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PERSPECTIVE

A seat at the energy table

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Abstract

Energy injustice persists due to the difficulty of meeting competing interests in a rapidly evolving system. Transformative energy technologies need to fit into existing structures while also improving upon those systems. To aid in complex decisions, this paper provides a simple checklist of four necessary and often missed concepts for energy justice. Energy choices should be *Supported, Environmental, Affordable*, and *Tolerable* to provide everyone a SEAT at the energy table, in other words to promote energy justice. For the purposes of this framework, *supported* indicates that supply chains and infrastructure to meaningfully participate are available, *environmental* considerations cover climate change and health-affecting pollutants as well as disposal affecting soil and water, *affordability* rather straight-forwardly requires equal economic access to the energy transition, and *tolerable* requires personal and political buy-in. This structure is intended to aid anyone that makes decisions, i.e. not only highly specialized academics. Many technologies that address one or two of these concepts are touted as solutions to injustice, but without additional structure, they may have disbenefits in other areas. By using a simple structure to illuminate this consistent difficulty, future research and policy will be better able to promote true justice instead of tangentially addressing it in ways that fail to capture the complexities of the system. The tension between benefits and unintended consequences is explored for several energy technologies at varying stages of implementation, including electric vehicles, cooking, time-of-use pricing, and air conditioning. Existing policy mechanisms that have tried to address only some barriers have not necessarily resulted in an equitable transition. This indicates that equity needs to be considered explicitly, and that all four chair legs need to be evaluated. This method highlights the principles most easily considered in non-specialist decisions and maps them to concepts that are easy to grasp.

1. Introduction

In research discussions with colleagues, two clarifications have become quite repetitive. Across broad collaborations, justice is a topic that everyone has heard of but frequently has only a hazy concept. Meanwhile, in more specialized groups, an explicit definition of the umbrella of energy research may be required. For the latter, we will consider it as 'nearly everything', as all human activities require energy in some form. Energy justice, and the connected terms environmental and climate justice, are also broad enough to affect research and policy across disciplines [1]. Therefore, it is important for everyone involved in research or policy work, or anyone who makes decisions, to have at least a cursory understanding of energy, environmental, and climate justice. This paper introduces some of the important aspects of each through a decision-making framework to identify Supported, Environmentally beneficial, Affordable, and Tolerable energy choices. These four tenets can be remembered as the legs supporting a SEAT, such as a 'seat at the table' for everyone in a just society. The goal of this paper is to introduce a framework for decision-making that can be used to guide questions for decisions at a variety of levels, including policy making, community interventions, and consideration of infrastructure permitting.

Energy directly affects transportation decisions, appliance purchase and use, the cost of products (including their transportation), and considerations of comfort and lifestyle. Highly specific energy research spans many disciplines, and systemic energy investigations include energy demands at the residential, commercial, industrial, and even national scale. However, due to the tendency toward academic silos, justice and fairness are not always well integrated into energy evaluations [2]. While projects may satisfy a minimum criteria established for equity considerations, such analyses often rely on utilitarian assessments or fail to account for all factors [3–5]. Rarely do energy ventures and applications consider distributive justice where the most marginalized are prioritized [5, 6]. Also, most of these decisions are made from the top-down approach without consulting communities being impacted in the development of various programs and policies [7] or ensuring that targeted populations are reached [8]. Enabling individuals and communities to create real opportunities for their functionings such as fresh air or comfortable indoor temperatures can improve the agency in determining justice and improve energy efficiency and sustainability [9]. To draw key constructs from distributive justice [9] in addressing energy poverty, it is critical to remove socio-economic and environmental barriers and promote political decision-making that establishes energy's SEAT at the table. Using the framework makes it easier to undertake the critical process of evaluating multi-dimensional perspectives and ensuring that all factors have been examined. Yet, there's a gap in energy evaluation frameworks that provide a basic structure to consider various conflicting perspectives that may arise to address injustices. The SEAT framework attempts to promote something simple enough to be practical while still addressing the complex inter-relationships that are not addressed by many equity adjustments reserved for the penultimate stage.

Each energy choice affects pollution, social consensus, and costs. These changes ripple out and affect many more people than just the decision maker. Justice requires consideration of the wellbeing of all involved [10]. One way this is accomplished is through evaluating the accumulation of stressors toward groups of people. Some of the dimensions across which people are grouped to determine whether burdens are unequally distributed include race, income, gender, and social environment. The social environment may refer to neighborhoods having previously been subject to explicit segregation or people having been given limited access to physical, economic, or social mobility. It is important to consider a multifaceted definition of justice [11]. Recent analyses [12, 13] have shown that considering a single metric when evaluating the equitability of a project may exacerbate inequality across a different axis. Discussions around equity in energy involve three interrelated concepts: environmental justice, climate justice, and energy justice.

Environmental justice refers to a broad range of quantitative observations that indicate that exposure to pollution is not equal across social variables [14]. This pattern is true both at local scales as well as globally where nations are affected differently. Many pollutants are released from energy-related processes, connecting ambient environmental conditions back to energy. Environmental justice investigations consider how the change in these burdens is not spread evenly across all individuals, and frequently hinder those that are already marginalized. The traditional example of this is industrial sources of emissions being more likely located in neighborhoods populated predominantly by people of color [14]. More recently, a subset of environmental justice has focused on climate justice. Climate justice is similarly concerned about the extent to which populations that are already experiencing burdens are more likely to suffer due to shifts in climate. Examples of this include many disadvantaged cities and countries being vulnerable to sea level rise and hurricane damage. Climate justice in particular also invokes discussion about future generations as a population group to consider [15]. Again, the emissions that contribute to climate change are generally tied to energy use. These emissions will be generally considered in the environmental leg of this framework.

While environmental and climate justice tend to be focused on the unintended effects of energy choices, there are also considerations of equity surrounding energy itself. Many discussions of energy justice focus on energy supply [16], or whether the choice is *supported*. Energy justice generally focuses on ensuring the ability to provide for energy-related needs now and into the future [17]. It is concerned with whether the processes, programs, and policy-making are fair and just. Most of our basic needs require energy, so multicultural survival depends on equitable access to energy. Food, one of our most basic needs, depends on energy for cooking. In addition, twenty-first century society requires electricity for nearly everyone to complete payments, communicate, and access knowledge. For the discussion of justice in the energy transition here, we will consider all three categories-energy justice, climate justice, and environmental justice-through consideration of supported, environmental, affordable, and tolerable energy choices.

2. A Supported, Environmental, Affordable, and Tolerable SEAT

The intersection of such broad justice-related topics has created tension through well intentioned mechanisms intended to level the playing field. Given the complexity of these interactions, there is benefit in a simple mnemonic framework that can simplify the decision-making process when evaluating the

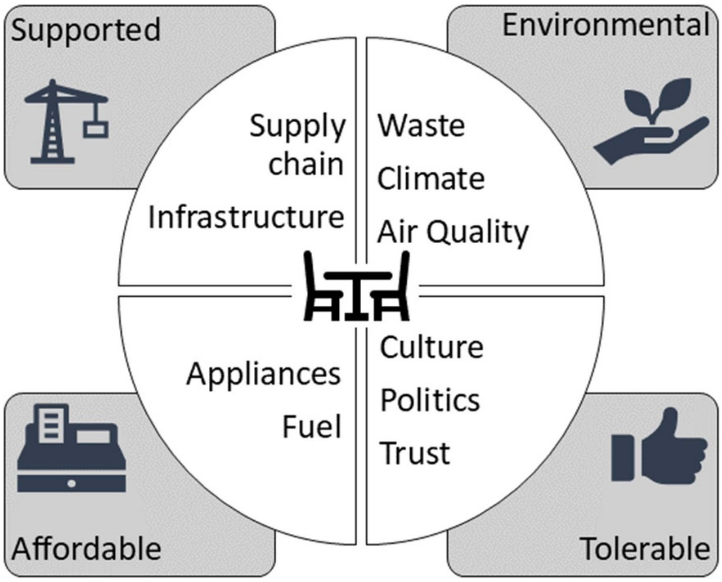

Figure 1. Common barriers to energy justice for each category in the framework, represented as loads on four chair legs. Considering whether an energy choice is supported, environmental, affordable, and tolerable will give everyone a SEAT at the table.

equitability of a program, project, technology or policy. Considering four critical factors: supported, environmental, affordable, and tolerable (SEAT) could provide a simpler framework in energy justice considerations. These four constructs provide checklist to considerations of distributive justice when initiating programs, projects, or policy. Due to the nature of a transition, the specific information available for each decision is still evolving [18, 19], and additional research is needed to continue to improve this field.

The decision-making tool described here derives from prior energy justice discussion [10], but leverages the increased awareness of the issue to present a simplified checklist to guide discussion. *Affordability* continues to be a high priority in making decisions regarding energy justice, and more independent than some other factors. We have collapsed some of the other considerations to better represent the interconnectedness of those decisions. Availability is one element of *supported* energy, but this leg of the chair really rests on large scale institutional support that also encompasses intragenerational and intergenerational equity. While there are strong arguments for more directly calling out these effects, their effects are felt in a similar manner. Many decision makers are already unclear about the delineation between sustainability and responsibility, therefore providing a simplified *environmental* descriptor reduces cognitive effort in separating them and ensures that the principle is covered. While good governance and due process contribute to *tolerability* of energy choices, this chair leg is expanded from the previous framework to not only ensure informed decision making, but also that the choices available actually meet the needs of society. This piece describes a tool to ensure that distributive justice is centered when addressing energy poverty, through policy or program assessment, implementation, intervention, or evaluation. Use of this framework will ensure that all voices, contexts, and perspectives are represented in every step of the process.

While consideration of equity in the larger energy system is necessary, most decisions are made focused on a subset of the system. Therefore, this method highlights the principles that are most easily considered in individual decisions, and maps them to concepts that do not require specialist knowledge to grasp. Each principle is described below, and common obstacles for each category are identified in figure 1. A non-exhaustive list of questions to identify relevant barriers to each category are presented at the end of the relevant subsections.

2.1. Supported

The first consideration should be to ensure that underlying systems to access energy are supported. In particular, energy justice requires an ability for all humans to access a reliable energy source that will meet their technological needs. Technological needs include the increasing necessity of internet connectivity as well as climate adaptation measures that reduce exposure to extreme temperatures. People across the globe have experienced or prepared for short or long term inability to stay warm or cool enough to remain healthy and avoid food spoilage. Examples include an energy crisis throughout Europe [20], a days-long power outage in parts of the US in 2021 [21], and millions of people across the African continent without electricity access at all [22]. Supported considers the supply chain of primary energy sources and ancillary technologies as well as the reliability of those supply chains and transmission mechanisms. Additionally, energy solutions must be something that can be implemented. If an energy solution would require significant infrastructure changes, provision needs to be made for those upgrades as part of the transition. For instance, energy efficiency and indoor air quality are frequently promoted through improved air conditioning (AC), insulation, and cooking systems, but these require alterations to residential structures. If the affected residents are not homeowners or there are other barriers to construction upgrades [23, 24], then adopting new energy technologies is not accessible to those residents. Housing quality issues beyond the issue at hand may present either legal or logistical barriers to improvements [25]. The split incentive problem is well known in promoting energy efficiency [24], but can affect energy justice in additional ways [26]. Even if the technology itself is affordable and accessible, the lack of support for auxiliary technology may create a barrier to access. If the necessary support structure is within the realm of authority of the decision maker, then this can be addressed coincident with the other parts of the energy transition.

Questions to ask when trying to understand whether a proposed technology (or policy supporting said technology) is *supported* include:

- Is the solution a modular replacement or will larger changes be required?
- How robust is the supply of fuel or energy that this technology will use?
- What changes to physical infrastructure will be required to use this technology?
- Who has (or does not) the authority to implement the required upgrades?
- How will this technology or practice integrate into existing systems?
- Will the maintenance needed be similar to existing paradigms?
- Is there available training capacity to deploy and implement new technology?

2.2. Environmental

Both systemic energy choices as well as individual decisions affect the release of pollutants to the environment. Air pollution is very unevenly distributed, and in the US the largest exposure disparities are found when comparing across racial and ethnic boundaries, not income [12]. Air quality, both outdoors and in, should promote the health of all people and allow them to fully participate in life activities. Beyond immediate health effects, energy-related greenhouse gas (GHG) emissions to the atmosphere are also the overwhelming driver of climate change [27] based on the definition of energy provided above. Climate change has the potential to exacerbate energy inequality by altering the demand for energy and can instigate an additional category of injustice associated with changes in resource availability, disaster resilience, and cultural stability [15]. Energy related resource extraction and disposal also affect geological and hydrological systems through runoff, mining, and landfilling.

Poor air quality restricts the daily activities of local residents [28] including negatively affecting the health of athletes [29, 30] and altering travel paths [31]. Although many current policy proposals intend to address inequities in air quality through overall emission reductions, it is not a guarantee that equity will be improved [13]. Even information about air quality is unequal [32]. Each change in emissions contributes to a complex system of sources, sinks, and transformations of atmospheric compounds. Through global circulation patterns, these emissions affect the health and climate of communities located in the immediate vicinity of the source as well as those further away. It is not even a necessity that climate and air quality policy are redundant [33, 34]. For example, biomass combustion has been discussed as an opportunity to promote energy expansion through a carbon-neutral renewable resource, but even carbon neutral combustion has negative effects on local air quality. There are existing tools for evaluating the atmospheric emissions of energy choices [35–41] and those should be incorporated into decision making.

Questions to ask when trying to understand whether a proposed technology (or policy supporting said technology) is *environmental* include:

- What lifecycle emissions changes would be instigated by the change? (both GHG and local pollutants)
- Are emissions primarily located near the user or others?
- Are any lifecycle emissions located near historically oppressed communities?
- In what locations are health-relevant emissions increases located? (same for decreases)
- What resource extraction and end-of-life processes will change?
- Are there proposed solutions to waste issues?
- Has disposal or refurbishment of existing technology been considered in the transition?

2.3. Affordability

Even if an energy technology is widely available and environmentally friendly, affordability can also be a significant obstacle [42–44]. Justice cannot be reached if a lack of affordability constantly keeps a group of people from accessing the necessary resources. Even if high performing, low emitting technologies are distributed broadly with a strong associated infrastructure, if those technologies are only affordable to a subset of the population, the transition will not improve justice. Money can be an obstacle at multiple stages of a technology. For some technologies the initial cost is so high that some people never have the option to adopt it. For other technologies, ongoing fuel costs may lead to a decline in use of the technology. Some attempts to improve energy access have provided equipment for households to use, in an attempt to remove the initial barrier to access. However, if the fuel costs are high, the equipment may not be used and therefore equity will not be improved. While it is true that the cost of many energy technologies decreases over time along a technological learning curve [45–48], enabling an equitable transition requires an analysis of the distribution of benefits. During the transition from technology development to adoption, there may be opportunities for initiatives to address the initially high cost of a new technology.

Questions to ask when trying to understand whether a proposed technology (or policy supporting said technology) is *affordable* include:

- What is the initial cost to adopt the technology?
- What fuel and maintenance costs are associated with its use?
- Can policy initiatives help address affordability concerns?
- Will associated behavior changes incur additional costs?
- Do proposed policy initiatives account for costs across the technology life cycle?

2.4. Tolerable

Another issue in the energy transition is acceptance or tolerability of the options. New technologies or policies need to be tolerable to potential adopters to actually be used and implemented. Consideration of context is a necessary factor when developing engineering solutions [49]. Resistance to technology adoption has been observed for a range of technologies, from cookstoves [50] to compact fluorescent lighting [51]. These examples show that both purchasers and users of a product must buy-in for successful implementation. At a higher level, many energy shifts are reliant on policy changes, either to expand infrastructure, legalize technologies, or adjust economic drivers. Thus, the energy transition will require acceptance from both consumers and policy makers. Another hinderance to tolerability is distrust in information. In a society where misinformation has been a hot topic, attempts toward environmental justice have their own brand of the tactic. While a diverse set of definitions of the term greenwashing exist [52], it has been shown to negatively affect consumer confidence in green products [53, 54]. This can increase reluctance to shift technologies.

Questions to ask when trying to understand whether a proposed technology (or policy supporting said technology) is *tolerable* include:

- How does the proposed solution compare to the current paradigm?
- What features are added or removed in the new technology compared to prior options?
- What aspects of the current technology are important to consumers?
- What policies might be required to enable or support adoption?
- Does the wording of existing policies present any obstacles to adoption?
- What communication might clarify features for consumers or adopters?

Existing policy mechanisms that have tried to address only one or two of these criteria have not necessarily achieved an equitable transition [5, 55]. This indicates that equity needs to be considered explicitly and broadly. These principles can be applied to any project attempting to improve energy justice in the energy transition, which should be every project. To further elucidate this framework, it has been mapped to several examples below and in table 1. These are instructive examples of how to structure the exploration and should not be considered an exclusive list of issues to which the framework can be applied. None of these issues constitute an insurmountable obstacle, and the potential conflicts will be presented alongside suggestions for solutions.

3. Explorations of energy justice

The interaction of the legs of the SEAT is explored in current selective, but not exhaustive examples of the energy transition using electric vehicles (EVs), AC, cooking, and electricity pricing. These examples represent mainstream energy discussions or are in the forefront of becoming mainstream resources in North America. This article is presented with a largely North American centered perspective, but the principles can serve as the foundation for a wide range of decisions. Examples for the Global South will be expanded in a

Table 1. Examples of concerns for elements of the energy transition as well as suggestions to expand energy justice for these decisions.

	Barriers				
	Supported	Environmental	Affordable	Tolerable	Suggestions
Electric Vehicles	Charging infrastructure	Some improvements mixed with problems	High initial cost	New paradigm with pros and cons	Enable additional transportation options; Establish subsidized charging infrastructure.
Air Conditioning	Home renovation & ownership	Increased emissions	High cost energy bills	No barriers	Urban design can reduce overall need. Provide access to cooling centers
Cooking	Kitchen size & home renovation	Indoor combustion increases exposure	Appliances can be expensive	Strong cultural importance of food	Holistic policy design considering split incentive & direct community engagement
Electricity Pricing	Information gap and technical ability to respond to signals	Improved only if addressed explicitly by the pricing design	Price increases affect energy burdened households	May add other lifestyle burdens	Pricing should account for existing energy burden. Objective should be to minimize emissions.

forthcoming article. The 'legs' to consider are the same in both contexts, and the general category of decisions are similar: the cultural touchstone of food shows up in both contexts as do changing transportation paradigms. The specifics of the decision making process vary based upon local conditions and resources, so the discussion is separated to appropriately target decision makers based on the region with which they most identify and ensure the examples are simple enough for the broad and interdisciplinary audience to which the discussion is targeted.

3.1. EVs

The tension between the potential benefits and disbenefits of EVs are frequently discussed [56], even beyond the realm of energy scholarship. The associated changes, summarized in figure 2, have several implications for equity. It is fairly well understood that *affordability* is a major obstacle to improving justice through EV adoption. Even if life cycle vehicle costs are lower, the initial capital cost of a vehicle is significant in comparison to household income [57]. This changing cost structure can exacerbate inequities. Additional barriers to a *supported* system include difficulty in charging the vehicle, especially for renters [58] and those without reserved parking. As we will see with many examples, ability to modify existing structures at any scale is a potentially significant barrier. In addition, possible redistribution of emissions from vehicles to electricity generation may exacerbate the inequalities in pollutant distribution [35, 58, 59]. When EVs replace combustion vehicles they improve near road air quality, which is likely to reduce exposure to pollution. Traffic related pollution has been shown to have highly localized health effects, which indicates that reducing the direct emissions in marginalized neighborhoods may have a beneficial justice effect [60]. However, depending on the electricity generation system in the area, there could be potential disbenefits to communities further from the roadways where the new vehicles are driven [44]. The batteries used in EVs also present multiple *environmental* challenges [61]. There are serious equity considerations in the resource extraction of the necessary materials to create lithium ion batteries (the currently predominant technology) that affect both the *environment* and ability to *support* EV growth [62, 63]. *Tolerability* of the vehicles also could lead to unequal adoption if the EVs do not meet the needs of all people. Range anxiety is one of the most commonly discussed hesitations, although advancements are being made in this area [44]. EVs have the potential to address energy justice concerns, but it will require a coordinated policy effort across several sectors to achieve these possibilities [37, 38, 64–67]. Although a newer development, the introduction of connected and autonomous vehicles may exacerbate the above-mentioned issues [64–66]. Expansion of public charging, continued reduction in emissions from electricity generation, and technology developments to reduce cost, increase range, and diversify battery technology will all be required for equitable EV adoption. Moving forward, consideration of unintended consequences in transportation should inform infrastructure and policy decisions. Enabling additional transportation modes, outside of private vehicle ownership, could help overcome potential issues of affordability and increased emissions through efficiencies in the economy of scale. However, expansion of public transportation should still consider the legs of the SEAT, as such systems still risk design choices that exacerbate inequality.

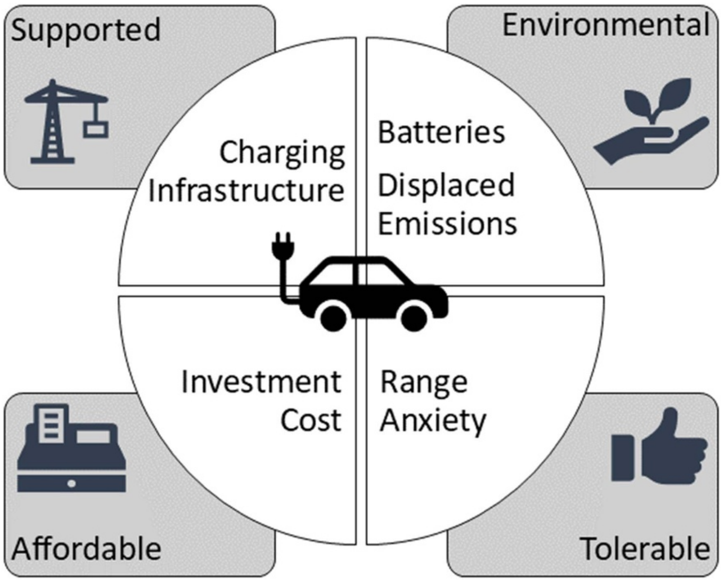

Figure 2. A schematic example highlighting obstacles to just vehicle electrification using the SEAT framework. A tolerable option would provide transportation that works within other lifestyle demands, such as trip distance. An affordable solution should be within reach of all target groups. There is a breadth of literature on the range of possible emissions to the atmosphere and the effects of mining rare earth metals. Support may require infrastructure changes depending on the existing parking paradigm of different groups.

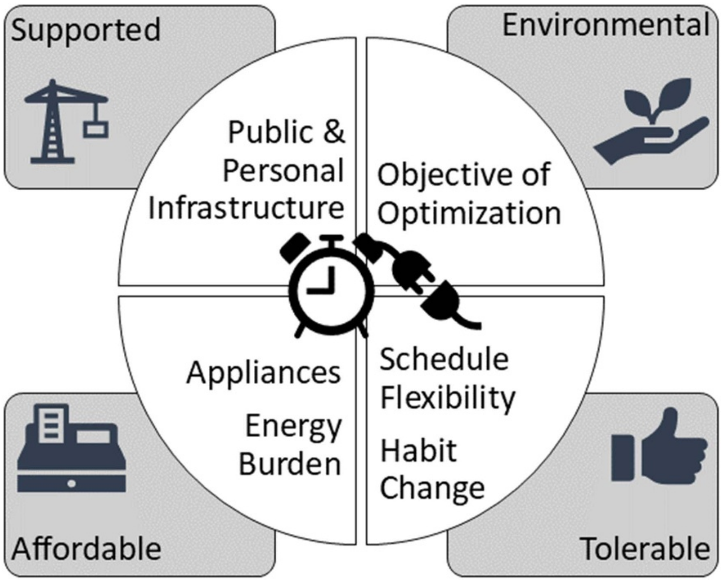

Figure 3. Potential barriers to justice in implementing time of use electricity pricing.

3.2. AC

The need for AC is both affected by and a part of the energy transition. Energy consumption contributes to global climate change and urban heat islands, which move AC from the realm of luxury to a necessity. The increasing exposure to extreme heat [68] and the associated health effects [69] mean that the *tolerability* of AC as a technology overall is high. The perception of heat is strongly tied to the measures taken to adapt to increasing temperatures [70] of which AC is an important resource [71]. The local climate might make certain types of cooling, e.g. evaporative cooling systems, less applicable, but generally AC is well accepted.

AC can be seen as a climate adaptation measure, and equitable access to cooling technologies is a factor in climate justice. Energy burden, the fraction of a household's income that is spent on energy costs, significantly affects the ability to adapt to extreme weather [43, 72]. Some households are already heavily energy-burdened and may not be able to *afford* additional energy costs to operate an air conditioner [43]. Efficient cooling can be achieved through a centralized AC unit with good insulation, but even in very hot regions, not all residences have the necessary infrastructure for quality cooling [73]. This affects both *support* and *affordability*. Lower income households are more likely to have indoor temperatures that more closely resemble outdoor temperatures, showing a distinct lack of justice for temperature conditions [74]. There are pervasive heat stress disparities in US cities, which are further exacerbated by higher outdoor heat stress in poorer and primarily non-white areas [75]. The residential segregation that still exists in the US is strongly associated with heat stress inequities [76]. Historically redlined neighborhoods show higher heat stress than other neighborhoods [77]. Increased AC will affect energy affordability and reliability as it will increase demand at peak generation times. As for the *environment*, an increase in electricity demand will likely increase emissions. One solution to manage these difficulties is to rethink urban design to reduce the heat island effect such that less AC is required for everyone. This can be accomplished through a combination of green infrastructure, cool pavement, and reduction in the generation of waste heat. In the near term, ensuring access to cooling stations in hot, urban areas is a way of creating *supported* infrastructure that minimizes additional *environmental* and cost burdens.

3.3. Cooking

The health and justice implications of cooking methods have long been discussed [78, 79]. Although some discussion of health implications is tied directly to the dietary makeup, many methods of cooking involve combustion of a fuel source within the home, which increases the concentrations of health affecting pollutants indoors [80–82]. Any combustion process will have *environmental* implications. From a gender equity perspective, women do the majority of household cooking [78, 83], and therefore are most exposed to the associated pollution. Gas stoves have been known contributors to indoor air pollution for decades [81, 84], and the effect on pollutant concentration is larger when used in smaller kitchens, which are most likely to be found in lower income households [80]. Support and affordability have historically been a focus in evaluating cooking processes, since food is a basic necessity. Although many day to day cooking costs and obstacles to food access lay outside the realm of energy, the energy source used for cooking is typically reliant on appliances within the home, which are expensive purchases. Policies that affect the options for necessary appliances should consider equity in the cost burden of these purchases as part of the *affordability* leg of the seat. Similar to the difficulties with EVs and AC, there may be limitations in *support* for alternative cooking methods if structural changes to the home are required. Such changes would include improved ventilation or changes to the fuel supply system. Cooking methods can also bring a heat to a conversation beyond that associated with spice or flame. People have strong preferences for cooking methods, and the dishes created using gas stoves and outdoor grills cannot be perfectly replicated through the use of electric appliances. Thus, *tolerability* is an important hurdle to increasing electrification (and decreasing emission) in cooking. Policies designed to encourage cooking that promotes healthy indoor air should consider mechanisms to address the high cost of replacing expensive appliances, including infrastructural costs beyond the appliance, while also consulting with residents to discuss their concerns about food quality.

3.4. Electricity pricing

While consideration of equity is important when considering household level shifts in energy use described above, systemic decisions have an even broader effect. Frequently, energy policy and energy justice evoke thoughts of the electricity distribution system. One issue with increasing electrification is a prolonged need to use combustion-based electricity generation, even as renewable generation increases, just to keep up with demand. This can be particularly negative for the *environment*. In addition, even with sufficient renewable capacity, if the demand is poorly matched with the electricity supply, reliability issues will require the use of less efficient combustion generation, increasing emissions even further. This idea was publicized through the introduction of the duck curve, named for the visual created by the mismatch of the supply and demand curves with high penetration of EVs and PV generation [85]. Encouraging people to charge vehicles at times that better match the electricity supply through variable electricity prices is often posed as a solution [86]. In this paradigm, the price consumers pay for electricity varies to encourage shifting of some loads toward times of day when the generation potential is high and the load is low [87]. Shifting demand can be a mechanism to improve air quality as it can allow for more renewable electricity generation, but may introduce obstacles to justice, as depicted in figure 3.

As an infrastructural solution, *support* is clearly an issue for this policy option. The largescale electricity infrastructure would need the capability to capture and report not only total electricity consumption at the consumer level, but the consumption rate at a high temporal resolution. Even if this public infrastructure is in place, responding to the pricing signals requires each consumer to have the information and ability to shift demand. While communication technologies for people have already been identified as a necessity, shifting load requires either appliances that have similar information access or schedules with sufficient flexibility to change behaviors. Proposed technology solutions include vehicle chargers that can respond to price and large appliances like clothes dryers to be connected and responsive. This additional barrier to access is also connected to the *affordability* of this solution. While the overall proposal of offering electricity at lower costs during certain times would seem to address affordability, the necessity of new appliances or flexibility to change schedules requires initial capital or employment security, potentially leaving the benefit unequally distributed. As this policy is designed to change behavior, there will be *tolerability* concerns. Schedule changes may lead to clanky laundry or dishwashing appliances interrupting sleep, uncertainty may increase EV range anxiety, or occupants may experience decreases in thermal comfort. Technology advancements such as smart devices and quieter appliances can help mitigate such concerns.

The pricing determination is usually configured through computational optimization, which means the improvement should consider an objective that incorporates justice elements. Personal dynamic pricing [88] may help ensure that choice is affected while not exacerbating inequality in energy burden. As important caveat is that time of use pricing is not necessarily designed to optimize for low emissions. The *environmental* benefits will only be achieved through dynamic pricing if emissions are accounted for in the optimization algorithm that determines the cost structure. Additional justice mechanisms can also be incorporated through technologies that allow for more responsive appliance operation at a low cost.

4. Conclusions

There is consistent recognition in the sciences that solutions to large challenges will necessarily be interdisciplinary [89, 90], but the exact nature of the collaborations needed has typically been rather vague. By highlighting specific tensions and complications to watch out for, projects, programs, and policies will be able to move along a strong path to solutions. While the framework laid out here is simplified, progress will be much easier with a large cohort of decision makers considering energy justice imperfectly than a small number doing it perfectly. Due to the complex interactions, justice must be considered explicitly and along multiple criteria, as the system is too complex for an equitable future to rise without steering in that direction.

While this framework builds upon previous efforts to improve energy justice and is designed to be simple to apply, any method to address such a complex topic cannot be foolproof. Potential challenges in implementing the SEAT framework include understanding the viewpoints of all stakeholders and prioritizing them to be represented in each phase of the decision making process. Encouraging stakeholders who may view themselves as part of opposing factions to work together may hinder or delay progress. While we have streamlined the considerations, the evaluation process is not trivial, therefore it is necessary to ensure that the decision making timeline has sufficient time to address justice concerns. Another challenge includes ensuring that those with authority to make changes are included in the effort. If a mechanism to improve justice is identified but lies outside the jurisdiction of the work group, additional effort will be required to recruit or persuade decision makers that have the needed authority. Due to the interconnected nature of many energy and environmental problems, it is likely that additional stakeholders or decision makers will be discovered after initial formation of an analysis team.

Setting a SEAT at the table for everyone amounts to progress, but this will not be the last word on this pervasive issue. The fast moving nature of energy systems and the geo-political factors affecting equity require reassessment. Additionally, future work could make this framework even more useful through the creation of a platform that even more explicitly guides decision makers through its use. Refinement of the guiding questions in response to further technological developments or based upon experience will continue to keep the framework useful.

Although much of the preceding discussion centers household level shifts in energy, the drivers of those changes are systemic. The household level decision-maker is not responsible for ensuring systemic equity, but the policy and infrastructure required for those decisions to have equitable options do need to consider equity. Systemic equity requires system level progress. Even in a society with high levels of *support* for advanced technological development, access to *affordable* energy technologies and a clean *environment* is not universal. Convincing users to shift will be easier if the new option is *tolerable*. Removing barriers to energy poverty and inequity requires identifying and finding solutions through comprehensive multisectoral approach that addresses the infrastructure, environment, socio-economic barriers and involving in policy-decision making. Prolific utilization or mandates of decision-making tools such as the SEAT can help prevent energy injustice in the long run.

Data availability statement

No new data were created or analysed in this study.

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