2030 greenhouse gas target[1]—a target that was "highly insufficient" from the beginning, and "not remotely in line with the international community's goal of limiting global warming to 1.5°C" (MacNeil, 2019, p. 156).

According to the 2019 United Nations Emission Gap report, emissions across the globe continue to rise at a pace that is inconsistent with a stable climate and current emissions pledges are not sufficient to limit warming to less than 3°C by 2100, let alone achieving the target temperature range of 1.5 to well-below 2°C of the Paris Agreement. As a result, severe climate impacts are being felt across the globe: wildfires, floods, droughts, and massive storms are already devastating lives, communities and ecosystems (Ripple et al., 2017; Peters et al., 2020). These impacts are only set to increase as global temperatures continue to rise, disproportionately impacting Indigenous Peoples given the unique climate risks as a result of how colonialism, in conjunction with capitalism, has shaped where they live, their socio-economic conditions, and how they exercise their relationships with Mother Earth (Whyte, 2017, 2018b). Clearly, it is "...therefore simply not rational for Indigenous [P]eoples to rely on these global, national, and regional economic and political frameworks for climate justice and a sustainable future" (McGregor et al., 2020, p. 36).

In lieu of this inaction, Indigenous Peoples have led, and continue to lead environmental and climate justice movements across the world (Gedicks, 1994, 2001; Gobby, 2020; Temper et al., 2020). For hundreds of years, they have generated and defended their relations and forms of social organization based on mutuality and reciprocity (Simpson, 2011; Coulthard, 2014). Recently, this has included advancing their own climate emergency declarations—declarations that emphasize the multidimensional, interconnected, and interrelated nature of climate solutions and that privilege the resurgence of Indigenous Peoples' sustainable self-determination. One such example is the Vuntut Gwitch'in First Nation (VGFN), in Old Crow, Yukon. Their declaration, entitled "Yeendoo Diinehdoo Ji' heezrit Nits'oo Ts' o' Nan He' aa," translates into "After Our Time, How Will the World Be?" This declared that "climate change constitutes a state of emergency for our lands, waters, animals, and peoples."

Indigenous climate policies, driven by fierce love for lands and waters and bolstered by inherent, treaty, constitutional, and international rights, emphasize the connection between colonialism and capitalism to understand, acknowledge and "challenge the unequal social and environmental relations in which carbon emissions are embedded" (Chatterton et al., 2013, p. 7). Scholars (Cameron, 2012; McGregor, 2018b) argue that those who fail to apply this analysis will be unable to understand the depth and scope of effects on Indigenous Peoples, and thus continue to fail. Indeed, the ongoing failure to address the climate crisis stems from a pervasive focus on the *symptoms* of the problem, rather than the *root causes* driving the crisis (Abson et al., 2017; Temper et al., 2018).

This study seeks to explore how climate policy can be more just, inclusive to Indigenous rights and knowledge systems, and more effective. We do this by analyzing two settler-developed climate plans in Canada—the Pan-Canadian Framework, a federal climate plan and the ZéN Roadmap, a provincial level, civil society led plan. More specifically, we ask whether these plans are: (a) in alignment or conflict with the governments' commitments to reconciliation and Nation to Nation relationships; (b) violating or respecting inherent, treaty, constitutional, and international Indigenous rights, and (c) centering or ignoring and erasing Indigenous perspectives, knowledge, and approaches to climate mitigation and adaptation. Couched with an Indigenous Research Paradigm (IRP), we

[1] https://unfccc.int/sites/default/files/resource/br4_final_en.pdf, page 27.

use a novel critical policy analysis based in sustainable self-determination, key-informant interviews, and our participant involvement in the development of the two policies (described in section Materials and Methods) to explore the inclusion, or more aptly exclusion of Indigenous Peoples and their rights, knowledge, and approaches, to climate action.

Our analysis found that, despite multiple references to Indigenous Peoples, both the Pan-Canadian Framework and the ZéN Roadmap failed to include Indigenous Nations and communities at the policy-making table. We argue that this exclusion constitutes a violation of Indigenous rights to self-determination and to free, prior and informed consent. In the case of the Pan-Canadian Framework, it is also in conflict with the federal government's commitments to reconciliation and advancing a Nation-to-Nation relationship. Further, the plans propose certain climate solutions—such as hydro-electric development and natural gas—that can disproportionately impact Indigenous Peoples. In these and other ways, we found that the Pan-Canadian Framework and the ZéN Roadmap ignore Indigenous perspectives, knowledge, and approaches to climate mitigation and adaptation.

Based on these findings, we propose some key principles for Indigenous-led climate policy agenda going forward. These include clear calls to action that climate policy must: prioritize the land and emphasize the need to rebalance our relationships with Mother Earth; position Indigenous Nations not as stakeholders, but as Nations with the inherent right to self-determination; prioritize Indigenous knowledge systems; and advance climate-solutions that are interconnected, interdependent, and multi-dimensional. Through this, we hope to contribute to the growing amount of literature that supports the development of Indigenous-led climate solutions, which can, when done correctly, "generate well-being and Indigenous-determined futures in the face of dramatic environmental and climatic change" (McGregor et al., 2020, p. 37). To begin, we discuss the origins of the two climate policies and then introduce our methods. This is followed by our results and discussion.

Description of the Cases

Compared to Indigenous land defense, which has been ongoing since European contact, settler-led environmentalism is relatively new in Quebec and Canada (Hill, 2010; Simpson, 2017). To fully understand the implications of this new history, we chose to focus on two climate policies, one top-down led by the federal government, and the other bottom-up led by the civil society movement in Quebec, Canada. In this section, we provide an overview of both plans.

Overview of the Pan-Canadian Framework

Canada's current efforts to reduce GHG emissions and take action on climate change is encapsulated in the Pan-Canadian Framework on Clean Growth and Climate Change.[2] The plan was released in 2016 at a First Minister's Meeting by the federal government—led by Justin Trudeau, eight provinces excluding Manitoba and Saskatchewan, and three territories. Touted as an important collaborative document, the Pan-Canadian Framework refers to itself as a "collective plan to grow our economy while reducing emissions and building resilience to adapt to a changing climate" (n.p.). The plan is intended to help meet Canada's emissions reduction target of 30% reduction in GHG emissions below 2005 levels by 2030—a target left over from the previous government led by Stephen Harper.

The plan, directed by the Vancouver Declaration, sought to capitalize on the momentum generated by the adoption of the 2015 Paris Agreement. It was developed by four working groups composed of federal, provincial, and territorial representatives: Pricing Carbon Pollution; Mitigation; Adaptation and Climate Resilience; and Clean Technology, Innovations, and Jobs. The Working Groups held roundtables and a multi-day stakeholder engagement event, processes which included national Indigenous organizations, stakeholders such as non-government organizations, think tanks, and industry associations including Canadian Association of Petroleum Producers. These four groups laid the groundwork for the four pillars of the Pan-Canadian Framework: Pricing Carbon Pollution; Complementary Actions to Reduce Emissions; Adaptation and Climate Resilience; and Clean Technology, Innovations, and Jobs. Since the launch of the plan, the Federal Government has been issuing periodic status reports of the progress in implementing the plan, beginning in 2017 and most recently in 2019. During the course of writing this, the federal government introduced a "strengthened climate plan," entitled *A Healthy Environment and A Healthy Economy.*

Table 1, presented below, provides a few examples of 83-times that "Indigenous" is referenced in the 78-page Pan-Canadian Framework (Lee, 2016).

Overview of the ZéN Roadmap

The Roadmap is a province-wide, bottom-up energy transition plan developed by civil society and environmental groups in Quebec to reach net zero emissions. It was led by with *Le Front commun pour la transition énergétique*[3] (FTCE), a network of over 70 environmental organizations, unions, and community groups united toward a justice-based energy transition in Quebec.

The ZéN Roadmap lays out concrete steps "towards a Québec that will be carbon neutral, more resilient and more just" (p. 3). The first section of the document focused on building *resilient communities*, by reclaiming "our living environments and the means to protect the ecosystems on which we depend" (p. 5). The second section offers a political framework for guiding the transition which includes (a) call for the coherence and accountability of governments, (b) a fair transition whereby no one is left behind, (c) a focus from the start on human rights, and (d) immediate and extraordinary efforts to finance the transition. The final section lays out the plan for reducing greenhouse gas emissions, offering actions that work across sectors—around the themes of economy and consumption, energy, and land use planning and biodiversity. This section also offers actions

[2] http://publications.gc.ca/site/archivee-archived.html?url=http://publications.gc.ca/collections/collection_2017/eccc/En4-294-2016-eng.pdf

[3] https://www.pourlatransitionenergetique.org/qui-sommes-nous/

TABLE 1 | Example mentions of the word "Indigenous" in the PCF.

Page number	Quote	Theme
Forward	"As we implement this Framework, we will move forward respecting the rights of Indigenous Peoples, with robust, meaningful engagement drawing on their Traditional Knowledge. We will take into account the unique circumstances and opportunities of Indigenous Peoples and northern, remote, and vulnerable communities. We acknowledge and thank Indigenous Peoples across Canada for their climate leadership long before the Paris Agreement and for being active drivers of positive change"	Knowledge, leadership
3	"The Pan-Canadian Framework reaffirms the principles outlined in the Vancouver Declaration, including…strengthening the collaboration between our governments and Indigenous Peoples on mitigation and adaptation actions, based on recognition of rights, respect, cooperation, and partnership"	Collaboration, engagement, rights
3	"The Pan-Canadian Framework reaffirms the principles outlined in the Vancouver Declaration, including…recognizing the importance of Traditional Knowledge in regard to understanding climate impacts and adaptation measures"	Knowledge
3	"Our governments will continue to recognize, respect and safeguard the rights of Indigenous Peoples as we take actions under these pillars."	Rights
4	"Indigenous Peoples will be important partners in developing real and meaningful outcomes that position them as drivers of climate action in the implementation of the Pan-Canadian Framework."	Collaboration, leadership
1	"Indigenous Peoples, northern and coastal regions and communities in Canada are particularly vulnerable and disproportionately affected. Geographic location, socio-economic challenges, and for Indigenous Peoples, the reliance on wild food sources, often converge with climate change to put pressure on these communities. Much has been done to begin addressing these challenges, including by Indigenous Peoples."	Vulnerabilities
8	"The federal government will also engage Indigenous Peoples to find solutions that address their unique circumstances, including high costs of living and of energy, challenges with food security, and emerging economies" and that "carbon pricing policies should include revenue recycling to avoid a disproportionate burden on vulnerable groups and Indigenous Peoples	Carbon pricing

specific to sectors including transportation, industries, buildings, agriculture, and waste.

Table 2, provides a few examples of 15-times that the word "Indigenous" is referenced in the 64-page ZéN Roadmap.

TABLE 2 | Example mentions of the word "Indigenous" in the ZéN.

Page number	Quote	Theme
3	"Indigenous Peoples have warned us against this for centuries and environmentalists have too for quite some time".	Knowledge, leadership
53	"What would prevent us from succeeding: Ignoring the knowledge of Indigenous Peoples and peasants regarding sustainable agriculture and land use planning".	Knowledge
20	"What we need to do to achieve that vision: Include from the start, in the decision-making process, the groups whose rights may be affected by the transition. Respect the right of Indigenous Peoples to a free, prior and enlightened consent".	Rights, collaboration
20	"Human rights issues will arise from the transition because the changes accompanying it could have specific impacts on certain groups of people such as women, youth, Indigenous Peoples, northern, coastal and insular communities, minorities and disabled people".	Vulnerabilities
34	"While respecting Indigenous Peoples' territorial rights, Québec protects half of its lands and half of its internal, coastal and marine waters, including those of crucial importance for biological diversity and ecosystem services (such as carbon control and sequestration)".	Rights

MATERIALS AND METHODS

"Some people need scientific data to understand that we should take action on climate change, and that's fine. Except that for us Indigenous people, it's something that's natural in us, respect for the land" (E#4).

To appropriately consider the inclusion of Indigenous Peoples within these two climate plans, we will base our analysis under the broad parameters of an IRP (Kuokkanen, 2000; Wilson, 2008). An IRP aims to empower Indigenous Peoples to drive research, shape ethical protocols, and define culturally relevant and accountable methodologies (Wilson, 2008; Kovach, 2010; Smith, 2012). It also seeks to decolonize the academy through the re-centering of research *by*, instead of *on*, Indigenous Peoples (Nakata et al., 2012; Smith, 2012). Following the recommendation of Nicoll (2004), we do this by refocusing the analytical and evaluative lens on "the innumerable ways in which white sovereignty circumscribes and mitigates the exercise of Indigenous sovereignty" (p. 19). By focusing on "being in" Indigenous sovereignty and considering the perspectives of Indigenous Peoples meaningfully, we challenge the dominant assumptions underlying colonial systems of climate "solutions" (Neville and Coulthard, 2019) and work to advance Indigenous climate futures in policy and practice. Through this, we work to simultaneously *unsettle* settler colonial present (Weiss, 2018).

To do this, we use sustainable self-determination as a critical conceptual lens to assess how each climate plan—the Pan-Canadian Framework and the ZéN Roadmap—considers

Indigenous Peoples and their rights (Reed et al., 2020). Sustainable self-determination, a concept advanced by Cherokee scholar Jeff Corntassel, refers to both an individual and community-driven process that ensures "...indigenous livelihoods, food security, community governance, relationships to homelands and the natural world, and ceremonial life can be practiced today locally and regionally, thus enabling the transmission of these traditions and practices to future generations" (Corntassel, 2008, p. 156). An important component of such an approach is to de-center the state, and refocus the discussion on the cultural, social, and political mobilization of Indigenous Peoples (Corntassel, 2012). This approach aligns well with the Intersectionality-Based Policy Analysis (IBPA) Framework introduced by Hankivsky (2012) and Hankivsky and Jordan-Zachery (2019). This seeks to critique and develop policy in such ways as to contribute to *transforming the inequitable relations of power* that maintain inequality, as well as the *complex contexts and root causes* of the social problems that the given policies aim to address (Wiebe, 2019). We do this by focusing on different components of Indigenous self-determination, mainly inherent, Treaty, and constitutionally protected rights (Borrows, 2002; Mills, 2016); Indigenous Knowledge systems (McGregor, 2004, 2018a); and Indigenous participation (Littlechild, 2014).

Methods

We developed a critical policy analysis framework, based on the concept of sustainable self-determination to examine the various dimensions of each climate plan. This included considering the inherent, Treaty, and constitutionally protected nature of Indigenous rights, drawing on the section 35 of the Canadian Constitution and minimum standards affirmed in the United Nations Declaration on the Rights of Indigenous Peoples (UNDRIP). To build on this rights framework, we considered the recommendations stemming from the Truth and Reconciliation Commission (TRC), the Royal Commission on Aboriginal Peoples (RCAP), and Reclaiming Power and Place: The Final Report of the National Inquiry into Missing and Murdered Indigenous Women and Girls[4]. These recommendations offer important insights for understanding the *root causes* driving the climate crisis and the disproportionate impacts facing Indigenous Peoples.

To learn more about the development of each policy document, including who was and was not invited to that policy-making table, we engaged in key-informant interviews and strategic partnerships with Indigenous-led organizations. For the Pan-Canadian Framework, we conducted a series of short telephone interviews with federal public servants involved in its creation. Based on their direction, we have kept each response anonymous. Future research, in partnership with Indigenous Climate Action, will be conducted with First Nations, Inuit, and Metis people from across the country to develop Indigenous-led climate policy and plans. For the ZéN Roadmap, we also conducted a series of in-depth interviews with Indigenous Peoples living in and outside Quebec. These Experts came from different Indigenous nations and brought different experiences and knowledge related to climate change, policy, and planning. In advance of the interview, each individual was asked to read the ZéN Roadmap (version 1.0) and provide feedback, critical commentary, and recommendations through an interview with one co-author (JG), which was recorded and transcribed. All Experts were compensated for their time, and recommendations were then shared with the FCTE who wove the critiques and recommendations into the final, 2.0 version of the ZéN Roadmap which was released to the public in mid-November 2020. Direct quotes from these Experts are included below and cited as (E#), to indicate which Expert is being quoted. A table of all Expert interviews are provided in the **Table 3** below provides a list of all Experts interviewed.

Beyond reflections on the literature and key-informant interviews, direct observation and engagement in the establishment of each climate plan also served to enrich our findings. In particular, one co-author (GR) participated in the design, negotiation, and implementation of the Pan-Canadian Framework, from 2016 to the present, working to advance First Nations rights, knowledge, and governance as a representative of a National Indigenous Organization. Another co-author (JG) was involved with the FCTE's process by gathering feedback from Indigenous people on the ZéN Roadmap and based on the feedback, revising it and drafting the 2.0 version. This process involved many meetings and negotiations.

Results/Discussion

The Pan-Canadian Framework and ZéN Roadmap add to the unrelenting number of pledges, declarations, and policies promising ambitious greenhouse gas emission reductions. Like many of these, both exhibit, in different ways, a fundamental flaw in the current neoliberal approach to climate policy: no amount of "tweaking" of the current system will get us to an equitable and abundant model of prosperity for all of humankind (Klein, 2014). Too often do governments, businesses, and non-government organizations pour time, resources, and advocacy

TABLE 3 | List of Indigenous Experts who were interviewed about the ZéN Roadmap.

Code	Nation	Gender
E#1	Ojibwe/Scottish	F
E#2	Anishinaabe	F
E#3	Anishinaabe	M
E#4	Innu	F
E#5	Mohawk	F
E#6	Western Métis	F
E#7	Anishinaabe/Ojibway	F
E#8	Innu	F
E#9	Mi'kmaw	F
E#10	Nisga'a	M

[4]https://www.mmiwg-ffada.ca/

into this model of "tweaking," where: "... [t]hey seek to escape the consequences of what [they] are doing, without changing what [they] are doing." (Rodriguez Acha, 2019, p. 252). Many criticisms based on this line of thinking already exist for the Pan-Canadian Framework (see **Table 4** presented below), however there has not been a systematic analysis from the perspective of Indigenous People, their rights, knowledge and approaches to climate action.

Table 4, presented below, provides an overview of existing critiques of the PCF.

In this section, we seek to advance these perspectives by drawing on our interviews and experience to ask whether each policy is: (a) in alignment or conflict with the governments' commitments to reconciliation and Nation to Nation relationships; (b) violating or respecting inherent, treaty, constitutional and international Indigenous rights; and (c) centering or ignoring Indigenous perspectives, knowledge, and approaches to climate mitigation and adaptation. Based on this exploration, we close with a discussion of what an agenda for Indigenous-led climate policy would look like.

TABLE 4 | Summary of other, existing critiques of the PCF.

Topic	Example criticism	References
Insufficient GHG reductions target	Various independent scientific analyses have shown the emissions reduction target that the PCF is designed to achieve, is highly insufficient and "not remotely in line with the international community's goal of limiting global warming to 1.5°C" (MacNeil, 2019, p. 156).	Burck et al., 2018; Climate Action Tracker, 2019; MacNeil, 2019
Inadequate policies and plans	The total emissions reductions that the PCF policies and plans are capable of, even if fully implemented, will fall short by 77 megatons of GHG emissions. As such the PCF is too weak to achieve even the insufficient target it is designed around.	Lee, 2016; OAG, 2018; CANRAC, 2019; Péloffy et al., 2019
Politically fragile	The PCF has proven to be "extremely politically fragile", developed within the context of ongoing tensions stemming from Canada being a federated state – meaning it is made up of provinces with their own constitutional authority to make and enforce laws.	MacNeil, 2019
Oil and gas industry	The PCF essentially gives the oil and gas industry a pass. Not only does the PCF lack any regulations to curb the expansion of the fossil fuel industry (other than a phase out of coal), but it in fact also allows the continuation of government subsidies to the industry until 2025.	Lee, 2016; Marshall, 2016; O'Manique, 2017
Failure to name and address causes and drivers of climate change	Along with failure to address fossil fuels as a driver of climate change, the PCF also fails to name, let alone address other primary drivers and root causes of climate change including economic dependance on endless growth and neoliberal logics.	O'Manique, 2017; MacNeil, 2019

Do the Plans Align or Conflict With Commitments to Advance Reconciliation and "Nation-to-Nation" Relationships?

Since 2015, the Trudeau government has campaigned on a proposed "new" relationship with Indigenous Peoples. He regularly stated that: "[n]o relationship is more important to Canada than the relationship with Indigenous Peoples. Our Government is working together with Indigenous Peoples to build a nation-to-nation, Inuit-Crown, government-to-government relationship – one based on respect, partnership, and recognition of rights" (Office of the PMO, 2017).[5]

In both plans, there are limited references to the approach that was taken to engage Indigenous Nations on a "Nation-to-Nation" relationship. The Pan-Canadian Framework called for "robust engagement" with Indigenous Peoples on one hand, but on the other refused to include Indigenous representatives on the four working groups mandated to develop the plan's four pillars. Far from sematic, this removed Indigenous Peoples from the decision table and instead identified them as one of many groups to consult with. In doing this, Indigenous Peoples were positioned as stakeholders—a position that minimizes their ability to exercise their own self-determination and afford them little opportunity to participate as self-governing Nations (Alfred and Corntassel, 2005; Von der Porten et al., 2015).

For the ZéN Roadmap, the organizing group was not able to reach Indigenous Peoples in Quebec and instead continued to draft the entire report themselves. Once the report was drafted, they then asked a co-author (JG) to conduct a consultation with Indigenous Peoples. Unfortunately, this is a common trend in the mainstream environmental organizing as described by one Expert: *"This methodology of 'we're having a project and we have in the back of our minds that it needs to be inclusive ... but we don't really know how to do it. We haven't built those relationships prior. So now we're still moving forward with the project because we're on a timeline ... oh and we need to Indigenize the document now that it's already produced'. This is kind of backward. There needs to be an explicit commitment because otherwise there's always the excuse" (E#9)*.

Much of the wording regarding Indigenous Peoples in the two plans are aspirational, with words such as "should," "the need for," "will find solutions," but no wording is included that commits to any of these, or no indication that these efforts have been commenced thus far. One such example is the usage of the phrase "unique circumstances" in the Pan-Canadian Framework to refer to the multiple and urgent crises facing Indigenous Peoples across Canada. Through choice of language, this reduces these crises to "unique circumstances" while falsely promoting a peaceful and respectful relationship. This diminishes and negates ongoing Indigenous claims for justice, furthering division and distrust between Indigenous Peoples and the state—a state that continues to place Indigenous Peoples systemically and actively in a vulnerable position through ongoing colonial relations, land dispossession and failure to take meaningful action on climate change (O'Manique, 2017).

[5]https://pm.gc.ca/en/news/statements/2017/06/21/statement-prime-minister-canada-national-aboriginal-day

Do the Plans Violate or Respect Inherent, Treaty, Constitutional, and International Indigenous Rights?

"[It's not] truly showcasing Indigenous world views and knowledge. It's more... like making sure it's there because now it's not politically acceptable anymore to not have it there. People are mindful to make sure that its mentioned and that's already a first step. But that doesn't mean that the education to fully understand about what it means to actually respect [Indigenous rights]" (E#9).

Indigenous rights are mentioned six times in the Pan-Canadian Framework. One of these references includes the UNDRIP, including the right to "free, prior and informed consent" (FPIC), which Canada signed on to as a "full supporter without qualification[6]" in 2016, the same year the PCF was released. Despite the mention of UNDRIP, other affirmations of Indigenous rights, such as inherent, treaty, and constitutional rights were not mentioned at all.

In the ZéN Roadmap, there was limited reference to the UNDRIP: a fact highlighted by one Expert: "*Naming all human rights declarations - civil, political,... but they don't mention UNDRIP until much later. And they just throw it in there. UNDRIP should be included in the first paragraph. It's fundamental to protecting our country against climate change."* They go on to provide an example of its importance: "*… when deciding whether to accept or reject industrial infrastructure projects. This has been done for decades - the disregard of human rights has given them the ability to create climate change. Because it's only because they disrespected human rights that they were able to impose that massive infrastructure*'" (E#6). Free, prior, and informed consent was repeatedly highlighted by all Indigenous Experts as an important guide for interactions between local, provincial, territorial, and national governments and Indigenous Peoples.

Pushing this one step further, neither plan discussed the right to self-determination: a right that is affirmed in the UN Declaration and provides Indigenous Peoples with the ability to "…freely determine their political status and freely pursue their economic, social and cultural development" (United Nations, 2007, p. 4). This is not entirely surprising, as for many states, there is fear that the advancement of Indigenous Peoples' self-determination corresponds to a loss of sovereignty or territorial integrity (Lightfoot and MacDonald, 2017). An Expert made this connection quite clear to climate: *"Indigenous sovereignty is really at the heart of this issue. The right to "protect the land" should be enshrined in the philosophy of this transition. Water is life. Water is sacred. The land is sacred"* (E#7). Expanding this further, a co-author (JG) in the meetings to revise the ZéN Roadmap observed significant resistance from within the FTCE—in particular the Industry unions and Quebec nationalists—to acknowledge Indigenous Peoples' right to self-determination.

At its core, both plans reference Indigenous rights repeatedly, but Indigenous rights appear to have had no influence on the actual policies and plans developed. An Expert captured this in her intervention: "*A lot of the time, there is no inclusion for First Nations when it comes to [decision-making about] things that are being extracted from land and waters*" (E#2). Such an approach aligns well with the "politics of recognition" introduced by Dene scholar, Coulthard (2014), used by Canada and the provinces to "...reproduce the very configurations of colonial power that Indigenous peoples' demands for recognition have historically sought to transcend" (p. 52). Asch et al. (2018) further this consideration: "…[r]ecognition can be a Trojan horse-like gift: state action often operates to overpower or deflect Indigenous resurgence" (p. 5). One Expert put it quite eloquently: *"In my opinion the way this is structured we're absolutely not reframing relationship with indigenous people and its not a decolonized exercise. Not only in the methodology that was put in place but definitely as well in the content that is presented"* (E#9). During the ZéN Roadmap process, an Expert echoed this observation: *"Indigenous rights are 'acknowledged' rather than integrated into the functioning of law and society. There is a missed opportunity here to discuss land rights specifically, as well as jurisdiction"* (E#10).

Do the Plans Center or Ignore Indigenous Perspectives, Knowledge, and Approaches to Climate Mitigation and Adaptation?

"Some people need scientific data to understand that we should take action on climate change, and that's fine. Except that for us Indigenous people, it's something that's natural in us, respect for the land" (E#4).

While both plans acknowledge the role of Indigenous Peoples in addressing climate change, neither included Indigenous Peoples in the design of the climate plan. For instance, the ZéN Roadmap only engaged Indigenous Peoples after the first version of the report was completed. The result of this oversight is that the plans reflect a western, reductionist worldview, whereby elements of the plan are not holistically integrated into others, but instead framed in isolation from each other. The Pan-Canadian Framework, for example, seems to break up the climate problem into four "pillars," overlooking how these pillars are interconnected to one another.

This approach aligns with the explanation of Behn and Bakker (2019), where the solutions to climate and environmental problems are rendered technical, attempting to de-politicize the issue and focus on the technological arrangements required to solve them. For Indigenous Peoples, it is the opposite, as one Expert highlighted that there is "*too much disconnection between points… We talk about resilient communities but we're separating that from education and social dialogue … having these separate spheres. We need to break the sphere and we need to realize the interconnectivity of everything*" (E#6). Behn and Bakker (2019) call this interconnectivity, "rendering sacred" as a way to discuss how relationships with land are perceived and acted upon.

As a result, it is clear that there was no critical interrogation of the limitations of settler ways of knowing and unwillingness to look to other ways of knowing, reproducing epistemological violence (Dugassa, 2008). As one Expert told us: *"I think the whole narrative would have been different with knowledge keepers involved, really passing on how they engage with the land and how they honour that relationship"* (E#9). Indeed, this cursory consideration of Indigenous knowledge often minimizes Indigenous values and concerns to be framed in terms of what

[6]https://www.justice.gc.ca/eng/declaration/index.html

can be "conveniently appropriated" from Indigenous knowledge (Littlechild, 2014). This reductionist approach simplifies the conceptualization of Indigenous knowledge to "data" to try to fit within existing hierarchical and colonial structures (Nadasdy, 2010).

Among other actions, the Pan-Canadian Framework and the ZéN do this by framing the climate problem as exclusively about reducing greenhouse gas emissions, rather than addressing the root causes of the crisis. An Expert spoke to this oversight in climate policy more generally: *"There's a common tendency for climate related conversations to do the same thing that they've always done - which is like either focus on mitigation, focus on adaptation without providing some form of intersectional lens on those two broad categories. This kind of misses the point of how we're thinking about climate as a multiplier of these existing realities and vulnerabilities."* They go on to discuss how climate policies needs to "*... remove that separation of climate action and people's everyday lives. and so, thinking about how do we address all of these intersecting vulnerabilities and structural factors that many people face but other folks capitalize on*" (E#3).

Another Expert echoed this sentiment by calling out the language contained with the Framework: "*... the framework and the narrative and the language is still very western... still us and the land as separate and not that we're actually part of that system, that we're related to the land*" (E#9)" Clearly, although both the Pan-Canadian Framework and the ZéN Roadmap reference Indigenous knowledge and perspectives to addressing the climate crisis, neither of them actually incorporate these perspectives meaningfully. The result is that both plans ignore Indigenous leadership, knowledge systems, and perspectives in their approaches to climate mitigation and adaptation.

Toward an Agenda for Indigenous-Led Climate Policy

Our analysis shows that, despite references to Indigenous Peoples, both the Pan-Canadian Framework and the ZéN Roadmap conflict with their commitments to reconciliation and the advancement of a Nation-to-Nation relationship; disrespects, and in some cases violates, the inherent, Treaty, and constitutionally-protected rights of Indigenous Peoples; and largely ignores Indigenous perspectives, knowledge, and approaches to climate mitigation and adaptation. While this not entirely surprising, given the Government's tendency to: "... introduce half-measures as a cover for the uninterrupted extraction and transportation of gas, coal, and oil" (Foran et al., 2019, p. 223), it does confirm that little meaningful progress has been made to address colonialism, reduce the disproportionate climate impacts on Indigenous Nations, and advance Indigenous-led solutions (Cameron, 2012; Maldonado et al., 2013). A similar lack of progress has occurred in the United States, as Indigenous scholars and allies document in the Indigenous-led chapter of the National Climate Assessment (Maldonado et al., 2013; Bennett et al., 2014).

In this light, it is clear that the only way to address the simultaneous three "c"s driving catastrophic climate change—capitalism, colonization, and (de)carbonization—is for Indigenous Nations to "... take matters into their own hands" (Ladner and Dick, 2008, p. 89). One expert called for a deep questioning and deconstruction of the *"capitalist concept of property"* as a necessary part of effective climate plans and policy (E#8). Another expert made clear that "*to [address the climate crisis] we need to change the system at its base, political, capitalist, corporations, banks, all of them... Its not just the government.... the government has little control over corporations. Quit asking the government, he has no power, he's just a puppet on a string*" (E#1) Indeed, Hayden King and Shiri Pasternak highlight this eventuality: "we also have to acknowledge that solutions might have to be realized outside of state processes. In fact, they may be more conducive to asserting alternative futures for life on this planet" (Pasternak et al., 2019, p. 12). To do this, we return to our Experts to begin outlining an Indigenous-led climate agenda that seeks to dismantle settler colonialism, capitalism, and heteropatriarchy simultaneously (Whyte, 2018a). Such lessons could be applied for informing climate policy more broadly, especially as international organizations such as the Intergovernmental Panel on Climate Change and the United Nations Framework Convention on Climate Change, increasingly recognize the role of Indigenous Peoples and their ways of knowing in climate discourse (IPCC, 2018).

Climate Policy Must Prioritize the Land and Emphasize the Need to Rebalance our Relationships With Mother Earth

The restoration of balance to the relationships between humans and nature, as well as between Indigenous Peoples and the Crown are intimately linked to another (Borrows, 2017). In a climate context, these connections are rarely discussed, which in Indigenous thought is preposterous. Truly transformative climate action can only be attained when "... they are based on the gift-reciprocity relationship of interdependency and mutual aid learning from Mother Earth" (Tully, 2017: p. 116). One expert pointed this out clearly: "*I don't think we can trust government to truly protect the land. Ever. This ties into the idea of teaching and re-education of people. If people accept a philosophy of the land and waters being sacred and understand the beauty and importance of the natural world, they become protectors. I think this is what you mean when you say, "our relationship with the ecosystems where we live must be revisited in depth*" (E#7). The restoration of balance is central to advancing Indigenous climate futures.

Indigenous Nations Must Be Positioned as Nations That Have an Inherent Right to Self-Determination

Throughout the analysis of the two climate plans, it was evident that governments, civil society, and industry associations were unwilling to acknowledge the true role of Indigenous Nations in the founding of Canada. Several Experts highlighted this role quite clearly: "*Personally, I see Indigenous Nations as sovereign. And as equivalent to the provincial and federal jurisdictions. So just recognizing that sovereignty. And when they say we want [an energy transition], let the Indigenous Nations decide. We have councils. There are governing bodies. They should have a seat at the table. That would help. That's decolonial. Create* *and leave room for new perceptions and new people to sit at the table. And not fight them*" (E#6). Another called on the inclusion of wording that explicitly recognizes the role of renewing historic agreements and treaties made with First Nations, recognizing that:*"the first treaties [provided guidance] of how to be mindful, of how we use to land, in order to think about the next seven generations for example*" (E#2). Decolonial climate policy requires the exercise of self-determination by Indigenous Nations.

Indigenous Nations, Peoples, and Representative Organizations Must Be Positioned as Leaders With Direct Decision-Making

While there was acknowledgment of the role of Indigenous Peoples climate leadership, it was not meaningfully incorporated in the design of climate solutions. This is a missed opportunity, as one Expert spoke to this quite clearly, highlighting that Indigenous Peoples have had "*…thousands of years about adaptations and thousands of years of knowledge [about the land]. Just acknowledgement that... and perhaps that the colonial project attempted to erode that. And that the resiliency [of Indigenous communities] as a reflection of being able to survive despite colonization*" (E#3). This includes those that continue to stand up in resistance against the capitalist mode of production and the logics of domination that maintain the structure of settler colonialism (Wolfe, 2006). Land and water protectors must be not only compensated for their contribution, but also should be considered as actively contributing to Canada's climate mitigation aspirations. While this is out of the scope for this paper, a future paper exploring this concept—the contributions of land protectors to mitigation—is much needed.

Prioritize Indigenous Knowledge Systems and Make Space for the Equal Consideration of Diverse Knowledge Systems

While not completely in the scope of this paper, it was clear that there is a deep ontological disjuncture between mainstream climate solutions and those that would be advanced by Indigenous Peoples. Indeed, one Expert pointed this out clearly: *"I think the whole narrative would have been different with knowledge keepers involved, really passing on how they engage with the land and how they honour that relationship"* (E#9). Not only is this central to working with Indigenous Peoples, but it is also important when within an IRP. Frameworks for the ethical treatment of Indigenous knowledge systems are well-known—Two-Eyed Seeing, Walking on Two Legs, Ethical Space, among many others—and must be integrated into climate policy moving forward.

Reflect the Diversity of Indigenous Nations

In the two climate policies, there was zero discussion of the diversity of Indigenous Nations, creating the impression of a homogenous reality across Turtle Island. This aligned with what one Expert pointed out: "*I feel like indigenous people are just kind of thrown in there … they're not necessarily all at the same... Some Indigenous communities are doing very well. To just kind of homogenize all of them into one big clump and say you are all disenfranchised. It's not really representative of the reality" (E#6).* Continuing this train of thought, another Expert highlighted the importance of recognizing the role of urban Indigenous Peoples, who: *"…[are] over 60% of indigenous people are not living in their communities or are extremely mobile, they still hold the level the knowledge. They should still be recognized and acknowledged*" (E#9). Extending this one step further, several Experts spoke to the importance of uplifting the voices of those structurally oppressed groups that must be involved in the development of climate solutions. One example to address this was proposed to highlight the root cause of the climate crisis: "*…say patriarchy, capitalism, colonization have created and imposed certain policies [that are driving these inequities] … But there are a lot of very strong racialized communities.... Climate migrants and refugees are very strong … "* (E#6).

Advance Climate-Solutions That Are Interconnected, Interdependent, and Multi-Dimensional to Simultaneously Advance Decarbonization and Decolonization

Many of the solutions proposed by the Pan-Canadian Framework and the ZéN Roadmap completely disregard the interconnectedness between proposed policies presented in different sections of the Plans. One clear example in the ZéN Roadmap is the proposal to eliminate single use plastic. This proposal wholly ignores the realities that many Indigenous Peoples still lack clean drinking water. Solutions must seek to address these systemic inequalities, and the ongoing legacy of settler colonization. One Expert proposed this approach instead: "*'We're going to eliminate plastic bottles, but first, we're going to make sure that everybody has drinking water and access to services and then they don't need to use plastic bottles'. There should be a proposed action to make sure that [all communities] have the essential services necessary to have that fair transition. Not just Indigenous communities but also other vulnerable communities like low-income communities and communities of color that are disproportionately not receiving the same services as others*" (E#6). Another example highlighted the tendency to overlook the disproportionate impact of large-scale hydroelectric and natural gas development on Indigenous Peoples and their territories, notably in Quebec: "…v*ast areas were flooded, people were displaced, wildlife was impacted, and the land upon which they relied, and their ways of life were permanently altered. This is an 'out of sight, out of mind' consequence in Quebec's claim to green energy"* (E#5).

CONCLUSION

Drawing on a novel critical policy analysis based in sustainable self-determination, key-informant interviews, and our participant involvement, we critically analyzed two settler-developed climate policies—the Pan-Canadian Framework and the ZéN Roadmap, a civil society-led plan in Quebec, Canada. Each conflicted with the aspirations of reconciliation, disrespected inherent, treaty, constitutional and international Indigenous rights, and largely ignored

Indigenous perspectives, knowledge, and approaches to climate mitigation and adaptation. In light of this failure—and the growing failure of mainstream climate policy to address the climate crisis—we drew on our Experts to propose six potential components of an Indigenous-led climate agenda. Lessons from this Indigenous-led climate agenda can support the aspirations of Indigenous Peoples across Turtle Island, as well as around the world, as they increasingly reassert their role in climate action.

We stress that this is only a starting point, and deep and meaningful engagement with Indigenous Peoples and Nations is required to breathe life into these components in a way that reflects each Nations' individual history, culture, jurisdiction and legal systems. These considerations are central to the development of Indigenous climate futures that not only support, but advance the flourishing of future generations (Wildcat, 2010; Whyte, 2017). An approach that is particularly relevant as Canada contemplates the implementation of its "strengthened" climate plan. Taking a page for Leanne Simpson, in doing this, we recognize that it is not enough to hypothesize futures without concrete action instead our futures are "…entirely dependent upon what we collectively do *now* as diverse Indigenous nations, with our Ancestors and those yet unborn" (Simpson, 2017, p. 246, *emphasis added*).

DATA AVAILABILITY STATEMENT

Due to respecting research ethics protocols and respecting confidentiality agreements with Experts interviewed, raw data will not be made available by authors.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Dr. Richard DeMont, Chair, University Human Research Ethics Committee, Concordia University. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

JG conducted interviews with experts. JG, GR, RS, and RI conducted policy analysis on the PCF. HM provided expertise on climate science. GR and RS provided expertise on Indigenous Knowledge and Indigenous approaches to climate policy. The writing of the article was led by GR and JG. RI and HM provided editing support. All authors contributed to the article and approved the submitted version.

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Sustainable Energy Policies and Equality: Is There a Nexus? Inferences From the Analysis of EU Statistical and Survey Data

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Energy Justice (EJ) and particularly Energy equality (EE), arguably a radical conceptualization of energy justice, advocated for distributional justice and policies addressing distributional inequalities. Distributional policies are known to be contentious and often raise debates on the opportunity to interfere with the free-market allocation of goods in capitalistic economies. Whether EE inspired policies might be considered implementable or not depends on their social acceptability. Therefore, holding on to previous research findings pointing to the higher acceptability of equitable climate policies and the relationship between economic inequality and environmental degradation, we analyse EU data regarding income and income and wealth inequality and data from the H2020 ECHOES project, which consists of an extensive European survey of household energy consumption attitudes. We found that economic equality accounts for 41% of the variance explained at the country level of our sustainable energy care index (SECI), accounting for sustainable energy attitudes. We conclude that the interplay between economic equality and sustainable energy attitudes deserves further attention and might warrant a broader discussion about distributive policies within and beyond the energy sector.

Keywords: energy justice, equality, inequality, attitudes, energy policy, income, wealth, energy transition

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INTRODUCTION

In recent years, a flourishing scholarship based on the concept of energy justice (Guruswamy, 2010; McCauley et al., 2013; Jenkins et al., 2016; Sovacool et al., 2016; Pellegrini-Masini et al., 2019, 2020a) has been developed to tackle the ethical shortcomings of energy policies.

While the merits of this work are evident by its rapid growth, suggesting a large readership, energy justice (EJ) has not exhausted the debate on ethical aspects of energy policy, and it appears as a yet evolving area of research.

This paper will focus on distributional justice, one of the three tenets of energy justice (McCauley et al., 2013). To a lesser extent, we also talk of procedural justice and formal equality, being the concept of equality in a broad sense at the root of the concept of energy justice as elsewhere discussed (Pellegrini-Masini et al., 2020a).

In the first part of this article, we discuss the theoretical underpinnings of energy equality, its ethical merits, its potential of addressing contentious policy issues and its critical aspects.

In the second part, we present the analysis of a study using data from Eurostat and from the European project ECHOES, whose aim is to test the hypothesis that distributional equality and proenvironmental energy attitudes are correlated.

DO WE NEED ENERGY EQUALITY?

Energy equality lies in the same area of ethical reflection on energy policy issues developed around Energy justice, which was defined as a concept that "… aims to provide all individuals, across all areas, with safe, affordable and sustainable energy" (McCauley et al., 2013, p. 1). McCauley et al. (2013) further indicated that three tenets define EJ, namely "distributional justice," "procedural justice," and "recognition justice." Distributional justice regards equity in the distribution of goods and is defined as follows: "Distributional justice is justice in the distribution of economic goods between the members of a society" (Bojer, 2003). Procedural justice relates to fair processes; it is based on the concept of procedural or formal equality (Pellegrini-Masini et al., 2020a), while recognition justice deals with recognizing and repairing injustices suffered by some groups or places (Jenkins et al., 2016).

It could be said that energy equality takes a more radical stance than energy justice, particularly in terms of distributional aspects. While energy justice deals mainly with equity issues regarding the spatial distribution of the negative externalities of energy production (Jenkins et al., 2016; McCauley, 2018), energy equality goes beyond that into conceptualizing equality of opportunity of the fruition of energy services and embodied energy. Energy equality was defined as a concept advocating for "providing all individuals with equal opportunities to use energy services, energy technologies, and consuming energy and embodied energy to satisfy personal needs and holding capabilities" (Pellegrini-Masini, 2019, p. 144). It was argued earlier that energy justice (Pellegrini-Masini et al., 2020a)—like all theories of justice—is rooted in the concept of equality (Kymlicka, 2002); therefore, it is not inaccurate to consider energy equality as a radical conceptualization of energy justice. Nevertheless, energy equality could be considered unnecessary by some who might discount the need for policies that seek to establish equality as a guiding principle in energy policy. After all, libertarianism has long advocated against state interventions aiming at distributional justice policies while maintaining a need exclusively for procedural equality (Hayek, 1998; Bojer, 2003).

However, the need for emphasizing the importance of distributional justice and equality is also rooted in several considerations regarding current patterns of resource consumption and their environmental and social consequences (Sovacool et al., 2014).

It could be argued that environmental equalitarian instances are the only solution to the "tragedy of commons" (Hardin, 1968), i.e., the problem of collective goods being compromised by self-interest led actions. Environmental protection and the "polluters pay" principle have not been sufficiently enforced by national and international legislation on carbon emissions, although this approach has been advocated for (Caney, 2005). To date, societies and individuals can pollute the global atmosphere with minor consequences despite profound inequalities in emissions across individuals and countries (Pachauri and Spreng, 2012; Gore, 2015). In this context, scholars have made equalitarian stances (Langhelle, 2000; Mészáros, 2001) who argue that sustainable development is centered on social justice and substantive equality.

ENERGY CONSUMPTION INEQUALITY AND GREENHOUSE GAS EMISSIONS

Energy consumption has environmental consequences in terms of carbon emissions and resource depletion. Research data shows deep inequalities of energy consumption and CO_2 emissions across and within nations (Pachauri and Spreng, 2012; Gore, 2015; Ritchie, 2018). Research (Gore, 2015) indicates that about 50% of global carbon emissions are attributable to the 10% wealthiest individuals on the planet, while the 50% poorest of the global population only contribute to 10% of GHG emissions and reside in the most vulnerable countries to climate change. Other research (Ritchie, 2018) indicates that those classified by the World Bank as high-income countries contribute to about 38% of carbon emissions while comprising only 16% of the world population.

Further, several scholars have hypothesized that income inequality leads to environmental degradation (Boyce, 2003; Downey and Strife, 2010; Cushing et al., 2015; Downey, 2015). One of the main hypotheses of these scholars is that economic inequality originates an imbalance of power, which allows some wealthier and hence more powerful subjects to shift environmental costs onto others. Further, Cushing et al. (2015, p. 194) indicate that beyond the already mentioned effects arising from inequality and political power, it is possible to hypothesize "effects mediated by a relationship between inequality and the environmental intensity of consumption, and effects mediated by social cohesion and cooperation to protect common resources." The first explanation, pointing to an imbalance of power, is relatively intuitive: in this perspective, the wealthiest would protect themselves from environmental degradation, escaping environmental pollution residing in less polluted upmarket areas and imposing on low-income neighborhoods the negative externalities, i.e., pollution and unsightly facilities, as many environmental justice scholars have pointed out in several countries (Bullard, 2000; van der Horst and Toke, 2010). Further, the imbalance of power would result in a legal framework that would prevent an efficient affirmation and implementation of the polluter-pays principle, thereby allowing the wealthiest to avoid bearing most of the price of the pollution that they are causing (Cushing et al., 2015).

The second pathway regarding the relationship between inequality and intensity of consumption points to the argument that inequality leads ordinary people to increase their consumption to emulate the wealthiest groups of society (Veblen, 2017). This issue, in turn, would lead to an increase in average yearly worked hours (Bowles and Park, 2005), which appears to have adverse environmental consequences (Knight et al., 2013), and particularly an increase in working hours leads to higher levels of consumed energy (Fitzgerald et al., 2015) and higher levels of carbon emissions (Fitzgerald et al., 2018). Finally, within the second pathway proposed by Cushing et al. (2015), it is also pointed out that income inequality slows down the diffusion of new technology, including environmental technologies (Vona and Patriarca, 2011), thereby causing further environmental harm. In fact, low-income households and societies have less possibility to invest in sustainable energy themselves, which means that they also will be the ones who benefit the least from any potential benefits of the energy transition (Sovacool et al., 2017; Pellegrini-Masini et al., 2020b).

The third pathway indicated by Cushing et al. (2015) argues that cooperation and social cohesion are hindered by inequality. This stance holds that inequality negatively affects trust, which appears to be the case along with increasing status anxiety (Delhey and Dragolov, 2014). In turn, it is argued (Cushing et al., 2015) that a lack of trust harms societal cooperation and that both trust and cooperation are necessary to face collective environmental challenges. Evidence has emerged that trust is an essential variable in generating social acceptance of climate change policies (Harring et al., 2013; Drews et al., 2016; Fairbrother, 2016), and it appears to be a key variable in local acceptance of renewable energy installations (Huijts et al., 2012; Pellegrini-Masini, 2020).

The hypothesis that inequality in a society favors environmental degradation has been supported by empirical research, albeit still limited (Wilkinson and Pickett, 2010a,b; Wilkinson et al., 2010). Wilkinson and Pickett (2010b, p. 40) show that for countries with higher equality, measured as the ratio of most affluent 20% to most deprived 20%, the kilograms of carbon emissions for every $100 of income generated is lower. It appears that high levels of economic inequality are positively correlated to higher levels of per capita carbon emissions both in mature and developing economies (Zhang and Zhao, 2014; Grunewald et al., 2017; Knight et al., 2017). The evidence is particularly compelling for top income inequality, i.e., the share of income received by the wealthiest 10% of the population (Hailemariam et al., 2020). Other indicators that support the hypothesis of a causal relationship between inequality and environmental degradation are also presented in the literature (Islam, 2015), such as the link between income inequality and higher loss of biodiversity. Specifically, it was found (Mikkelson et al., 2007) that any increase of one per cent in the Gini coefficient, which measures economic inequality, leads to a 2% rise in the number of threatened species.

Also, research investigating the relationship between pro-environmental attitudes and equalitarian values has been conducted for long and appears well-established. Scholars (Drews et al., 2016) point out that evidence has emerged in multiple studies in several western countries that progressive political values, of whose equalitarian views are a core value (Neumayer, 2004; Illuzi, 2014), lead to a broader acceptance of climate policies or a broader belief in climate change (Hornsey et al., 2016). Similarly, evidence has been presented (Franzen and Vogl, 2013) and reviewed from multiple studies (Gifford and Nilsson, 2014) that in several countries, political orientation correlates with environmental attitudes, with progressive individuals displaying higher levels of pro-environmental attitudes. Regarding precisely energy policies, Carlisle and Smith (2005) found that egalitarians tend to support increasing gasoline and energy taxes, reducing the standard of living, slowing population and industrial growth, while they tend to oppose nuclear power.

Given that there is only limited research on the relations discussed in the previous sections, especially from large-scale datasets, we utilize a combinbation of several of such datasets to shed some more light on the relation between the level of inequality in a country and sustainable energy attitudes (here operationalized as energy use attitudes, behavior, and support for energy policies).

HYPOTHESES AND METHODS

In this study, we hypothesize that countries with higher levels of economic equality, i.e., income or wealth equality, which express in their economic and social fabric egalitarian values, will show higher levels of pro-environmental attitudes regarding energy consumption behaviors and actions. Further, in order to contextualize the results in the longstanding debate that postmaterialist values in higher-income countries lead to widespread pro-environmental attitudes (Inglehart, 1990; Franzen and Vogl, 2013), for which mixed evidence has been presented, mainly when referred to support of pro-environmental policies (Kahn, 2007) or attitudes (Schultz and Zelezny, 1999), we also include measures of country wealth into our analysis, i.e., GDP per capita and median income.

To test our hypothesis, we are mainly using a dataset from the H2020 ECHOES project[1] combining data from an extensive multinational survey conducted in 2018 across 31 European countries (EU-28, Norway, Turkey, and Switzerland) during 4 months, with about 600 respondents recruited in each country through a random sampling procedure, and a total sample of over 18,000 respondents. The survey targeted individuals' energy-related behaviors, attitudes covering six main areas of life (housing, mobility, diet, consumption, leisure, and information acquisition). The dataset was then integrated with statistical data sourced at the country level regarding the Gini coefficient of equivalized disposable income[2], the Gini coefficient of wealth distribution[3], both for the year 2018, GDP PPS per capita[4] and country median income. The Gini coefficient of equivalized disposable income (which for Germany is limited to the territory

[1]https://echoes-project.eu/

[2]"The Gini coefficient is defined as the relationship of cumulative shares of the population arranged according to the level of equivalised disposable income, to the cumulative share of the equivalized total disposable income received by them". Source of data: Eurostat, available at: https://ec.europa.eu/eurostat/web/products-datasets/-/tessi190

[3]Source of data: Credit Suisse Global wealth databook 2019, available at: https://www.credit-suisse.com/media/assets/corporate/docs/about-us/research/publications/global-wealth-databook-2019.pdf

[4]In PPS, purchasing power parities, year 2018. Source of data: Eurostat. Available at: https://ec.europa.eu/eurostat/databrowser/view/tec00114/default/table?lang=en

TABLE 1 | Gini coefficient of equivalized disposable income of European countries 2018.

Country	Gini disposable income 2018
Slovakia	20.9
Slovenia	23.4
Czechia	24.0
Norway	24.8
Belgium	25.7
Finland	25.9
Austria	26.8
Sweden	27.0
The Netherlands	27.4
Denmark	27.8
Poland	27.8
France	28.5
Hungary	28.7
Malta	28.7
Ireland	28.9
Cyprus	29.1
Croatia	29.7
Switzerland	29.7
Estonia	30.6
Germany (until 1990 former territory of the FRG)	31.1
Portugal	32.1
Greece	32.3
Luxembourg	33.2
Spain	33.2
Italy	33.4
United Kingdom	33.5
Romania	35.1
Latvia	35.6
Lithuania	36.9
Bulgaria	39.6
Turkey	43.0

TABLE 2 | Gini coefficient of wealth distribution.

Country	Gini wealth distribution
Slovakia	49.8
Belgium	60.3
Malta	64.0
Croatia	64.5
Romania	64.7
Greece	65.4
Bulgaria	65.9
Slovenia	66.2
Hungary	66.3
Lithuania	66.3
Italy	66.9
Luxembourg	67.0
Poland	67.7
Portugal	69.2
Spain	69.4
France	69.6
Switzerland	70.5
Estonia	71.6
Czechia	72.5
Austria	73.9
Finland	74.2
United Kingdom	74.6
Latvia	78.9
Turkey	79.4
Ireland	79.6
Norway	79.8
Cyprus	80.1
Germany	81.6
Denmark	83.8
Sweden	86.7
The Netherlands	90.2

of the former FRG[5]) shows a coefficient ranging from 21 for Slovakia, with a relatively higher level of equality in distribution of disposable income, to 43 for Turkey with a relatively less equal distribution (see **Table 1** for a list of all countries included in the analysis). Country wealth inequality often has a different pattern than income inequality. In this case, we can appreciate the difference for the countries considered, with countries with a relatively more equal distribution of disposable income, such as e.g., Norway, which shows instead a relatively more unequal distribution of wealth (see **Table 2**).

ANALYSIS

This section explains the primary statistical operations; for the full details regarding the statistical methods, please see the Stata syntax file in the **Appendix** in Supplementary Material. Firstly, we created a sustainable energy caring index (SECI) with the eight items listed in **Table 3** taken from the ECHOES survey[6]; to see how the average SECI and economic inequalities vary across European countries (see **Figure 1**). For the analysis, we combine them into one aggregated index variable. Factor analysis indicates that all items load sufficiently on one factor to justify this simplification. Also, Chronbach's alpha for the resulting index was 0.85, suggesting a solid index for energy care.

To remove the impact of slightly different sample sizes per country (very small countries were only represented with about 200–300 participants in the ECHOES survey), we weighted the participants, so all countries had an equal contribution to the analysis. We argue this is more suitable for answering our research question, as we investigate the existence of a relationship

[5]Nevertheless the current population of the territory of the former FRG corresponds to about three quarters of the whole German population.

[6]Please be aware that they were constructed initially to capture different (but related) constructs around support of the energy transition.

TABLE 3 | Items included in the sustainable energy caring index (SECI).

Item	M	SD
I feel proud if other people save energy	3.8	1.04
I am angry about the fact that many people in do not save energy	3.7	1.08
The use of more renewable energy sources will benefit the environment.	4.3	0.92
The use of more renewable energy sources will create new jobs	3.6	0.98
I feel a personal obligation to be energy efficient (e.g., using public transport instead of a personal car, turning off lights when leaving the room, using technical appliances which help to save energy).	3.9	1.00
I feel a personal obligation to support energy policies that support the energy transition.	3.7	1.02
I intend to use energy in a way that helps bringing the transition to a renewable energy system.	3.8	0.87
I would accept energy policies that protect the environment even when these induce higher costs (e.g., policies that increase the prices of fossil fuels).	3.3	1.13
Sustainable Energy Caring Index (SECI)	3.7	0.71

and not the strength of a relationship across a whole area[7]. We produced three multilevel regressions models with the SECI as the dependent variable, where the countries acted as the level two units: one empty model to estimate variance on both levels of analysis, which was later used to calculate explained variance, another model with only the covariates used in the analysis (see below), and finally one full model to see the explanatory power of income and wealth inequality on the country-level SECI variation. Variables used in the regression are listed in **Table 4**. To estimate the difference in explained variance between the models, we calculate the difference in unexplained variance divided by the unexplained variance of the empty model (as suggested by Mehmetoglu and Jakobsen, 2016). Finally, we calculate the standardized coefficient to make the effect size of variables comparable.

RESULTS AND DISCUSSION

Multilevel regression analysis suggests that income and wealth distribution explain 41% of the 8% of the total SECI variance allocated to between-country factors (see **Figure 2**).

GINI income and wealth are remarkably better predictors of energy caring than the median income of a country (see **Table 5**). Model 1 shows that only 8% of the observed variance in SECI is at the country level, while 92% is at the individual level. In models 2 and 3, individual-level variables account for 4% of the variance at the individual level; thus, most of the variance in the SECI scores between people in a country is explained by variables not included in the model. In model 2, the median income accounts for 22% of the between-country variance in SECI scores. When adding the GINI variables in model 3, a significant increase of explained variance can be seen, where the country-level variables together explain 41% of the between-country variance.

Additionally, we see that the median income becomes non-significant when accounting for the GINI variables. In other words, the degree of equality in disposable income and wealth in a county are better predictors of a country's average level of SECI than the median income. However, while more equality in disposable income decreases a country's SECI, more equality in wealth distribution increases it (while controlling for equality in disposable income and the covariates in the analysis).

The findings of this study are to an extent supportive of our hypothesis that higher levels of economic equality would increase pro-environmental attitudes, albeit modestly. The most striking result is that economic equality variables explain 41% of the sustainable energy caring index variance at the country level, suggesting an important role of economic variables in explaining differences across countries.

That economic inequality could influence negatively prosocial behaviors, particularly of high-income households, appears to have found lately empirical evidence (Côté et al., 2015; Duquette, 2018; Du et al., 2020), albeit not consistently (Schmukle et al., 2019). Our research could be seen as further supporting evidence that favorable attitudes toward a specific subset of pro-environmental behaviors, regarded by many as a specific type of prosocial behaviors (Kollmuss and Agyeman, 2002), appear to be possibly reduced by higher economic inequality. Nevertheless, that high-income households might be less disposed toward pro-environmental behaviors is not confirmed in our sample. Our model and the correlation tests that we run between self-reported "social status" and SECI (0.084, $P \leq 0.01$) found a negligible positive relationship between higher social status and higher SECI. The same was found when we checked the correlations between self-reported income thresholds and SECI, with individuals having a higher income than the third quartile threshold of national income distribution negligibly but positively correlating with higher SECI scores (0.045, $P \leq 0.01$).

The opposite sign that we found in the model of the relationships between the Gini wealth and the Gini income indexes with the SECI is puzzling. The first has a negative relationship, meaning that with the growth of the Gini wealth, i.e., more wealth inequality in a country, the SECI score is lower for the sample's surveyed country respondents. Inversely when the income inequality is higher, the SECI score would appear higher too. However, it has to be said that in our model, this last relationship is borderline significant ($P = 0.047$), although if tested through a Pearson correlation test, the relationship appears significant ($P \leq 0.01$) and still positive.

It is difficult to speculate on these opposed signs; perhaps what could be said is that wealth, which comprises assets, inherited or accumulated, explains significantly more perduring social inequality than income because it usually generates income by itself and significantly expands the abilities to sustain consumption beyond the income level of households (Islam and McGillivray, 2020). While income is mainly tied to an individual's professional choices and achievements, wealth might only loosely relate to it (Berman et al., 2016). In fact, countries

[7]Researchers that aim to answer questions such as "What is the relationship between income and wealth equality and energy caring in Europe/Asia/Africa" should weigh according to population.

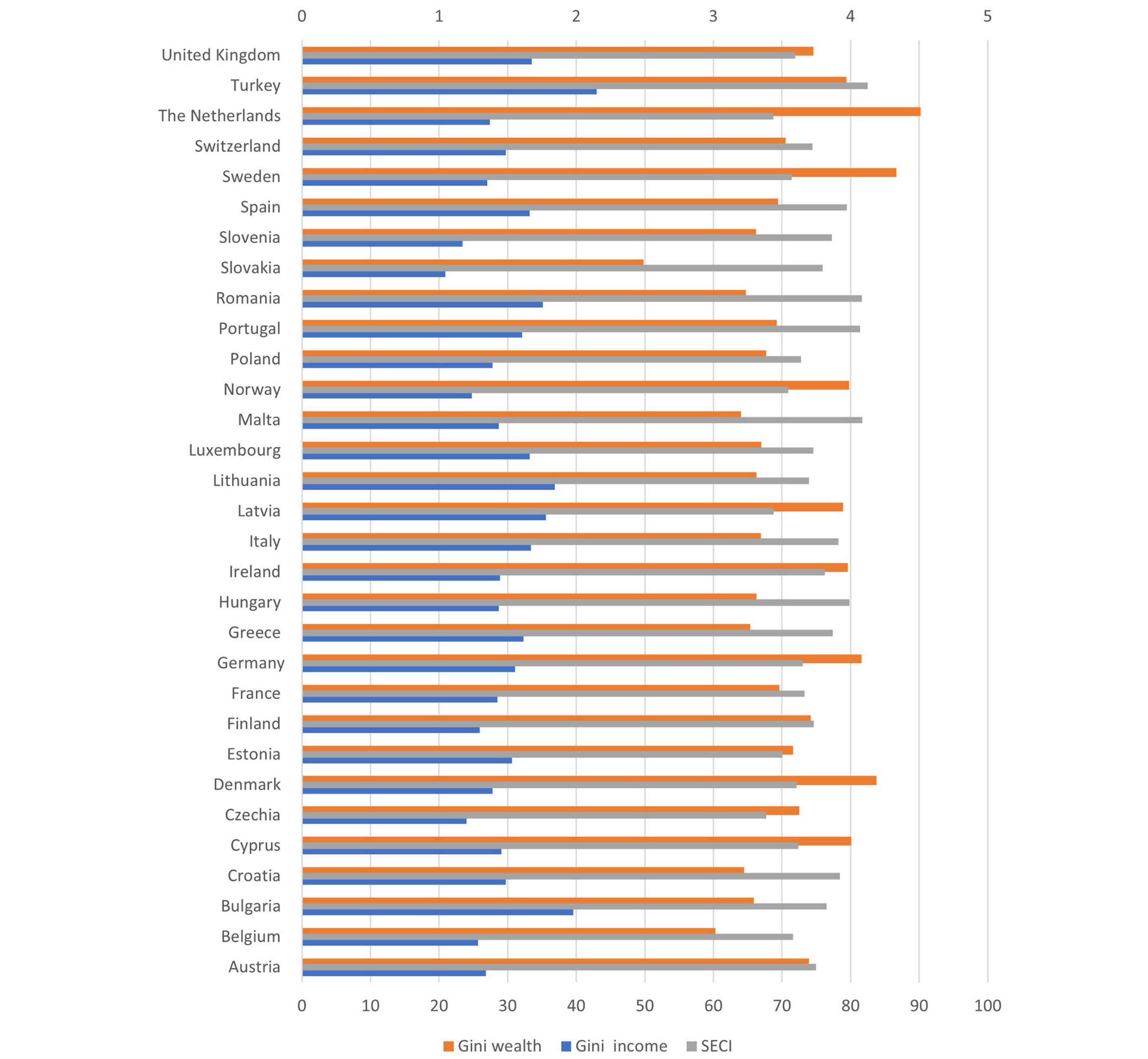

FIGURE 1 | Gini wealth index, Gini income index, and SECI score for European countries.

with progressive income taxes appear to be efficient in reducing income inequality but not wealth inequality (Berman et al., 2016). If income inequalities have been considered, to some extent, by economists as a necessity to increase economic efficiency (Okun, 2015), wealth inequalities have been criticized for producing inefficiencies and slowing down economic growth (Islam and McGillivray, 2020). Income inequalities, to an extent, increase economic efficiency and, therefore, growth, although excessive income inequality appears to hinder growth too (Cingano, 2014).

In our sample, interestingly, countries that have higher GDP PPS per capita correlate negatively with SECI, although very modestly (−0.076, $P \leq 0.01$), this appears to contradict the established view that environmental concern is higher in higher income per capita countries (Inglehart, 1990; Franzen and Vogl, 2013). Similarly, very weak but still negative is the correlation between the median income of countries and the SECI score (−0.106, $P \leq 0.01$). When we look at how measures of societal wealth, GDP per capita and median income, correlate with wealth and income inequality Gini indexes, we find that higher wealth inequality correlates positively with median income (0.387, $P \leq 0.01$) and with GDP PPS per capita (0.302, $P \leq 0.01$). However, the opposite is true for the Gini income index, i.e., income inequality, which negatively correlates with median income (−0.339, $P \leq 0.01$) and GDP PPS per capita (−0.217, $P \leq$

0.01). In sum, our data suggest that there might be a connection between higher wealth inequality, higher GDP per capita and higher median income, and lower SECI. Considering the weak or modest correlations found, these findings need to be explored and probed in further studies.

Less surprisingly, we found that individuals with right-wing social and economic outlook are less concerned with sustainable energy (correlations coefficients are respectively −0.123, $P \leq 0.01$ and −0.125, $P \leq 0.01$), which appears coherent with previous research (Franzen and Vogl, 2013; Gifford and Nilsson, 2014; Drews et al., 2016). While, higher educated individuals and women in our model appear more caring of sustainable energy, which, again is consistent with previous research on environmental attitudes (Franzen and Vogl, 2013). Finally, it is also unsurprising that right-wing social and economic outlooks are negligibly but positively correlated with social status (respectively 0.064 and 0.093, $P \leq 0.01$).

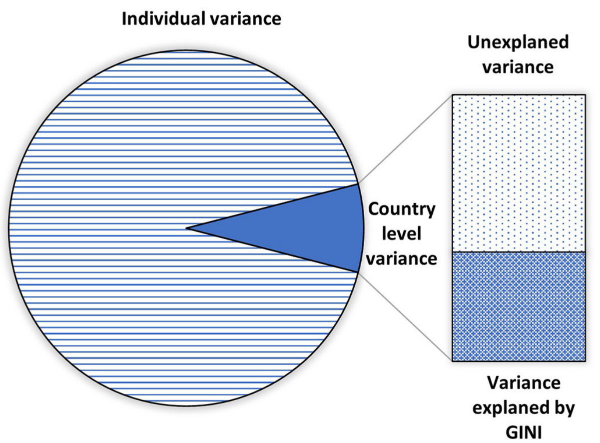

FIGURE 2 | Share of variance explained by GINI wealth and income coefficients.

CONCLUSIONS

This research has attempted to develop, from ethical considerations regarding energy justice, a focus on energy equality and the intersection of distributional injustices and sustainable energy policies. The current debate on energy justice needs to rest on empirical evidence supporting the shift advocated by energy justice scholars toward just energy policies, which ultimately are policies inspired by equalitarian principles (Pellegrini-Masini et al., 2020a). In this paper, our focus has been on energy equality and distributional justice. Finding empirical evidence supporting a nexus between sustainable energy attitudes and reduced economic inequalities has returned complex results; nevertheless, distributional patterns appear to explain a large amount of variance of sustainable energy attitudes at the country level in our sample. These findings support the view that a nexus between economic inequality and sustainable energy attitudes is indeed present, although the relationships of income and wealth inequalities with such attitudes need further research to be fully explained. What appears evident, and coherent with previous research, is that equalitarian values in the shape of progressive social and economic outlooks seem to underpin sustainable energy attitudes, thereby lending further credit to the importance of promoting these values in order to further the energy transition and the shift toward a society implementing sustainable energy policies.

How do these findings sit in the context of the energy justice research debate? In our view, they strengthen the need for an

TABLE 4 | Variables included in the regression analysis.

Item	Question	Scale
Age	How old are you?	18–34; 35–44; 45–54; 55+.
Gender	Please indicate your gender	1 Female; 2 non-female*
Education	Which of the following best describes you?	Elementary or secondary school; Professional training; A-Levels; University or college degree*
Social status	Where would you place yourself on this ladder?	1 worst off; […] 5 best off
Economic outlook	How would you describe your political outlook with regard to economic issues (e.g., taxes, cooperative vs. protective foreign economic policy, etc.)?	1 Left; […] 5 Right
Social outlook	How would you describe your political outlook with regard to social issues (e.g., family, religion, traditional values, etc.)?	1 Left; […] 5 Right
Personal income	Is your household's monthly net income less that [quartile income of country]?	1 <1st quartile; 4 >3rd quartile; 5 >90th percentile income
Median Income	Median monthly net income of the country the respondent belongs to	–
GINI Income	[Insert GINIindex2 explanation]	–
GINI Wealth	[Insert GINI_wealth2 explanation]	–

**See syntax file for further details.*

TABLE 5 | Multilevel regression on the sustainable energy caring index (SECI).

Variable	Model 1	Model 2			Model 3		
		Coef.	C-Z	*P*	Coef.	C-Z	*P*
I - Age		0.039575	0.0461163	<0.0005	0.0395191	0.0460512	<0.0005
I - Gender		0.0852198	0.0426076	<0.0005	0.0852352	0.0426153	<0.0005
I - Education		0.0612678	0.0648487	<0.0005	0.0610339	0.064601	<0.0005
I - Personal income		0.0201653	0.0279445	0.001	0.0200394	0.0277701	0.002
I - Social status		0.0693078	0.0526277	<0.0005	0.0694507	0.0527362	<0.0005
I - Economic outlook		−0.0430792	−0.0490509	<0.0005	−0.0430929	−0.0490666	<0.0005
I - Social outlook		−0.035707	−0.0418444	0.001	−0.0357621	−0.0419091	0.001
C - Median Income		−0.005866	−0.0658983	0.018	−0.0010803	−0.0121361	0.689
C - GINI Income					0.0139574	0.066903	0.047
C - GINI Wealth					−0.0097319	−0.0824155	0.002
Constant	3.748259	3.345039	3.746914	<0.0005	3.540807	3.746918	<0.0005
Residual country variance	0.0397338	0.0307504			0.0234518		
Residual individual variance	0.4572319	0.4373367			0.4373366		
Share of country variance explained		22.6%			41.0%		
Share of individual variance explained		4.4%			4.4%		

I, individual factor; C, Country factor; C-Z, Standardized coefficients. Share of variance explained indicates how much of the variance attributed to individual factors (92%) and country factors (8%) is explained by the variables in the regression. All models apply country as level 2 indicator.

approach to energy justice that stresses the importance of aiming at equalitarian policies addressing distribution inequalities. This approach emphasizing the need for redistributive policies has been argued to be desirable concerning energy policies (Galvin, 2019; Pellegrini-Masini, 2019; Pellegrini-Masini et al., 2020b), but it has also been advocated concerning sustainable development (Langhelle, 2000; Mészáros, 2001; Pereira, 2014; Grossmann, 2021).

More broadly, our findings join growing empirical evidence about the nexus between environmental sustainability and distributional equality (Wilkinson and Pickett, 2010a,b; Wilkinson et al., 2010) that could strengthen the political argument in favor of redistributive policies within the energy sector and society at large. This area of research is crucial because so far, debates on the importance of a socially just energy transition have been chiefly relying on ethical arguments, which have been suggested to be ineffective in shifting the policy consensus (Galvin, 2019). This stance is disputable because cultural debates never cease to influence political decisions. However, it is fair to assume that providing empirical evidence of a nexus between environmental sustainability and contained economic inequality might have a far greater impact on the politics of sustainability than philosophical arguments alone.

Inevitably this work comes with some limitations, the main one being that we looked at the relationship between economic inequalities and attitudes; while it is well-known that attitudes do not always translate into behaviors, the so-called "value-action gap" (Kollmuss and Agyeman, 2002). Nevertheless, pro-environmental attitudes translate into sustainable behaviors, at least in perceived low-cost situations (Diekmann and Preisendörfer, 2003; Pellegrini-Masini, 2020) and specifically regarding energy consumption behaviors (Von Borgstede et al., 2013). Further limitations regard our focus on the country level of analysis and economic inequality; this deliberate choice omits empirical analysis and even considerations on individual and country level variables, i.e., cultural differences across countries, which would possibly explain more of the variance.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found at: https://db.echoes-project.eu/echoes/raw-data.

AUTHOR CONTRIBUTIONS

GP-M conceived and redacted most of the article. LE carried out the data analysis and contributed to writing the results section. CK and EL reviewed the manuscript provided comments and suggested modifications. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2021.663000/full#supplementary-material

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Characterizing the Energy Burden of Urban Households in Mexico: The Impact of Socioeconomic and Temperature Conditions Across Metropolitan Areas

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The transition toward sustainable cities requires evaluating current energy policies to reshape established patterns of energy supply and use. Ignoring socioeconomic and geographic differences among households in the energy policy-making process jeopardizes the government's ability to achieve a fair distribution of resources and advance energy equity. Hence, tailored urban energy strategies that address specific opportunities to improve local sustainable development and energy justice are needed. In this paper, we use the energy burden, i.e., the share of household income spent on energy services, as a metric to characterize energy affordability for urban households in Mexico. We estimate the electricity and gas consumption as well as their resulting financial burden for 17,850 urban households in 72 metropolitan areas. The calculated median monthly energy consumption of Mexican urban households is 453 kWh and is dominated by gas consumption. This results in a median energy burden of 3.5%. However, we observe a large diversity among households in energy consumption and, consequently, in energy burden, due to variations in energy use among urban households derived from their socioeconomic and geographic conditions. In addition, we analyze the role of the temperature-based residential electricity subsidy. We find that even with subsidized electricity prices, the current subsidy scheme is insufficient to alleviate energy vulnerability in urban Mexico, and at the same time, it has a regressive effect by benefiting those consuming more. Based on the analysis of the energy burden at the city level, we highlight evident problems and potential solutions missed by one-size-fits-all energy policies. This analysis provides a better understanding of the drivers and distribution of energy burden in urban households. It also presents practical insights that could help policymakers ensure that energy is available to all households according to their needs and that demands for reductions in energy consumption as well as for adoption of clean energy technologies and energy efficiency measures come from each according to their capacity.

Keywords: energy burden, electricity consumption, gas consumption, urban households, Mexican metropolitan areas, electricity subsidy

1. INTRODUCTION

The transition toward sustainable cities requires that energy policies have equity and justice at their core (Jenkins, 2016; Jenkins et al., 2016). Ignoring the social, economic, and geographic factors of energy use in the development and implementation of energy policies jeopardizes the fulfillment of the population's energy needs and the fair and efficient distribution of resources. There is a need for more effective targeting to identify and react to the specific energy needs and opportunities of all households (Bednar et al., 2017). An initial step toward this goal is to draw attention to where energy injustices occur, including the unequal allocation of benefits and burdens, and to understand the underlying reasons for their uneven, inefficient, or unfair distribution (Walker, 2009; Bouzarovski and Simcock, 2017; Lamb et al., 2020; Velasco-Herrejon and Bauwens, 2020).

Inequitable impacts of residential energy consumption are often analyzed in the context of energy poverty. Even though there is no universal definition of energy poverty, it is widely described as the inability of a household to secure a socially and materially necessary level of domestic energy services (Bouzarovski and Tirado Herrero, 2017). Its assessment depends on the conceptualization and evaluation of the underlying factors (e.g., accessibility, adequacy and affordability of energy services) and these are usually particular to the case under study (Schuessler, 2014).

Energy poverty studies in Mexico are limited and focus mainly on measuring energy access (Garcia-Ochoa and Graizbord, 2016; García Ochoa and Graizbord Ed, 2016; Santillán et al., 2020). They do not take into account the affordability of energy services. Measuring affordability requires assessing the financial burden for households resulting from the satisfaction of their energy needs (Dubois and Meier, 2016). Studies of this sort traditionally address energy poverty in OECD countries, where energy access is not an issue (Schuessler, 2014; Dubois and Meier, 2016; Thomson et al., 2017; Kontokosta et al., 2020). However, cities in developing countries with high electrification rates are often overlooked in accessibility studies, as their energy vulnerability is only associated with access to energy services and not with the affordability or adequacy of such services (Nussbaumer et al., 2012; Schuessler, 2014; Santillán et al., 2020).

The energy burden, i.e., the percentage of household income used for energy expenditures, is a widely used objective metric to assess energy poverty in terms of affordability of energy services (Reames, 2016; Bednar et al., 2017; Thomson et al., 2017; Tirado Herrero, 2017; Agbim et al., 2020; Drehobl et al., 2020; Kontokosta et al., 2020). Drehobl et al. (2020) describes that the intensity of energy burdens is a consequence of the physical characteristics of the household (e.g., location, housing type, number and type of appliances, heating and cooling systems), the resident's socioeconomic status and behavioral patterns (e.g., recurrent income level, ability to afford up-front costs of energy-related investments, energy-saving practices), and the availability of policy-related resources (e.g., direct or indirect subsidies for bill assistance and energy efficiency). Therefore, causes of high or low energy burdens are usually a combination of these drivers.

High energy burdens can result in energy insecurity and create a negative feedback loop that reinforces social inequality (Urban, 2019; Drehobl et al., 2020). According to Brown et al. (2020), low-income households often make trade-offs between meeting alternative critical household expenditures like rent, food, healthcare or telecommunications, to avoid energy shut-offs. This can lead to or exacerbate poor health due to constant thermal discomfort and stress caused by the uncertainty of affording energy bills (Agbim et al., 2020; Drehobl et al., 2020; Memmott et al., 2021). However, high energy burdens might also be explained by high energy requirements or low levels of energy-saving practices (Evergreen Economics, 2016). On the other hand, low energy burdens might indicate hidden energy poverty, particularly for low-income households that prioritize other expenditures (Tirado Herrero, 2017). Yet, they might also result from energy efficiency strategies or low and distorted energy costs resulting from universal energy policies. Since the underlying factors of energy burdens are multifaceted and thus, lead to a broad spectrum of energy burden intensities among households, it is necessary to carry out studies that address the multiple dimensions of energy inequality and its drivers, including the geographic dimension.

The objective of this work is to characterize the distribution of energy burden of urban households in Mexico at the national level and across metropolitan areas. For this purpose, we first estimate the electricity and gas consumption of Mexican urban households based on their expenditure and local tariffs for these services. We investigate the variations in energy use among urban households derived from their socioeconomic and geographic conditions in terms of income, dwelling and household size, tenure status, education level, and local temperature. This analysis is key to understanding the underlying determinants of the wide range of energy burden values. Then, we categorize household energy burdens into five levels, from very low to very high. In doing so, we identify at one end, highly energy burdened households that, even with the current electricity subsidy scheme, spend disproportionately more of their income in energy bills, and at the other end, energy secure households for whom paying for energy services, with or without subsidy, represents only a small fraction of their income. In this way, we recognize the enormous diversity among urban households. We argue that one-size-fits-all energy policies, especially the current Mexican residential electricity scheme, invisibilize the particularities of household energy consumption and, at the same time, have a high fiscal cost due to their inefficiency in distributing the benefits. Furthermore, we investigate and compare the energy use and energy burden of 72 metropolitan areas in Mexico. We identify similarities and differences across cities that highlight specific needs and opportunities at this spatial level. Therefore, this study may assist policy-makers with the development and integration of better-targeted energy affordability and energy burden goals in policies toward sustainable cities.

2. LITERATURE REVIEW

2.1. Measuring Energy Poverty

Energy poverty is a complex phenomenon and has no universal definition (Schuessler, 2014; García Ochoa and Graizbord Ed, 2016). It can be generally described as the inability of a household to secure a socially and materially necessary level of domestic energy services (Bouzarovski and Tirado Herrero, 2017). Schuessler (2014) describes the crux of energy poverty as the unavailability and/or inappropriately high costs of procuring such services at the household level. However, how to measure energy poverty depends on the conceptualization and assessment of the underlying phenomena, which has prompted the development of different approaches for measuring it. Three main directions are identified in literature (Schuessler, 2014; González-Eguino, 2015; Tirado Herrero, 2017; Agbim et al., 2020): (1) comparing the level of domestic energy services vs a predefined standard for a quantitative measure of accessibility and/or adequacy of energy services, (2) expenditure-based indicators for a quantitative measure of affordability of energy services, and (3) subjective qualitative assessments of energy-related living conditions. Studies of energy poverty in developing countries traditionally focus on accessibility of energy services (Nussbaumer et al., 2012; García Ochoa and Graizbord Ed, 2016; Sadath and Acharya, 2017; Santillán et al., 2020), while high electrification rates and rising energy costs have extended energy poverty studies to adequacy and affordability of energy services, mainly in OECD countries (Drehobl and Ross, 2016; Dubois and Meier, 2016; Thomson et al., 2017; Brown et al., 2020).

Expenditure-based definitions are the most used quantitative instruments to define and measure the intensity of energy poverty (Schuessler, 2014; Tirado Herrero, 2017). Discussions in this regard began in the UK in the 1970s to identify households that were unable to attain adequate room warmth at reasonable costs. Boardman (1991) proposed the popular ten-percent-rule, which categorized households that spent more than 10% of their income in energy spending as fuel poor. This threshold served as the official energy poverty line indicator in the UK until 2012 and allowed the monitoring of the national incidence of energy poverty for more than a decade (Thomson et al., 2017). This expenditure-to-income ratio transitioned from being a metric with a focus on heating costs to an indicator that captures all domestic energy services, commonly referred as energy burden (Schuessler, 2014).

Similar to the ten-percent-rule, the energy burden has been used to identify energy-poor households by defining a threshold of maximum fraction of income spent on energy services (Schuessler, 2014). Due to their simplicity, energy burden studies spread from the UK to other European countries (Thomson and Snell, 2013; Heindl, 2015; Rademaekers et al., 2016) and recently also to the US (Drehobl and Ross, 2016; Cook and Shah, 2018; Agbim et al., 2020; Brown et al., 2020; Drehobl et al., 2020; Kontokosta et al., 2020). However, there is a lot of discussion around the assessment of energy poverty using solely an objective metric and an arbitrarily defined or uncritically transferred threshold, as it might not capture all those facing energy poverty (Tirado Herrero, 2017). Researchers argue that energy burden analyses often ignore social, economic and geographic factors, as well as the diversity in energy end-uses, and thus also fail to identify the drivers of energy poverty (Tirado Herrero, 2017; Agbim et al., 2020). Although it is recognized that the assessment of energy poverty should be a multi-dimension investigation and preferably follow a multi-indicator approach (Rademaekers et al., 2016; Thomson et al., 2017), such an analysis would require the availability of household-level information on all the dimensions to be investigated, which is rather a difficult task for most countries. This sustains that using the energy burden as a pragmatic indicator to establish a baseline for assessing energy poverty is a good option for case studies with limited information, provided that a fixed percentage threshold is empirically confirmed, adequately modified, and regularly updated to account for the temporal and spatial dynamics of energy poverty Schuessler (2014); Agbim et al. (2020).

The definition of an energy burden threshold for quantifying fuel poverty should not necessarily be the same for different countries and even for different cities within the same country; it is case-specific. Nevertheless, the underlying assumptions for its definition should be clearly stated for transparency, replicability, monitoring, and benchmarking purposes (Rademaekers et al., 2016). Consider for example, Boardman's fuel expenditure vs. household income maximum threshold of 10%. It represented the actual average share of energy spending among the 30% of the poorest households in the UK, as well as roughly twice the median share of the actual energy spending for all households in 1988 (Boardman, 1991). Another example is the 6% affordable burden for home energy bills commonly used in energy poverty studies in the US (Fischer Sheehan and Colton, 2013; Drehobl and Ross, 2016; Reames, 2016; Bednar et al., 2017; Cook and Shah, 2018; Brown et al., 2020). This maximum energy burden is based on the premise that housing costs should account for no more than 30% of household income, and household energy costs should not exceed 20% of housing costs (Fischer Sheehan and Colton, 2013; Drehobl et al., 2020). Both thresholds, widely used in literature, are defined differently, but seek to characterize energy affordability for low-income households in the UK and the US.

Worldwide, energy and sustainability strategies at the city level are becoming more common. One of the main reasons is that the city is often the administrative tier of the local government with the principal competence for energy policy (Asaporta and Nadin, 2020). This calls for the spatial characterization of energy burden, at least at this spatial scale, either through city-level comparison studies (Drehobl and Ross, 2016; Drehobl et al., 2020; Kontokosta et al., 2020) or detailed intra-city analyses (Mayer et al., 2014; Bednar et al., 2017; Agbim et al., 2020).

Drehobl and Ross (2016), measure individual energy burdens in several cities in the US and use the median percent of income used for energy expenditures of each city as a threshold for a household to be considered energy poor. In this way, they take into account regional differences in economic characteristics, climate and diversity in energy end-uses within the same country. Kontokosta et al. (2020) analyze energy audit reports of households in five US cities and examine the distribution of energy burdens among household demographic and socioeconomic characteristics. They report the median annual energy cost per square foot and resulting energy cost burden by city and income band, rather than the classic binary classification of households as being energy poor or not. This approach allows the direct comparison of energy burden values across cities, and furthermore, decouples energy poverty from a national fixed percentage threshold. In a similar way, Drehobl et al. (2020) present a snapshot of US energy burdens nationally, regionally, and in 25 selected metro areas. They also present the raw energy burden values and further compare them to a country-wide criterion of 6% and 10%, for high and severe energy burdens, respectively. Thus, they offer a clear overview of the intra-national differences while providing cities and states a starting point for incorporating energy burden goals in local energy policies and programs to achieve more equitable energy outcomes.

In summary, the existing literature shows that the energy burden is a straightforward metric that can provide an insight into the affordability of energy services. Statistical analyses of energy burden allow the identification of those households that spend disproportionately more -and less- of their income on energy costs. The understanding of the spatial and temporal distribution of the financial burden the population faces in meeting their energy needs is key to the generation of just energy policies, insofar as the underlying factors of high -and low- energy burdens are understood. Yet, most of the existing literature refers to studies conducted in Europe and the US. This calls for energy burden studies in other regions of the world, especially in developing countries, that consider the contextual differences of households in these regions.

2.2. Energy Use and Energy Poverty in Mexico

Electricity and domestic gas are the main energy sources in households in Mexico. According to Franco and Velázquez (2016), the percentage distribution of energy consumption by end-use activity in 2014 was: water heating (65.0%), food cooking (17.2%), air conditioning and ventilation (7.0%), food refrigeration (6.9%), lighting (2.8%), and entertainment and others (1.1%). Gas use in households is linked to cooking, hot water consumption, and clothes drying, the latter being by far the least common end-use activity (INEGI, 2019d). Still, electricity and other less usual energy carriers, such as wood, can replace gas use in some cases. In 2016, 95.5% of urban households reported using electricity and gas as energy sources (INEGI, 2019d). However, the share of clean and modern fuels in rural households decreases to 88.7% (Franco and Velázquez, 2016).

Several studies have analyzed the disparities in energy use in Mexican households, particularly regarding the effect of income inequality and consumption patterns within the country (Rosas et al., 2010; Rodriguez Oreggia and Yepez Garcia, 2014; Franco and Velázquez, 2016; Jimenez Mori and Yepez-Garcia, 2017; Santillán Vera and de la Vega Navarro, 2019). Scholars agree that there is a significant difference among the energy consumption of rural and urban households, with urban households consuming more energy and spending proportionately less of their income than rural households (Franco and Velázquez, 2016; Jimenez Mori and Yepez-Garcia, 2017). This inequality is not only driven by diverse energy consumption trends, but is also rooted in differences in energy access. Energy poverty assessments with a focus on accessibility of energy services show that households in rural areas have significantly less access to energy services than those in urban areas, particularly concerning lighting, entertainment, water heating and cooking (García Ochoa and Graizbord Ed, 2016). García Ochoa and Graizbord Ed (2016) find that the household income, the type of settlement (urban or rural) and the regional climate are the main determinant factors linked to energy deprivation.

Most of the existing literature on energy use and energy poverty in Mexico does not address the geographical inequities. To our knowledge, only (Garcia-Ochoa and Graizbord, 2016) offer a first approach to the geography of energy poverty. They identify a spatial pattern of energy poverty in which low-income states with a need for thermal comfort and located in the southern part of the country exhibit the highest levels of energy deprivation. States in the center of the country with moderate climates and no need for thermal comfort experience medium levels of energy deprivation. Moreover, states in the north with a need for thermal comfort but with above-average income levels have the lowest levels of energy deprivation. Apart from grouping urban and rural households in the subnational results, this analysis focuses only on quantifying energy deprivation and does not provide an insight on the financial burden of covering domestic energy needs.

Rodriguez Oreggia and Yepez Garcia (2014) and Jimenez Mori and Yepez-Garcia (2017) analyze the household energy expenses using microdata at the household level from the Income-Expenditure National Survey of 2010 and 2014, respectively. Rodriguez Oreggia and Yepez Garcia (2014) report that urban households spend around 10% of their income on energy, including electricity, domestic gas, and gasoline for private transportation. This energy burden is similar for all income groups, but gasoline accounts for a larger share with increasing income. A similar trend is reported by Jimenez Mori and Yepez-Garcia (2017) for all rural and urban households in Mexico. When considering only electricity and gas, the energy burden of households in the poorest quintile represents 6.8% of their income, whereas it decreases to 3.8% in the richest quintile. These studies already provide valuable information on energy spending and affordability at the national level. However, they overlook the geographically embedded and dependent nature of the underlying causes. The spatial disaggregation of the energy affordability and its determinants is fundamental to complete the geographic picture of energy poverty in Mexico. This work aims to address this gap by estimating the spatial distribution of energy burden at the city level.

3. MATERIALS AND METHODS

The energy burden is calculated as the share of household income spent on energy services. This paper considers electricity and domestic gas expenditures and focuses only on urban households in Mexico. Even though the spatial unit of energy burden is the household, it has a local and specific nature, making it necessary to incorporate the spatial dimension as a contextual factor (Garcia-Ochoa and Graizbord, 2016). In this way, spatial and regional differences become relevant elements of analysis for a better understanding of the distribution of the energy burden in any given study area.

Our main data source is the National Survey of Household Income and Expenditure (ENIGH) of INEGI (2019c). The expenditure-to-income ratio can be estimated from this dataset alone. However, understanding the underlying drivers of the intensity of the resulting energy burdens requires the computation of the actual household energy consumption. For this purpose, we calculate the electricity and gas consumption at the household level based on their reported expenditure and local tariffs for these services. The latter are defined according to the national subsidy schemes, which, in the case of electricity, depend on the local average summer temperature of the household's geographic location. Therefore, we use a second dataset, the Digital Climate Atlas of Mexico (UNIATMOS, 2019), to estimate the average minimum summer temperature of surveyed households in the ENIGH to find out their corresponding electricity tariff and associated subsidy. We investigate the variations of energy use among urban households in terms of income, dwelling and household size, tenure status, education level, and local temperature. Furthermore, we analyze the distribution of energy burdens nationally and for 72 metropolitan areas defined in a third dataset, the National Urban System of CONAPO (2018). Additional details on the three main datasets as well as on the calculation methods for electricity and gas consumption and energy burden are found in the following subsections.

3.1. Data

3.1.1. Household Income and Expenditure

The National Survey of Household Income and Expenditure (ENIGH, *Encuesta Nacional de Ingresos y Gastos de los Hogares*) provides a statistical overview of the characteristics and trends of income and expenditures of Mexican households in terms of their amount, origin and distribution (INEGI, 2019c). It also offers information regarding the occupational and sociodemographic characteristics of household members, as well as an insight on the housing infrastructure and appliances. This survey is carried out every 2 years by the National Institute of Statistics and Geography (INEGI, *Instituto Nacional de Estadística y Geografía*). The ENIGH of 2018 has a sample size of 87,826 households and includes information on both rural and urban households throughout the country ensuring a statistical representativeness at the state-level (INEGI, 2019c). This study focuses only on urban households. The urban sample consists of 31,000 households as shown in **Table 1**.

Regarding household expenditure in energy services, the ENIGH includes electricity and domestic gas (liquefied petroleum gas (LPG) or natural gas) expenditure information corresponding to a billing period of 3 months (INEGI, 2019b). For each household, this information is usually the last paid bill closest to the time of the survey. Since the survey was conducted from August 21 to November 28, 2018, with most of the interviews carried out in the first half of this period, we assume that reported energy bills were paid between July and September. Additionally, we consider only observations with complete data for both electricity and gas expenditures because our analysis includes the correlation between the use of both energy carriers. We do not exclude users without access to electricity or gas as households without access to either service report a consumption of zero. Zero gas consumption is double-checked by verifying that the household does not report using gas-fired cooking or water heating appliances. Accordingly, the number of urban households in the survey containing complete entries for expenditures on electricity and gas is reduced to 18,629 (see **Table 1**).

TABLE 1 | Number of samples from ENIGH 2018 (INEGI, 2019a) that correspond to urban areas and have data for electricity consumption, gas consumption, and income.

Data	Sample size
urban samples	31,100
with electricity consumption data	28,303
with gas consumption data	20,102
with electricity and gas data	18,629
with income data	18,623
urban samples without extreme outliers	17,850

From the reduced data set, we filtered out six households without income data. Furthermore, 773 observations (4% of the remaining households) were identified as extreme outliers and were removed from the dataset. These households include possible data entry errors and income or energy expenditure values that lie at least five times the interquartile range below the 1st quartile or above the 3rd quartile. Thus, our final sample size consists of 17,850 urban households with complete data on income and expenditure on both electricity and gas. Additional to the information on household income and energy expenses, four socioeconomic variables, namely, household size, status of dwelling ownership, number of rooms in the dwelling, and education level of the head of household were also extracted from the ENIGH to explore patterns of energy consumption among urban households Mexico.

3.1.2. Temperature

The Digital Climate Atlas of Mexico [UNIATMOS2019] provides raster maps of the mean monthly temperatures from 1902 to 2011 for the whole country. Using these maps, we calculate the average minimum summer temperature (average of June, July and August) of 2018 at the municipality level using a zonal statistics analysis. Due to privacy concerns, ENIGH observations have a geographic reference up to this level. Therefore, all households within a municipality are assumed to have the same temperature. The resulting temperature values at the metropolitan area level are listed in the Supplementary Material in **Table B**.

3.1.3. Definition of Metropolitan Areas

The National Urban System of 2018 defined by the National Population Council (CONAPO, *Consejo Nacional de Población*)

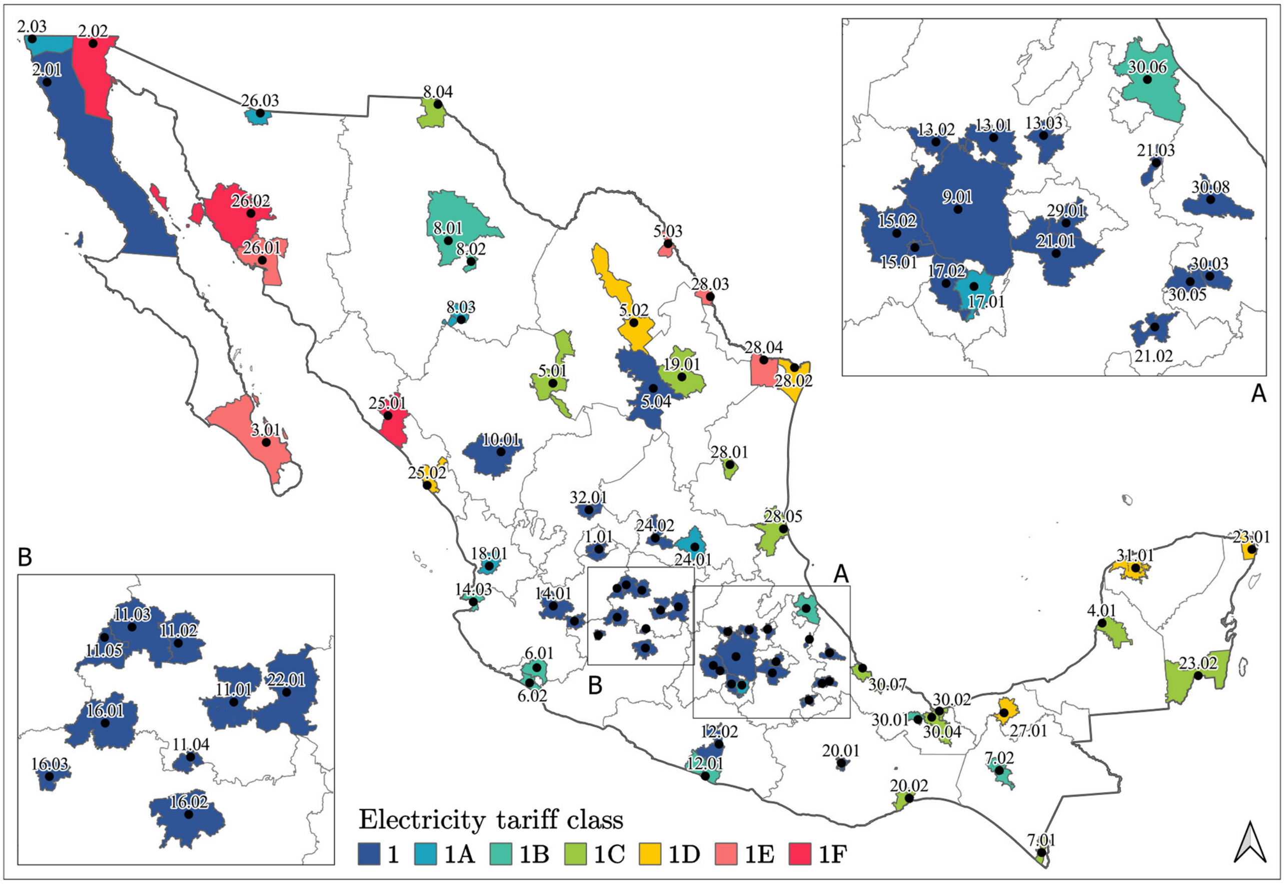

FIGURE 1 | Metropolitan areas in Mexico according to the Urban National System (CONAPO, 2018) and their regular electricity tariff class. Each metropolitan area has an identification code of the form X.Y, where X is the federal state and Y is an increasing number that enumerates the metropolitan areas within the same state. **Table A** in the Supplementary Material lists the key information of the metropolitan areas in this map.

identifies 401 cities that together host almost 93 million inhabitants, ca. 75% of the Mexican population. Among these, 74 cities are denominated metropolitan areas, which are characterized by their size and high functional integration, even when encompassing more than one municipality (CONAPO, 2018). This makes metropolitan areas the smallest administrative tier with the competence for energy policy. For this reason, we focus on a spatial energy burden analysis at this level.

The map in **Figure 1** shows the 72 metropolitan areas considered in this study, all of them with a population above 100 thousand inhabitants (CONAPO, 2018). Each metro area has an identification code of the form X.Y, where X is the federal state and Y is an increasing number that enumerates the metropolitan areas within the same state. Their associated electricity tariff class, derived from the calculated average minimum summer temperature, is represented by the color of each polygon. **Table A** in Supplementary Material lists the metropolitan areas and their identification code, belonging federal state, population in 2015, and number of complete household observations. Two metropolitan areas, namely Ocotlán (14.02) and La Piedad-Pénjamo (16.01), were not included in this work, as the ENIGH 2018 reported no observations with complete information on expenditures for electricity and gas from these cities. The surface area of metropolitan areas in **Figure 1** corresponds to the administrative area, and not to the actual built-up area. Therefore, especially in the north of the country, where administrative areas tend to be larder, urban households do not occupy all the space depicted but are concentrated in a smaller area (not visible in the map).

3.2. Calculation of Household Energy Consumption

3.2.1. Electricity Consumption

Residential electricity consumption in Mexico is heavily subsidized. The residential electricity tariff and subsidy structure is complex and is composed of 40 tariff levels (Sánchez et al., 2018). There are seven regular tariff classes: 1, 1A, 1B, 1C, 1D, 1E, and 1F, which are divided into three or four increasing consumption blocks and eight tariff regions linked to average minimum temperatures during summer months. All regular

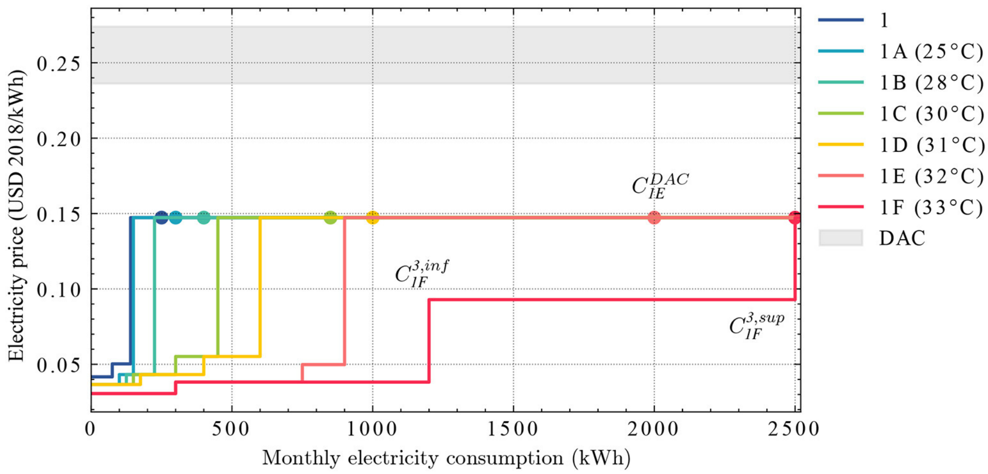

FIGURE 2 | Residential tariff scheme for Summer 2018 with increasing block prices for the seven regular tariff classes and the unsubsidized DAC tariff. The mathematical notations of the monthly consumption threshold to be considered a DAC user for tariff class 1E and the inferior and superior limits for the third consumption block of tariff class 1F, C_{1E}^{DAC}, $C_{1F}^{3,inf}$ and $C_{1F}^{3,sup}$, are displayed for illustrative purposes.

tariffs are below the supply cost and therefore, are subsidized. An additional tariff class, the high-consumption tariff (DAC, *Tarifa Doméstica de Alto Consumo*), applies above a specific consumption threshold which varies significantly depending on the tariff region. Once the consumer surpasses the monthly consumption threshold (calculated as the average of the last 12 months), DAC users are penalized by losing the federal subsidy and by paying their electricity at a price approximately 50% above the real supply cost (Hancevic and Lopez-Aguilar, 2019). The DAC price, composed of a fixed charge and a uniform marginal cost, applies to the whole consumption disregarding previous consumption blocks. This creates a strong incentive for DAC households to undertake actions to keep electricity consumption from the grid under the DAC threshold, such as the adoption of solar technologies and energy efficiency measures.

A subsidized scheme, where high temperature zones get lower marginal prices and have larger consumption blocks, is the backbone for determining the electricity price for all tariff levels (Hancevic and Lopez-Aguilar, 2019; Hancevic et al., 2019). **Figure 2** illustrates the summer tariff structure in 2018. The average minimum temperature for each regular tariff class is shown in the legend. The electricity price, $p_{elec,i}^{j}$, varies according to the tariff class i and consumption block j. The monthly consumption threshold to be considered a DAC user, C_i^{DAC}, is indicated with a colored circle for every regular tariff class i. The inferior and superior electricity consumption limits for every tariff i and consumption block j are $\check{C}_i^j$ and $\hat{C}_i^j$, respectively. The mathematical notation of the monthly consumption threshold to be considered a DAC user for tariff class 1E, C_{1E}^{DAC}, and the inferior and superior limits for the third consumption block of tariff class 1F, $C_{1F}^{3,inf}$ and $C_{1F}^{3,sup}$, are displayed in **Figure 2** for exemplary purposes. Notice that while the electricity price for tariffs with moderate minimum summer temperatures (1, 1A and 1B) can jump very quickly into the DAC price, p_{elec}^{DAC}, larger consumption blocks are allowed for users in warmer regions as higher electricity consumption is assumed due to cooling and ventilation needs.

Data reported in the ENIGH likely correspond to the most recent utility bill. Therefore, we assume that reported values refer to quarterly expenditure on electricity at summer prices including taxes. The summer rate is billed from May 1st to October 31st. Let x_{elec} be the monthly household expense for this service. A tax a of 16% is assumed for all households except for those located in municipalities at the border with the US where $a = 11\%$. The untaxed expenditure on electricity services without taxes, x^*_{elec}, calculated in Equation (1), is used together with the summer tariff scheme in **Figure 2** for the backwards calculation of the monthly electricity consumption, E_{elec} as shown in Equation (2). E_{elec} is computed for all households in the sample size. Each household is assigned a regular tariff class based on the calculated minimum summer temperature in section 3.1.2. Thus, a household in tariff class i with consumption blocks $j = 1, ..., m$, is assumed to lie within the consumption block L if $\sum_{j=1}^{L} \check{C}_i^j \, p_{elec,i}^{j-1} \leq x^*_{elec}$ with $0 < L \leq m$. Additionally and similarly to the calculation in Hancevic and Lopez-Aguilar (2019), in order to identify potential DAC households, the monthly electricity consumption that would emerge if it were a DAC user is compared with the monthly DAC threshold, C_i^{DAC}. All users who exceed this threshold are considered DAC users. This is shown in the second case of the function in Equation (2).

$$x^*_{elec} = \frac{x_{elec}}{(1+a)}, \tag{1}$$

$$E_{elec}(i,j) = \begin{cases} \check{C}_i^L + \frac{1}{p_{elec,i}^L}(x_{elec}^* - \sum_{j=1}^{L} \check{C}_i^j\, p_{elec,i}^{j-1}) & \frac{x_{elec}^*}{p_{elec}^{DAC}} < C_i^{DAC} \quad \text{Regular user} \\ \text{with } 0 < L \leq m \text{ and } \sum_{j=1}^{L} \check{C}_i^j\, p_{elec,i}^{j-1} \leq x_{elec}^* & \\ \frac{x_{elec}^*}{p_{elec}^{DAC}} & \frac{x_{elec}^*}{p_{elec}^{DAC}} \geq C_i^{DAC} \quad \text{DAC user} \end{cases} \tag{2}$$

3.2.2. Gas Consumption

Household gas consumption values are derived from the quarterly expenditures on natural gas and LPG. Although both energy carriers involve different infrastructures and supply chains, they are used for exactly the same purposes in the Mexican residential sector and can therefore be equated. The monthly gas expenditure, x_{gas} is then the addition of the monthly expenditures on natural gas and LPG, x_{NG} and x_{LPG} (Equation 3). The use of natural gas, however, is limited to cities with a natural gas network. Thus, only households in the regions indicated in SENER (2020) have natural gas expenditure. Yet, it is possible that households in these cities also report LPG expenditure due to the fuel's high flexibility for transportation and storage. Consequently, the monthly gas consumption, E_{gas}, is calculated as:

$$x_{gas} = x_{NG} + x_{LPG} \tag{3}$$

$$E_{gas} = \frac{x_{NG}}{p_{NG}} + \frac{x_{LPG}}{p_{LPG}}, \tag{4}$$

where p_{NG} and p_{LPG} are the retail prices for natural gas and LPG. The retail price of natural gas used in this study is 6.25 USD(2018)/GJ (0.02 USD(2018)/kWh) and corresponds to the average price of all residential distributors for the summer season of 2018 (SENER, 2020). For the case of LPG, two different retail prices are used: 0.54 USD(2018)/L for the refill of stationary tanks and 1.01 USD(2018)/kg for the sale of gas cylinders. Both prices correspond to the national average price reported for the summer season of 2018 (CRE, 2018). Additionally, a calorific value of 13.6 kWh/kg and a density of 0.51 kg/L were used for the energy calculation. This results in an energy price of 0.07 USD(2018)/kWh for the LPG, 3.2 times more expensive than natural gas.

3.3. Energy Burden

The energy burden, EB is computed in Equation (5) where I is the monthly household income.

$$EB = \frac{x_{elec} + x_{gas}}{I} \tag{5}$$

Similar to Kontokosta et al. (2020), rather than defining an energy poverty line, we report the distribution of energy burden values at the national and city-levels. This approach allows the decoupling energy poverty from a national fixed percentage threshold. Furthermore, we classify the level or intensity of energy burden into five classes, from very low to very high and with equal intervals as shown in **Table 2**. In this way, we can easily identify those households that spend proportionately more —and less— of their income in energy services.

TABLE 2 | Classification of levels of energy burden.

Class	Energy burden
Very low	<3%
Low	3–5%
Moderate	5–7%
High	7–9%
Very high	>9%

4. RESULTS AND DISCUSSION

How much energy a household consumes is a key determinant of its energy burden. Therefore, we begin this section with a detailed analysis of the energy consumption of Mexican urban households. We first present a statistical analysis of energy consumption at the national level and then explore variations in energy use derived from households' socioeconomic and geographic characteristics. Next, considering these findings, we analyze the distribution of energy burden for all urban households focusing on disparities by consumption and income level. Finally, the energy burden is spatialized in a subnational analysis that benchmarks 72 metropolitan areas. At this spatial scale, we identify similar consumption and energy burden patterns and point out challenges and opportunities for a better-targeted energy policy toward sustainable cities.

4.1. Monthly Household Energy Consumption

The normalized histograms in **Figure 3** show how energy consumption is distributed among Mexican households for electricity, domestic gas, and their aggregate consumption. The median consumption value is indicated with a dashed line and the legend in each subplot displays its skeweness and kurtosis for a better comparison of the shape of the distributions.

The national median monthly electricity consumption for urban households is 158 kWh (**Figure 3A**). This value corresponds to the summer season and is 7% lower than the average consumption of July, August, and September of 2018 reported by the Federal Electricity Comission (CFE, *Comisión Federal de Electricidad*) (CFE, 2018). Such difference is likely attributable to the uncertainty of the month reported in the ENIGH. While September remains a month of high temperatures in northern Mexico and, therefore, shows a high electricity demand, this is not the case in the central region, where temperatures have already dropped for that time of the year. Due to higher electricity consumption in summer months because of cooling and ventilation appliances, particularly in households with tariff classes 1D to 1F (see **Table 4**), the average monthly electricity consumption is significantly lower than the calculated

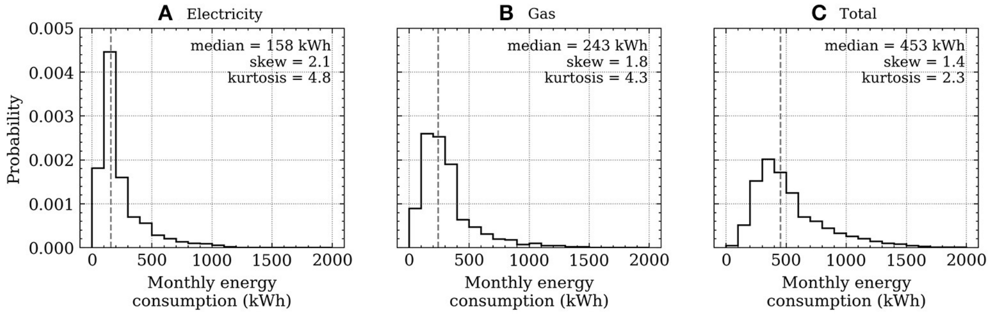

FIGURE 3 | Normalized histogram (solid line) and median (dashed line) of monthly consumption of **(A)** electricity, **(B)** gas, and **(C)** total energy for urban households in Mexico (sample size = 17,850).

value for the summer season; approximately 25% lower according to CFE (2018). In the absence of disaggregated consumption data at the household level outside the summer season, we carry out the rest of the study with these summer values.

Regarding domestic gas consumption in urban households, the national median monthly consumption is 243 kWh (**Figure 3B**). This value includes the consumption of both natural gas and LPG, which corresponds to 16 and 84% of the total observations, respectively. Overall, the median monthly energy consumption of the urban residential sector is dominated by the consumption of gas and reaches 453 kWh (**Figure 3C**). Computed as shares of the total household energy consumption, electricity and gas account for 40 and 60%, correspondingly. These values are similar to the percentages reported for urban households by Franco and Velázquez (2016) of 45% for electricity and 55% for gas use.

Median values of monthly energy consumption already provide a first glimpse of the differences in the amount of electricity and gas used in Mexican urban households. This difference is more noticeable if we compare their distributions in **Figure 3**. We observe that the three distributions are positively skewed indicating that most households are at the lower end of consumption. However, this skewness is more pronounced for electricity consumption (skew = 2.1). The kurtosis value of this distribution (kurtosis = 4.8), a measure of the thickness of the tails, is also the largest of the three distributions. This implies that the electricity consumption of the observed households tends to remain relatively close to the median value, while this distance increases for the gas consumption. Moreover, as illustrated in **Figure 3C**, the total consumption values are more spread out, suggesting that high electricity consumption does not necessarily correlate with high gas consumption.

These differences in energy use raise questions as to which factors are influencing gas and electricity consumption. Are households at the low end of the total energy consumption range meeting their energy needs, or are they potentially constrained by their income? At the other end of the spectrum, are households in the high consumption range victims of circumstance, i.e., trapped in a position of high energy need, or is their high consumption the result of immoderate energy use? To facilitate this assessment, we present further analyses in the following sections looking at how these consumption patterns relate to socioeconomic and geographic factors, and consequently, to the energy burden.

4.2. Assessing Variations in Energy Use

Once the average household direct energy consumption is estimated for each observation, it is possible to investigate the relationship between energy use and factors related to the household and its members. We present three sets of analyses in this section: firstly, the influence of household income in energy consumption is assessed; secondly, four sociodemographic variables namely household size, number of rooms, dwelling ownership, and education level of the household head, are linked to energy use; and thirdly, the impact of the local temperature is evaluated.

4.2.1. Energy Use and Income

Household income data is reported in the ENIGH as the aggregate of the last 3 months prior to the time of the survey. The household quarterly income in MXN is converted into monthly values in USD using the exchange rate 1 USD (2018) = 19.02 MXN. The median monthly income for urban households in Mexico reached 796 USD in 2018.

An initial investigation of the relationship between income and energy consumption indicates that energy consumption tends to increase by income decile. This finding is in line with previous studies (Rodriguez Oreggia and Yepez Garcia, 2014; Franco and Velázquez, 2016; Jimenez Mori and Yepez-Garcia, 2017; Santillán Vera and de la Vega Navarro, 2019). **Figure 4** shows the distribution of monthly household energy consumption as a boxplot and the median income as a dot for each income decile. While each median consumption value is slightly higher than the previous one, there is a considerable overlap of the boxes, whiskers and outliers between deciles. Such overlaps illustrate the broad spectrum of individual practices and actions around domestic energy needs, which are permeated by climatic, social and cultural factors that determine a standard of living or social status (García Ochoa and Graizbord Ed, 2016). Determining whether energy needs for all income levels are adequate or whether these are satisfied is not within the scope of this paper. However, the direct comparison of median energy

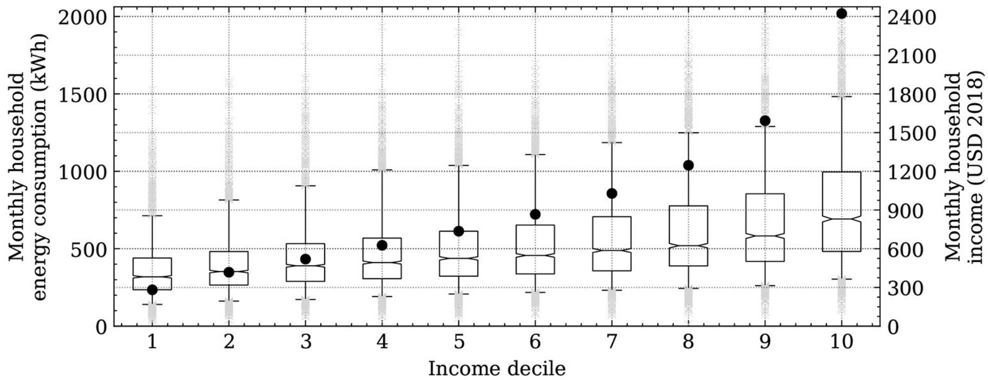

FIGURE 4 | Monthly energy consumption (boxplots) and median income (dots) for Mexican households by income decile.

consumption by income level already yields an insight into the relationship between income and energy use.

The relative difference in median income between deciles is larger than the difference in energy consumption, particularly for higher income deciles (**Figure 4**). Thus, income is not the overall determinant in energy consumption but certainly a relevant one. This finding is in line with the work of Steinberger et al. (2020) that demonstrates that electricity use is highly dynamically coupled to domestic purchasing power but highlights that satisfaction of energy services improves lives only up to a threshold of consumption. Moreover, investments in improving household energy efficiency are usually more common with ascending wealth (Chatterton et al., 2016; Baltruszewicz et al., 2021), potentially decoupling absolute consumption from income as the latter increases.

Similar to Chatterton et al. (2016) in their analysis of energy use for the UK, **Table 3** shows the differences in the median household energy consumption between the lowest and the highest income deciles. In the case of electricity, households in the lowest income decile consume 59% of that in the highest decile. This difference is more evident for gas consumption. Overall, the median energy consumption of the wealthiest households (10th income decile) is more than double that of households in the lowest income decile, while their income is more than eight times higher. The income inequality among urban households is reflected not only in the inequality in energy consumption, but also in the per capita CO2 emissions gap. Santillán Vera and de la Vega Navarro (2019) calculate that in 2014 the CO_2 emissions per capita of the richest 10% were 5.4 times those of the poorest 10%.

TABLE 3 | Differences in the median monthly household energy consumption between highest and lowest income deciles.

	Income USD(2018)	Electricity kWh	Gas kWh	Energy kWh
Lowest income decile	281	125	176	318
Highest income decile	2,422	212	367	692
Ratio lowest decile/highest decile	0.12	0.59	0.48	0.46
Ratio highest decile/lowest decile	8.59	1.69	2.08	2.17

4.2.2. Energy Use and Sociodemographic Variables

We explore the relationship of four sociodemographic variables in **Figure 5**. The first plot, **Figure 5A**, displays the variation of energy consumption depending on the household size. As the number of household members increases, so does the median monthly energy consumption. Even though each household member has specific energy needs, common spaces involving shared or simultaneous energy use dominate the overall household energy consumption. Increasing the size of the household by one person represents, on average, an increase of 18 kWh in the household monthly energy consumption. The level of dwelling ownership, from lent (L) to owned (O1 and O2), shows clear influence in the energy consumption in **Figure 5B**. Dwellings that are owned present the highest median energy consumption values. We observe an average jump of 29 kWh in the household monthly energy consumption between tenure levels. The size of the dwelling, expressed as number of rooms, has an incremental effect in the energy consumption of 33 kWh per extra room as depicted in **Figure 5C**. However, this behavior is not monotonic as from seven rooms on, having one more room does not considerably affect the household energy consumption. Finally, we observe in **Figure 5D** that a higher education level of the head of household results in a higher median energy consumption. We calculate an average increase of 40 kWh/month in the total energy consumption for each education level.

The variables dwelling ownership and dwelling size are directly associated to the household income. The wealthier the household, the greater the probability of owning a house. In any given tenure status, larger houses usually imply higher acquisition and maintenance costs, and therefore, greater purchasing power of the household members. Moreover, according to CEPAL (2018), in Latin America, the level of education is the factor that produces the most significant income differences in the labor market. Therefore, the rising household energy consumption observed in **Figures 5B–D**, can be explained

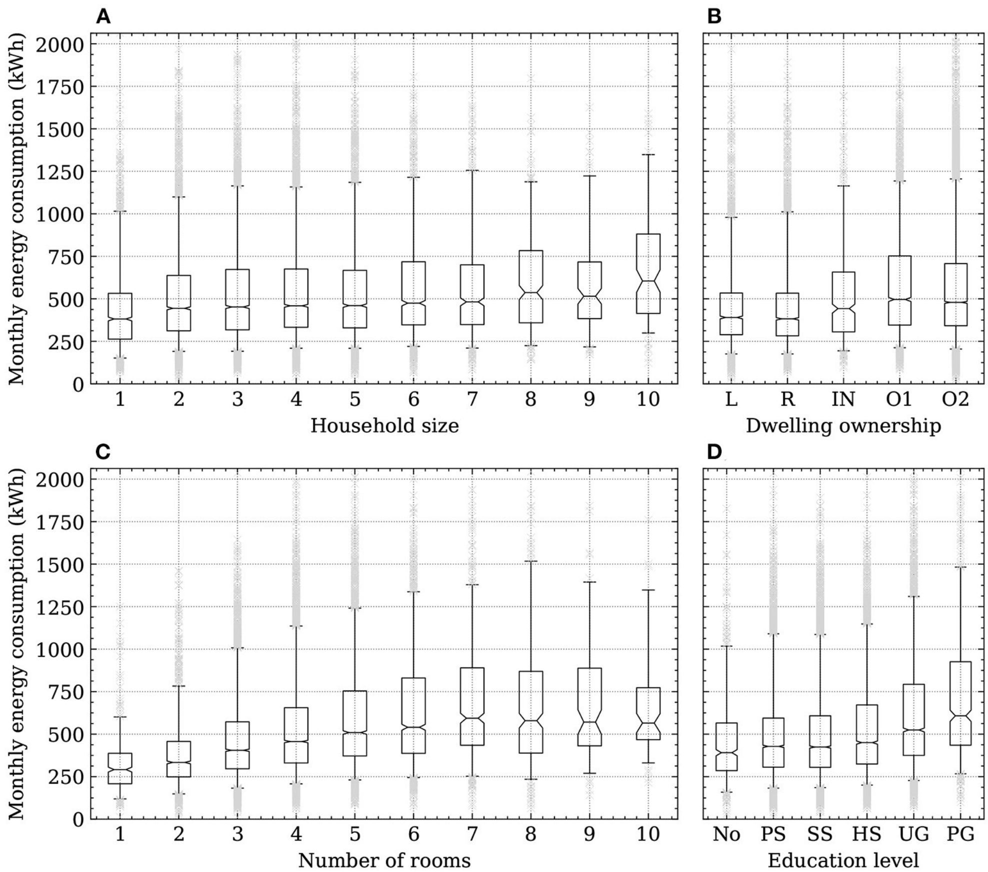

FIGURE 5 | Socio-demographic variables and household energy consumption. **(A)** Number of persons living in the household. **(B)** Status of household ownership: R, rented; L. loaned; O1, own and still paying; O2, owned and paid; IN, intested. **(C)** Number of rooms in the dwelling. **(D)** Completed education level of the household head: no education, PS, primary school; SS, secondary school; HS, high school; UG, undergraduate studies; PG, postgraduate studies.

by an implied increasing income. Yet, similarly to the boxplots in **Figure 4**, it is noticeable that, within the different categories for the four analyzed variables, there are likely to be households that are either well above or well below median household energy consumption values.

4.2.3. Energy Use and Temperature

Climatic conditions, in terms of ambient temperature, influence the use of cooling and ventilation equipment, as well as hot water for showering purposes. **Table 4** shows the calculated median monthly electricity and gas consumption for urban households for different temperature values. These temperatures correspond to the average minimum summer temperature of each regular electricity tariff class.

We observe that electricity consumption tends to increase with higher summer temperatures. Howell et al. (2017) determine a maximum temperature threshold of 26°C for active ventilation systems to operate. This implies that any household located in climatic zones whose average monthly temperature exceeds 26°C requires fans or air conditioning units for their thermal comfort. Certainly, not all households in tariff classes 1B to 1F in the northern and southern parts of the country (see **Figure 1**), own such appliances. González Osorio and Beele (2016) identify that the penetration of active ventilation systems depends not only on ambient temperature but also on the electricity tariff and household income, with the latter being the most influencing factor. Even so, higher ambient temperatures lead to more pronounced thermal discomfort and thus higher penetration of active ventilation systems, which in turn results in a higher residential energy demand. Our calculations show that the median electricity consumption of households located in regions with an average minimum summer temperature of 33°C (tariff class 1F), is 5.4 times that of households in mild climate regions (tariff class 1). Nonetheless, the impact of cooling and ventilation appliances on the national electricity consumption is smoothed since most households belong to tariff class 1 and only 14.7% of the total observations are located in regions with average minimum summer temperatures greater than 30%. This distribution is similar to the reported by CFE for 2018 (CFE, 2018).

Domestic gas consumption, on the other hand, presents an opposite but weaker trend. In general, the use of gas decreases with increasing temperatures. Diego-Ayala and Carrillo-Baeza (2015) show that polyethylene water tanks, usually located in residential building rooftops all over the country, heat the stored

TABLE 4 | Distribution of ENIGH 2018 households per tariff class and calculated median monthly energy consumption by energy carrier; primary energy carrier, i.e., energy carrier that dominates the total energy consumption, and its percentage difference with respect to the secondary energy carrier.

Tariff	Average summer temp. (C)	% of users	E_{elec} (kWh)	E_{gas} (kWh)	E_{total} (kWh)	Primary energy carrier	% diff. w.r.t. secondary energy carrier
1	< 25	46.6	120.8	258.8	390.1	gas	130
1A	25	9.5	136.6	235.3	391.8	gas	47
1B	28	7.2	202.7	243.1	458.9	gas	27
1C	30	21.4	285.2	264.7	569.8	gas	1
1D	31	7.1	320.4	212.7	553.7	electricity	65
1E	32	3.9	474.9	182.3	735.6	electricity	102
1F	33	3.7	652.8	147.0	867.3	electricity	285
DAC	–	0.5	634.9	439.5	1133.2	electricity	54
All	–	100.0	158.1	243.1	453.2	gas	52

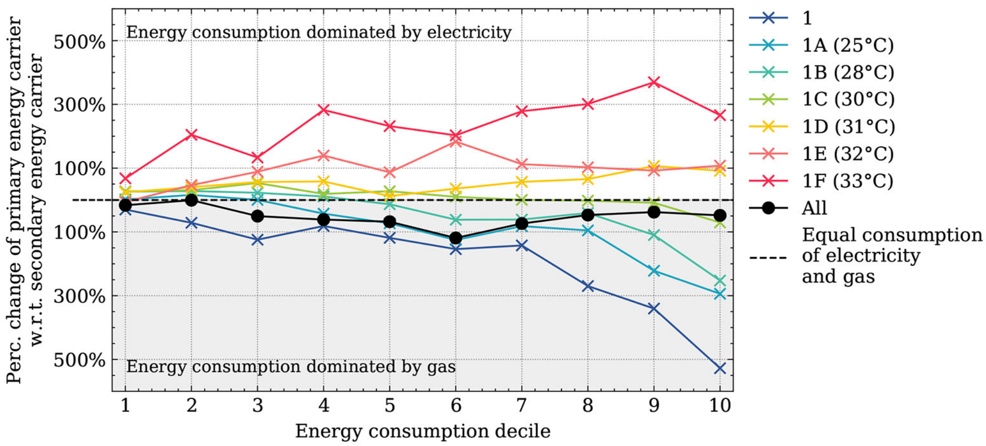

FIGURE 6 | Percentage difference of monthly energy consumption of primary energy carrier with respect to secondary energy carrier by energy consumption decile and electricity tariff class.

water up to 38°C during days with 30°C of average maximum temperature. Therefore, the demand of additional energy sources for heating water, including gas, is reduced.

Energy consumption patterns due to temperature, and thus, to the geographic heterogeneity of the country, are evident. Gas consumption clearly dominates the total household energy consumption for households with mild and warm temperatures (tariff classes 1 to 1C) while electricity dominates it for higher temperatures (tariff classes 1D-1F). The last two columns of **Table 4** show the dominant or primary energy carrier and its median percentage difference with respect to the secondary energy carrier. Households in tariff class 1, for example, consume 130% more gas than electricity. Conversely, electricity consumption of households in tariff class 1F, is 285% greater than gas consumption. Households in tariff class 1C have similar consumption values for both energy carriers.

How dominant is the use of electricity or gas in a household does not depend on temperature alone. **Figure 6** further disaggregates the tariff-based percentage difference between primary and secondary energy carriers in energy consumption deciles. The doted black line indicates an equal consumption of electricity and gas. Above this line, the household energy consumption is dominated by electricity and below this line, within the shaded area, it is dominated by gas. We identify significant differences in how households use electricity and gas depending upon their total energy consumption. The less energy consumed, the more equal is the use of electricity and gas across all tariffs. However, as energy consumption increases so does the difference between tariff classes and thus, the impact of temperature is accentuated. Households in regions with mild climates and in the high consumption range consume up to 500% more gas than electricity, a very different picture than the observed for households in lower consumption ranges.

4.2.4. Summary

Table 5 summarizes the correlation, r, between household energy consumption and the selected economic, sociodemographic and geographic factors analyzed in this section. We observe that household electricity consumption is mainly influenced by ambient temperature (r = 0.64), followed by household income

($r = 0.25$). In the case of gas consumption, household income is the most important influencing parameter ($r = 0.36$) followed by the dwelling size ($r = 0.31$).

4.3. Energy Burden of Mexican Urban Households

Household energy consumption has multiple drivers, as already investigated in the previous sections. This results in a wide range of energy consumption totals, which in turn, translates into varied energy burden values. For 2018, the calculated median energy burden, *EB*, for Mexican urban households is 3.5%. This value is slightly higher than the national average energy burden in the US of 3.1% reported in Drehobl et al. (2020). **Figure 7A** shows the distribution of the calculated energy burden as a normalized histogram. Here, the fraction of households facing a specific level of energy burden are identified by color. We observe that 35% of the total observed households have a very low energy burden, i.e., their expenses on energy services account for less than 3% of their income. An the opposite end, 10% of the households have a very high energy burden as they spend more than 9% of their income on energy bills.

The energy burden in **Figure 7A** considers the current residential electricity tariff system, which allocates a federal subsidy that increases according to the average minimum summer temperature, and decreases with increasing consumption (see **Figure 2**). If a household consumes more electricity than the consumption threshold defined to be considered a DAC user, the household is no longer eligible for the subsidy and is further penalized by an electricity price higher than the actual supply cost. This creates a strong incentive to avoid wasteful consumption. However, the median electricity consumption is well below the DAC threshold for all regular tariff classes as shown in **Table 4**. Here, we observe that only 0.5% of the households in the reduced ENIGH sample are identified as DAC users. This value is smaller than the actual share of DAC users reported by CFE (2018) of 1.2%. In any case, almost all Mexican households qualify for subsidized electricity. We calculate that urban households pay, on average, only 36% of the supply cost. Hancevic and Lopez-Aguilar (2019) and Hancevic et al. (2019) report similar values of subsidy and further calculate that the fiscal burden associated to the residential electricity subsidy represents approximately 0.5% of the national GDP.

Subsidies are often justified as policy instruments to protect the most vulnerable sectors from price increases. However, in the case of universal subsidies, the exclusion error is minimized at the cost of maximizing the inclusion error (Hancevic and Lopez-Aguilar, 2019). In the case of the electricity subsidy in Mexico, the risk of excluding vulnerable households is eliminated at the expense of including households who can afford the actual supply cost. This is observed in the energy burden distribution that results from households paying the unsubsidized electricity price in **Figure 7B**. Assuming an average DAC price 50% above the supply cost (Hancevic and Lopez-Aguilar, 2019), we calculate an unsubsidized electricity price of 0.17 USD(2018)/kWh and apply it for the whole consumption. Our findings show that even without the electricity subsidy, 15% of the households present a very low energy burden. Yet, the share of households with a very high energy burden increases to 34%. This suggests that, at the national level, the current electricity subsidy scheme does alleviate the financial burden, but does so for both vulnerable and non-vulnerable households.

TABLE 5 | Spearman correlation coefficients of household characteristics and household energy consumption; *p*-values are shown in parentheses.

	Electricity consumption	Gas consumption	Energy consumption
Household income	0.25 (2e-123)	0.36 (1e-300)	0.41 (1e-300)
Household size	0.14 (6e-076)	0.04 (2e-008)	0.10 (5e-040)
Dwelling ownership	0.09 (7e-036)	0.13 (6e-084)	0.15 (1e-092)
Number of rooms	0.14 (3e-079)	0.31 (1e-300)	0.30 (1e-300)
Education level of head of household	0.07 (4e-022)	0.16 (3e-100)	0.16 (8e-106)
Average summer temperature	0.64 (1e-300)	-0.09 (4e-034)	0.34 (1e-300)

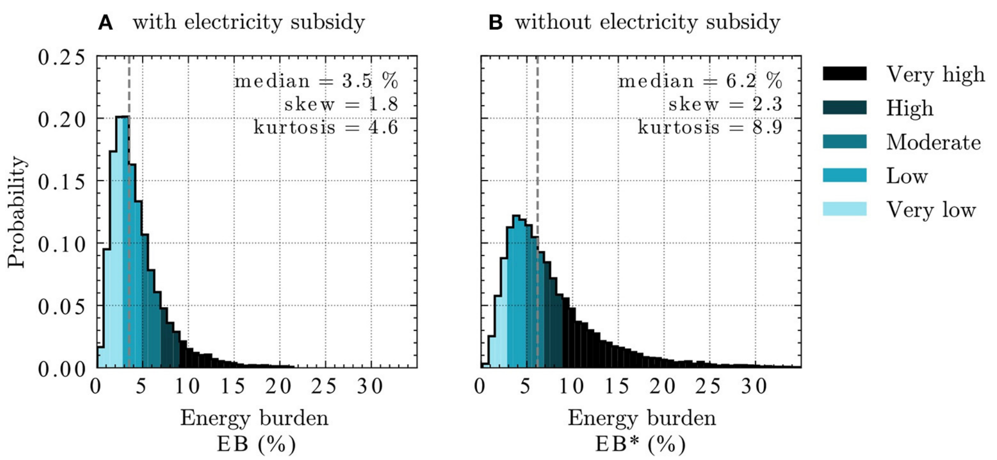

FIGURE 7 | Distribution of energy burden with **(A)** and without **(B)** electricity subsidy. Levels of energy burden are identified by color.

Nonetheless, a more detailed analysis is necessary to characterize the distribution of the energy burden and thus, find out how the benefits of the electricity subsidy are distributed. **Figure 8** shows the distribution of energy burden with and without subsidized electricity among urban households in Mexico by income and energy consumption decile. Each heat map is divided into 100 cells. Each cell clusters the urban households that lie in a specific income and consumption decile and displays three different outputs. The first number is the median energy burden as a percentage. This value is associated to a level of energy burden which is represented with the cell color. The second number, in parentheses, is the share of total households in that particular cell; this number is also a percentage. Adding these percentages per row or column yields 10%. For example, households in the fifth income decile and fifth energy consumption deciles in **Figure 8A** account for 1.1% of the total households and have a moderate energy burden with a value of 4.2%.

There is a significant association between the intensity of energy burden and household income. We observe an inversely proportional relationship between the lowest income levels and the energy burden in both heat maps. This relationship weakens as income increases and strengthens as energy consumption increases. In the case of the energy burden considering the current electricity subsidy scheme in **Figure 8A**, we find that households in the lowest income and highest energy consumption deciles have a median energy burden of 14.2%. A similar consumption value (1,159 kWh/month) represents only 2.7% of the income of households in the tenth income decile, indicating an energy inequality. On the other hand, even the median energy consumption in the lowest consumption decile (194 kWh/month) signifies already 4.6% of the median income (194 USD) for the poorest households and 0.5% of that of the richest households (2 422 USD). Overall, low-income urban households spend 7.3 times more of their income on energy costs compared to the median spending of the tenth income decile (10.7 vs. 1.5%) and 3 times more than the national median energy burden. This inequality becomes more evident in **Figure 8B** which shows the energy burden values without the electricity subsidy. In this case, the energy burden for the poorest households (first decile) ranges from 8.5 to 29.1% while the wealthiest households keep a very low level of energy burden up to the seventh consumption decile.

The fact that low-income households still present very high and high levels of energy burden, even with subsidized electricity prices, demonstrates that the current residential electricity subsidy scheme is insufficient to alleviate energy vulnerability in urban Mexico. Particularly, the very high median energy burdens of households in the lowest income deciles and top consumption deciles in both heat maps, suggest that such households might be trapped in a position of high energy need, possibly driven by the use of active ventilation appliances and the limited agency to reduce their electricity consumption. At the other end, low-income households in the lowest energy consumption deciles might also reflect hidden energy poverty (Tirado Herrero, 2017). Their energy consumption might be potentially constrained by their income, preventing them from meeting their energy needs due to prioritizing more urgent household expenses.

Consequently, low-income households at both ends of the energy consumption range face energy insecurity. This situation can create a negative feedback loop that reinforces social inequality making it extremely hard for such households to break out the poverty cycle (Brown et al., 2020; Kontokosta et al., 2020). For example, the health effects due to constant thermal discomfort and the stress caused by the uncertainty of affording energy bills, reduce productivity and increases healthcare expenses (Drehobl et al., 2020). Moreover, energy insecurity can also result in energy theft. Briseño and Rojas (2020) identify that households with illegal electricity connections to the public network are often located in low-income areas where violence is already a means of covering basic needs.

Additionally, we observe that the widespread eligibility for subsidized electricity has a regressive effect as it benefits those that consume more. In **Figure 8**, the share of households in the top energy consumption deciles increases with increasing income, indicating that the wealthiest households are consuming more energy and therefore, receiving a disproportionate share of the total residential subsidies. Vagliasindi (2013) calculates that Mexican households in the top decile accounted for more than 15% of the total residential electricity subsidies in 2008. A situation that has not improved in recent years (Hancevic and Lopez-Aguilar, 2019; Hancevic et al., 2019).

The very low energy burden values found across almost all energy consumption deciles in the top income decile in both heat maps in **Figure 8**, suggest that the electricity subsidy does not considerably impact the finance of these households. Furthermore, as stated in Chatterton et al. (2016), the large difference between the energy burden of high- and low-income households indicates that expectations or compulsions for households to reduce their consumption might be placed much more fairly on high-consumption households, where high incomes and low energy burdens imply a greater capacity to control their energy consumption. However, distorted price signals due to inefficient subsidies encourage wasteful consumption and mute incentives for users to invest in energy efficiency, to take energy saving measures or to adopt green technologies (Komives et al., 2008; Vagliasindi, 2012, 2013; Sánchez et al., 2018; Hancevic and Lopez-Aguilar, 2019; Hancevic et al., 2019). This is not only economically costly to taxpayers, but also has an important opportunity cost to society and the environment.

The highly regressive nature of the residential electricity subsidies in Mexico has been confirmed in several studies (Komives et al., 2008; Vagliasindi, 2013; Sánchez et al., 2018; Hancevic and Lopez-Aguilar, 2019; Hancevic et al., 2019). The varied energy burden values among urban households in Mexico reflect that inter-household diversity is not adequately considered in the current universal subsidy scheme. Nevertheless, subsidies could be more effectively allocated with policy instruments that fit the segments of target groups. This requires as a first step, identifying target groups and understanding the drivers of their behavior (Egmond et al., 2006). To this end, we compare 72 metropolitan areas and

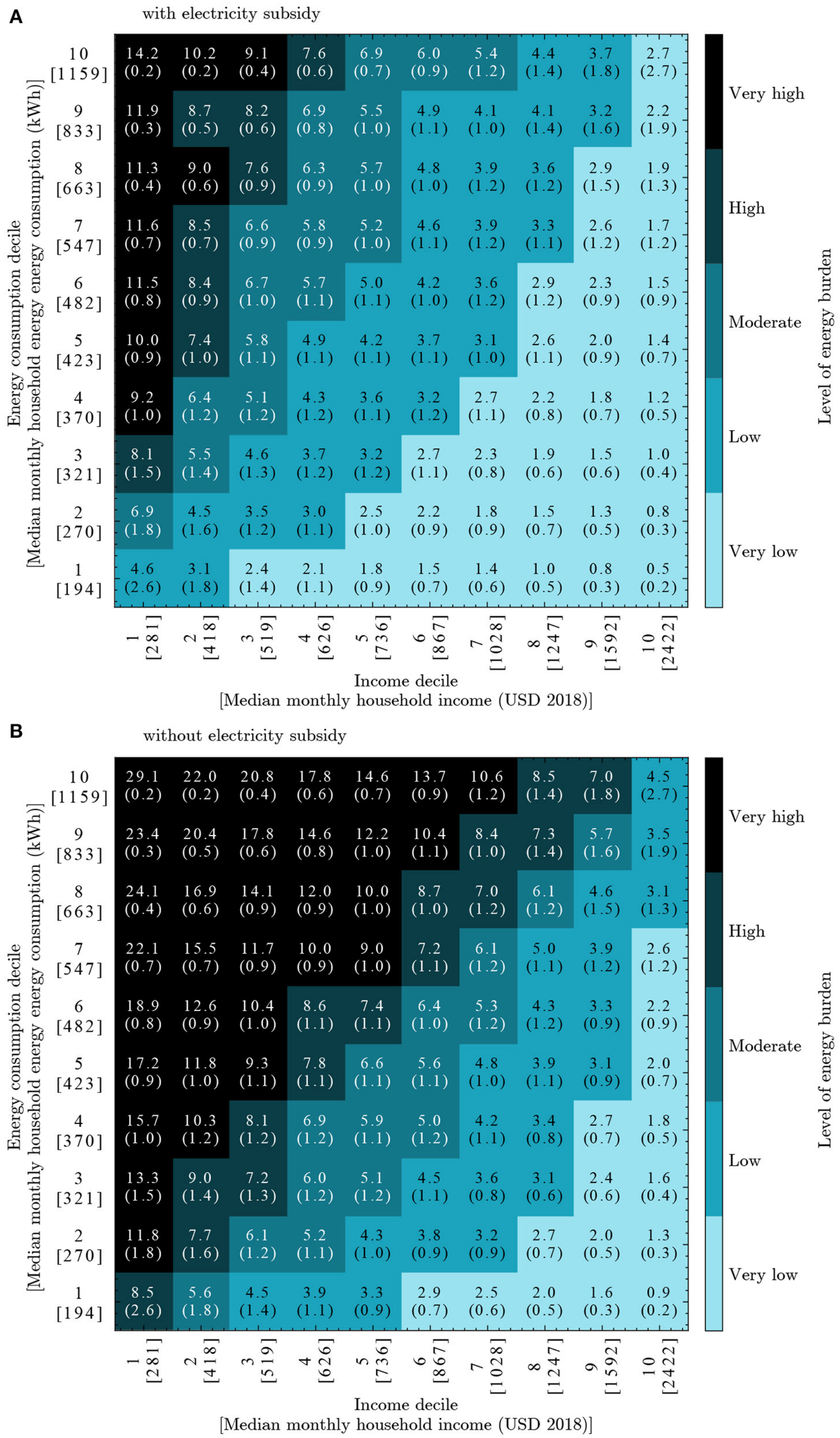

FIGURE 8 | Distribution of energy burdens of Mexican urban households by income and energy consumption decile. Energy burden values and share of population (in parentheses) are displayed as percentages inside each cell. Median absolute values for each decile are shown in brackets for both axes. **(A)** with electricity subsidy. **(B)** without electricity subsidy.

pinpoint patterns of energy use and energy burdens that might be useful to address targeted energy needs and opportunities.

4.4. Energy Use and Energy Burden in Metropolitan Areas

A national energy burden analysis does not account for regional differences in economic characteristics, climate and diversity in energy end-uses (Agbim et al., 2020); thus, analyses at higher spatial resolutions are needed. In this way, we recognize the geographic variation of energy-related (in)justices and its underlying drivers. We select the metropolitan area as the spatial unit to carry out a detailed analysis on energy use and resulting energy burdens as it is often the smallest area with economic, social and territorial cohesion (CONAPO, 2018) as well as the administrative tier of the local government with the principal competence for energy policy (Asaporta and Nadin, 2020).

Figure 9 condenses key information on energy use and the resulting financial burden of covering energy services for households in 72 Mexican metropolitan areas in six charts. The first column displays the median energy burden value, *EB*, in 2018. This value considers the current subsidized electricity tariff. The second column is the median energy burden without the electricity subsidy, EB^*. The median price-cost ratio, P/C, i.e., the fraction of the supply cost paid by households in each metropolitan area, is visualized in the third column. A lower ratio corresponds to a higher federal subsidy. The fourth chart concerns the distribution of urban households by energy burden level and shows the median household income in the upper x-axis. The median monthly energy consumption divided into the corresponding shares of electricity and gas (lower x-axis) along with the average minimum summer temperature (upper x-axis) in the city are shown in the fifth chart. Finally, the size of the city in terms of number of inhabitants is presented in the sixth column. The metropolitan areas are sorted in descending order according to their energy burden, *EB*. Additional details to better understand the spatial picture of energy affordability in Mexico are found in Figure A and Table C in the Supplementary Material. **Table C** in Supplementary Material lists the metropolitan areas along with the distribution of energy burdens across the defined five levels and **Figure A** in Supplementary Material shows the geographic distribution of the energy burden in Mexico.

We observe that most metropolitan areas have a moderate median energy burden. Nevertheless, more than a third of them (27 out of 72) have more than 20% of households facing high and very high energy burdens. Conversely, 90% of the cities show at least 20% of the households with a very low energy burden, and this shares reaches up to 40% for a quarter of the analyzed urban centers. This suggests that one-size-fits-all energy policies jeopardize the government's to ensure a fair distribution of resources and advance energy equity. Instead, there is a need for tailored urban energy strategies that address particular opportunities for improving local sustainable development and energy justice, two agendas that are closely intertwined (Jenkins, 2016).

The five cities with the highest energy burden levels are relatively small cities that also show some of the lowest levels of energy consumption and income. At the same time, two of them, namely, Tehuantepec (20.02) and Acayucan (30.01), have higher than average summer temperatures, indicating that households in these cities are potentially unable to switch on active ventilation systems, despite the high electricity subsidy of 70%. González Osorio and Beele (2016) identify that the penetration of air conditioning units and fans in high temperature regions augments with increasing household income. They show that without economic restrictions, the probability of a household owning active ventilation systems would drastically increase, particularly in the southern part of the country, where Tehuantepec and Acayucan are located (see **Figure A** in Supplementary Material). Therefore, the median low energy consumption in contrast to the high expected electricity demand in these two cities suggests that the median household cannot afford to meet its energy needs. Households in the other three cities in this cluster, Moreolón-Uriangato (11.04), Córdoba (30.03), and Teziutlán (21.03), might be able to cover their energy needs, but their low income might push them into energy insecurity. Poverty alleviation strategies, tailored to the needs of energy-insecure households to avoid getting caught in cycles of poverty, might improve the economic situation, and consequently, the energy burden in these five cities (Bohr and McCreery, 2020).

At the other end of the spectrum, the five cities with the lowest energy burden, namely, Querétaro (22.01), Saltillo (05.04), León (11.03), Aguascalientes (01.01), and Oaxaca (20.01), have a similar moderate energy consumption dominated by gas and an average-to-high median household income. Due to their geographic location (see **Figure 1**), they have a mild climate and therefore, the federal subsidy represents more than 63% of their electricity price. With close to 80% of the households in these cities with low energy burdens, electricity subsidies could be reduced by, for instance, decreasing the DAC threshold or adjusting the consumption blocks (Sánchez et al., 2018). Except for Oaxaca, these cities host close or more than one million inhabitants. Therefore, there is a significant saving potential of federal budget that could be directed to other sustainable development goals.

Moreover, given a reformed residential electricity tariff with a focus on reducing energy vulnerability, households in metropolitan areas with above-average energy consumption and incomes, like Guaymas (26.01), La Paz (03.01), Chetumal (23.02), Chihuahua (08.01), Monterrey (19.01), and Cancún (23.01), are likely to have a greater ability to undertake action to reduce their energy consumption and energy burden given their greater level of financial freedom. Chatterton et al. (2016) suggest that such users also share structural factors such as control over their housing, either through ownership or because they live in a house rather than an apartment, that can potentially unlock greater willingness to take up energy efficiency measures or invest in clean energy technologies. This could trigger a faster market development of solar photovoltaic panels and solar thermal collectors, which according to Báez Fumero and Molar-Cruz (2021) is still unexploited despite the vast solar potential in Mexico. The use of large-scale renewable energy in urban environments is a concrete solution to promote sustainable

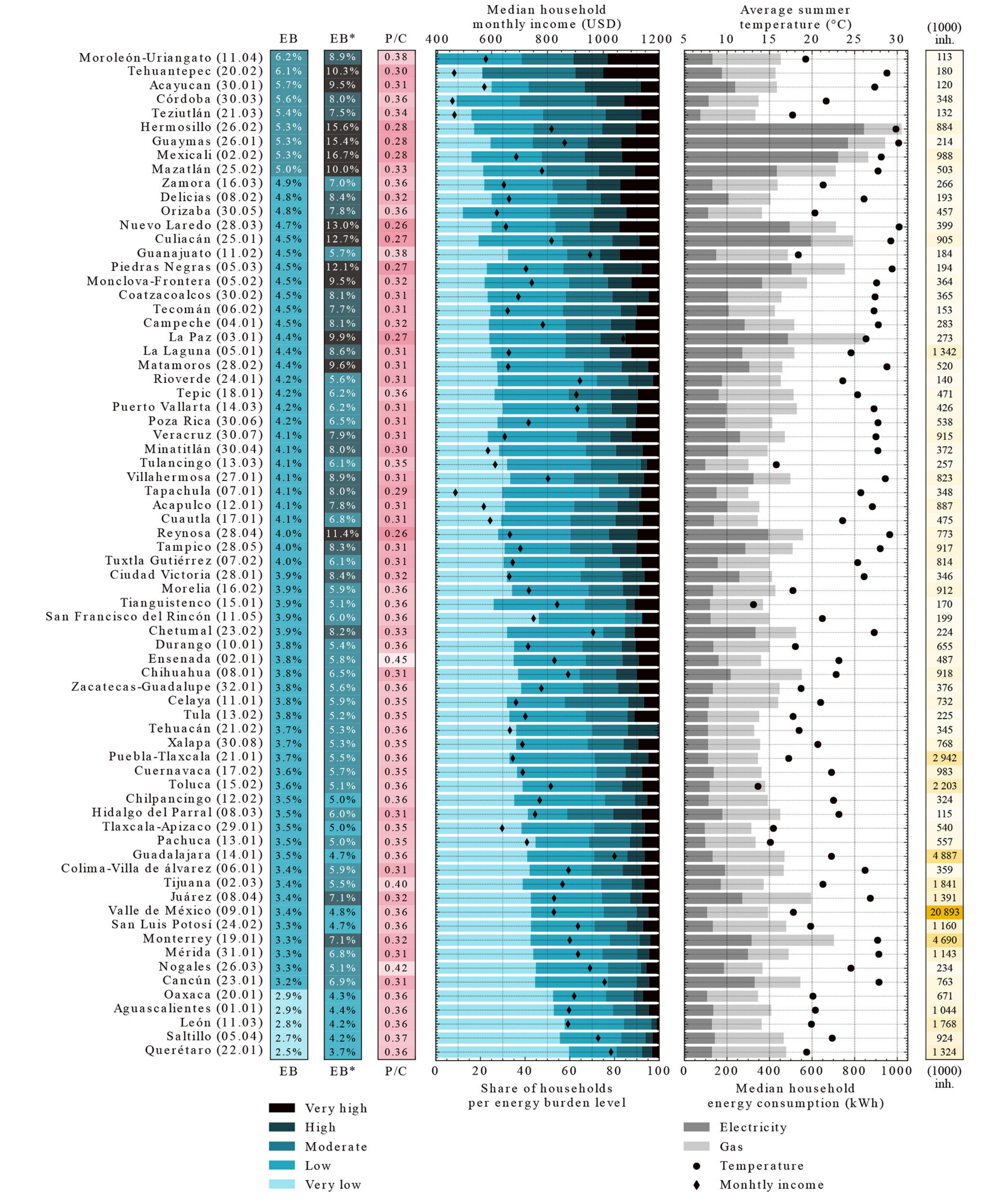

FIGURE 9 | Energy burden with and without subsidy, electricity price/cost ratio, distribution of energy burden, household income, energy consumption, average minimum summer temperature, and population of 72 metropolitan areas in Mexico.

development, as it maximizes economic opportunities while minimizing the impact of urban energy demand by reducing CO_2 emissions.

The metropolitan areas with the highest median household electricity consumption are Hermosillo (26.02), Guaymas (26.01), Mexicali (02.02), and La Paz (03.01). These cities are located in hot climatic regions and consequently, receive some of the highest subsidies paying only 28% of the actual supply cost. In spite of their low electricity price and because of their high electricity demand, Hermosillo, Guaymas, and Mexicali still have a high energy burden. More than 10% of the observed households have very high energy burdens and an additional 15% face high burdens. Nevertheless, their resulting energy burden without considering a subsidized electricity price, would surpass more than 15% of the median household income. This indicates that the temperature-based residential subsidy scheme is actually effective in these cities. However, better-targeted energy-efficiency programs might help reduce the electricity consumption of, for example, active ventilation systems and thus, lessen the fiscal burden due to the electricity subsidy. Hancevic and Lopez-Aguilar (2019) show that a national energy efficiency improvement program could reduce the residential electricity consumption by 9.9%, decreasing the associated expenditure by 11.3%.

La Paz (03.01), on the other hand, shows a high consumption of electricity and gas. Even though this city shows the highest median household income, its energy burden reaches 4.4%. Gas use is mainly associated to cooking and hot water, with the latter being usually the highest energy consumption activity. The inversely proportional relationship between the increase in ambient temperature and gas demand for water heating purposes (see Section 4.2.3) suggests that households in La Paz might be consuming energy, particularly gas, immoderately. This might be the result of wealth and cultural conventions that determine a standard of living or social status.

The transition toward sustainable cities requires the evaluation of current energy policies to reshape the established patterns of energy supply and energy use. The analyses above highlight that one-size-fits-all energy policies, particularly, the Mexican residential electricity subsidy, are not effective as they usually miss evident problems and solutions. Nonetheless, the design and implementation of energy policies toward sustainable development at this spatial level would require a new sampling and survey for each city to ensure the representativeness of the results.

5. CONCLUSION

This work presented an overview of the distribution of the energy burden, i.e., the percentage of household income used for energy expenditures, in urban residential Mexico. Using three publicly available data sets, namely the National Survey of Household Income and Expenditure (ENIGH) of 2018, the Digital Atlas of Mexico and the Urban National System, we calculated the consumption of electricity and gas, as well as the resulting financial burden for paying for these services for 17 850 households in 72 metropolitan areas.

The median monthly consumption of urban Mexican households in 2018 reached 158 kWh for electricity, 243 kWh for domestic gas, and 453 kWh for both energy carriers. However, we observed a large inter-household diversity. We found that the variations of energy use are mainly influenced by the household's income and temperature. Households in the top income decile consume 2.17 times as much energy as households in the bottom income decile. Moreover, households in the electricity regular tariff class 1F (minimum average summer temperature $\geq$33°C) consume 2.22 times as much energy as households in the regular tariff class 1 (minimum average summer temperature $<$25°C). Our analysis showed that the energy consumption for households located in the warmest regions is dominated by the consumption of electricity due to the need for active ventilation systems, whereas gas is the primary energy carrier for households in temperate regions, which comprises the majority of the urban households.

How much energy a household consumes is a key determinant of its energy burden. However, so is the price of energy services and, certainly, the household income. For 2018, the calculated median energy burden for Mexican urban households was 3.5%. We analyzed the role of the current electricity subsidy and found that it does alleviate the financial burden of electricity services. However, it does so for both vulnerable and non-vulnerable households, thus resulting in an inefficient mechanism that is not only economically costly to taxpayers, but also has an important opportunity cost to society and the environment.

Our analysis of the distribution of energy burdens across income and consumption deciles demonstrated that even with subsidized electricity prices, the temperature-based electricity subsidy scheme is insufficient to alleviate energy vulnerability in urban Mexico. This is confirmed in the analysis at the city level where more than a third of the 72 metropolitan areas analyzed presented more than 20% of households facing high and very high energy burdens. On the other hand, our calculations showed that 90% of the cities had at least 20% of the households with a very low energy burden ($<$3%), and this share reached up to 40% for a quarter of the analyzed urban centers. Even without the electricity subsidy, 15% of the urban households in Mexico would still have a very low energy burden.

The transition toward sustainable cities requires the evaluation of current energy policies to reshape the established patterns of energy supply and energy use. Tailored urban energy strategies that address particular opportunities for improving local sustainable development and energy justice must be at the core of this transition. Therefore, we identified evident problems and possible solutions at the city-level, as strategies at this spatial scale could better address the particularities of households and take advantage of the economic, social and territorial cohesion of the city. However, this is only the first step, as future research toward the design and implementation of such strategies require analysis at an even higher spatial resolution to capture the intra-city household diversity.

An analysis of the distribution of energy burden already provides valuable information on the affordability of energy services. However, this indicator does not cover all dimensions of the agendas of sustainable development and energy justice. Further efforts to create city databases that allow for a more detailed analysis of the dynamic urban system are key to drawing a more complete picture of the urban energy system. Only in this way can we develop just energy policies that are as targeted as possible to exploit as many opportunities as possible to improve urban sustainability.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

AM-C: conceptualization, methodology, investigation, validation, formal analysis, visualization, writing–original draft, supervision, and administration. SH: methodology, software, data curation, visualization, and writing–original draft. TH: resources, writing–review and editing, and supervision. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2021.662968/full#supplementary-material

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