RAND CORPORATION

Research Report

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Equity Metrics for Climate Adaptation in the Electricity Sector

Equity is a comparative construct, describing fairness across different groups. The problem of equity in the utility power sector is not new: It has been a persistent concern since the inception of modern bulk power delivery in the United States. Because of the technological limitations and the high costs of construction and operation, electricity was only available to those few who could afford it in the late 19th and early 20th centuries (Small, 2017; Tuttle et al., 2016). There were some early policy efforts to broaden access to electricity, such as

KEY FINDINGS

- *Equity* is a sense of fairness and speaks to differences in experiences and outcomes among disparate groups. *Energy equity* is the sense of fairness applied to the power sector. The California Public Utilities Commission's decision defines for whom and why energy equity should be pursued and partially articulates how. However, it does not specify the procedural, distributive, or contextual concerns around equity in climate adaptation.
- In the context of this work on distributional equity, *equity metrics* measure how costs and benefits of a system or intervention accrue to different groups. An organization's choice of metrics should be informed by its equity goals and how it intends to achieve those goals.
- Many metrics developed by state and local governments appear to be derived from the U.S. Department of Energy's Clean Energy for Low-Income Communities Accelerator (CELICA) partnership. Most of the California Energy Commission's indicators have a direct analogue to a CELICA indicator or metric.
- For Southern California Edison, the following equity metrics are a useful starting point for assessing equity in its projects: investment, employment, participation, electricity burden, implementation cost share, System Average Interruption Duration Index, System Average Interruption Frequency Index, account attrition because of nonpayment, hospitalization rates, weighted value of lost load for businesses and households, and community benefit.
- There are at least three ways to use the metrics: to consider whether a project is equitable, to consider the project's impact on inequities, and to assess the equity of a portfolio of projects.

the passage of the Rural Electrification Act of 1936, which expanded electrical distribution by providing federal loans that allowed utilities to provide power to isolated rural areas where service was otherwise uneconomical. However, issues of equitable access, cost, and energy burden did not receive widespread attention until the late 1990s as an issue of "climate justice" (Jenkins, 2018). It was further refined in 2013 as the more policy-oriented concept of *energy justice* (Jenkins, 2018) or energy equity. Today's discussions of equity in the electricity sector emerge from this highly inequitable past (Bednar and Reames, 2020).

In September of 2020, the California Public Utilities Commission (CPUC) adopted its *Decision on Energy Utility Climate Change Vulnerability Assessments and Climate Adaptation in Disadvantaged Communities* (Decision 20-08-046) in which the policymakers sought to codify equity in climate adaptation (Batjer et al., 2020). This rulemaking raises two interrelated questions. The first is "How should the energy utilities that we [CPUC] regulate assess and adapt to California's vulnerabilities caused by climate change?" The second is "How should the utilities engage with the most vulnerable and disadvantaged communities on climate adaptation related to the utilities' infrastructure, operations, and services so these communities are not left behind the rest of the state?"

In Decision 20-08-046, the term *disadvantaged vulnerable communities* (DVCs) identifies those communities most vulnerable to climate change. The decision states,

> vulnerable communities experience heightened risk and increased sensitivity to climate change and have less capacity and fewer resources to cope with, adapt to, or recover from climate impacts. These disproportionate effects are caused by physical (built and environmental), social, political, and/or economic factor(s), which are exacerbated by climate impacts. (Batjer et al., 2020)

With this framing in mind, the CPUC defined DVCs as communities that meet any of the following four criteria:

> [t]he 25% highest scoring census tracts according to the California Communities Environmental Health Screening Tool (CalEnviroScreen);[1] all California tribal lands; census tracts with median household incomes less than 60% of state median income; and census tracts that score in the highest 5% of Pollution Burden within CalEnviroScreen but do not receive an overall CalEnviroScreen score due to unreliable public health and socioeconomic data. (Batjer et al., 2020)

The decision requires that CPUC-regulated utilities engage DVCs and assess (1) their vulnerability to climate impacts and (2) how utility climate adaptation efforts promote equity in those communities.

Research Questions and Approach

Southern California Edison (SCE), the sponsor of this work, is one of several investor-owned utilities (IOUs) regulated by the CPUC that must adhere to this rulemaking. In response, SCE has begun to develop an equity framework in which metrics will be used to evaluate the equity of adaptation projects

Abbreviations

AMI	area median income
CEC	California Energy Commission
CELICA	Clean Energy for Low-Income Communities Accelerator
CPUC	California Public Utilities Commission
DVC	disadvantaged vulnerable community
ER	emergency room
FPL	federal poverty level
FTE	full-time equivalent
IOU	investor-owned utility
LADWP	Los Angeles Department of Water and Power
LEAD	Low-Income Energy Affordability Data
SAIDI	System Average Interruption Duration Index
SAIFI	System Average Interruption Frequency Index
SCE	Southern California Edison
SFPUC	San Francisco Public Utilities Commission
VoLL	value of lost load

in the energy sector. SCE asked the RAND Corporation to assist by developing an illustrative set of context-specific equity metrics that SCE could then build on and incorporate into its ongoing work.

To conduct this work, RAND addressed the following questions:

- What is *equity*, what is *energy equity*, and how does the CPUC decision that motivates this work align with these definitions?
- What are *equity metrics* and how should they be developed?
- What are extant energy equity frameworks, what equity metrics do they include, and to what extent are they relevant for SCE's goals?
- What equity metrics would be relevant for SCE's goals of assessing the equity implications of climate adaptation projects that it might be considering, and how should they be used or not be used?

Parallel to the publication of this report, SCE is engaging community-based organizations in discussing energy equity metrics and is working to adjust them further for various purposes. This report does not describe SCE's efforts, which are ongoing and beyond the scope of this research.

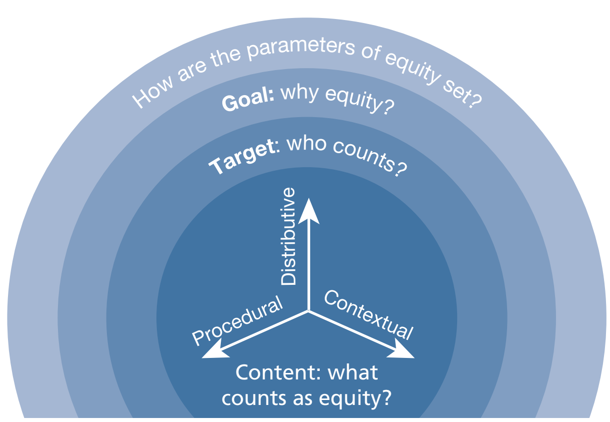
Understanding Equity and California Public Utilities Commission's Decision

What Is Equity?

Equity is a sense of fairness, and fairness is a complex construct. Fair in what way? For whom? By what means? For what purpose? According to whom? In the context of what prior experiences? Furthermore, implicit to the idea of fairness is that equity is a comparative construct. Equity speaks to differences in experiences and outcomes *among* disparate groups. By contrast, measuring changes in the experiences and conditions of *a single group*, though important, is not sufficient for describing equity.

McDermott, Mahanty, and Schreckenberg's 2013 equity framework (reproduced in Figure 1) helpfully formalizes these ideas into four interrelated *parameters* of how equity is defined (McDermott, Mahanty, and Schreckenberg, 2013). The first parameter asks, "What counts as equity?" This is the content of equity and often recalls a sense of fairness in outcomes. The first dimension of this parameter is *distributional equity*, i.e., whether the benefits and costs of an activity are distributed fairly. But distributional equity

FIGURE 1
A Framework for Equity



SOURCE: McDermott, Mahanty, and Schreckenberg, 2013. Reproduced with permission.

is only one of three dimensions of what counts. A second dimension is *procedural equity*, i.e., which stakeholders are recognized and included in processes, and is such engagement fair? A third dimension is a *contextual equity*, which seeks to understand the preexisting conditions that influence access to procedures, resources, and outcomes.

A second parameter asks, "who counts?" That is, among which groups is an organization or policy trying to achieve equity? Frequently, equity concerns are organized around race and ethnicity or socioeconomic status, though there are other characteristics of concern as well, including disability, age, gender, sexual characteristics, and incarceration status. There is particular interest in understanding the challenges of intersectionality, i.e., people who have more than one characteristic that might place them at a disadvantage (Crenshaw, 1991). The "who" can also be defined at different scales, e.g., equity among individuals, households, or larger communities; equity across generations; and even equity among humans and the environment or other species.

A third parameter asks, "why equity?" In other words, *what is the goal of considering equity?* This makes explicit what a policy or activity around equity is trying to achieve. It might be attempting not to exacerbate inequity, or it might be seeking to improve equity.

A fourth parameter asks, "How are the parameters of equity set?" Specifically, *how are these issues of what, who, and why decided, and by whom?* The answers to the first three parameter questions will necessarily reflect the perspectives of the parties involved and the process they use to set equity parameters.

What Is Energy Equity?

Energy equity is the sense of fairness applied to the power sector, including electricity, natural gas, gasoline or petroleum for transportation, and other sources and uses of energy. It is closely related to the idea of *energy justice*, which is used to describe activities aimed at achieving energy equity, although the two terms are sometimes used interchangeably (Tarekegne et al., 2021).

In aggregate, the literature on energy equity broadly aligns with the framework offered by McDermott, Mahanty, and Schreckenberg, 2013, but authors use different terminologies to describe closely related concepts. For example, in a review of energy equity measurement, the Urban Institute identified six dimensions of energy equity (Martín and Lewis, 2019). In this work, "access discrimination," "output differences," and "disparate impacts" all describe the distributive dimension of equity, while "inclusion of other voices" speaks to procedural equity and "historical legacies" describe the contextual equity. "Awareness of populations" corresponds to the target of equity.

The literature on energy equity and energy justice places particular emphasis on distributional and procedural equity. Sovacool and Dworkin, 2015, defines *energy justice* as "a global energy system that fairly disseminates both the benefits and costs of energy services and one that has representative and impartial energy decision-making" (p. 436). The dissemination of benefits and costs directly maps to the concept of *distributive equity* in McDermott, Mahanty, and Schreckenberg, 2013, and representation in decision-making maps to their notion of procedural justice (Sovacool and Dworkin, 2015). Similarly, Fuller and McCauley, 2016, frames *energy justice* in terms of distributional and procedural fairness in both the production and consumption of energy. McCauley et al., 2013, and Jenkins et al., 2016, describe three tenets of energy justice: *distributional justice* (where energy injustices are located geographically), *procedural justice* (ways in which decisionmakers engage with different communities), and *recognition justice* (which sections of society have been misrepresented or ignored).

Equity in the Context of California Public Utilities Commission's Decision

We find the breadth of the equity framework created by McDermott, Mahanty, and Schreckenberg, 2013, helpful in understanding the dimensions of equity addressed in the CPUC's Decision 20-08-046. In its rulemaking, the CPUC has explicitly defined the "who" of equity: The commission is seeking to address equity between DVCs and non-DVCs. It is important to note, however, that DVCs are themselves diverse and defined by a variety of characteristics. DVCs include communities that face significant exposure to environmental hazards, experience greater poverty, or live on tribal lands. The CPUC also defines communities at different scales—by census tract and by tribal land designation. Thus, the "who" defined by the CPUC is not monolithic in nature or scale.

The CPUC has also implicitly spoken to the "why" of equity. Decision 20-08-046 states, "The Community Engagement Plan will include, among other things, a discussion of how IOUs *promote equity* related to the IOUs' climate adaptations in DVCs based on the communities' adaptive capacity" (emphasis added; Batjer et al., 2020, p. 4). This suggests that the CPUC is concerned with reducing inequities between DVCs' and non-DVCs' experiences of climate-related risks in the power sector and inequities in the efforts to mitigate those risks.

The CPUC has at least partially articulated the "how" of equity, noting that IOUs must consult extensively and formally with vulnerable communities as IOUs undertake efforts to adapt to climate change and must survey community-based organizations to assess the effectiveness of this outreach. Implicitly, this suggests that DVCs will have an important role in shaping an IOU's framing of equity.

However, the CPUC has not clarified the "what" of equity. It does not specify the procedural, distributive, or contextual concerns around equity in climate adaptation or how they should be assessed.

SCE asked us to develop equity metrics to help begin to fill in this gap. Our effort focuses on *distributive equity*, which are characteristics of projects. Procedural and contextual equity are equally important but are in many ways more relevant to SCE's *process* of assessing and undertaking projects than to characteristics of individual projects. As a result, procedural and contextual equity are largely outside the scope of this work. Nevertheless, we encourage users of these metrics to also develop explicit assessments of procedural and contextual equity. As just one reason, observations of distributive inequity might reveal little about the source or causes of the inequity. Assessment of procedural and contextual equity can shed light on those underlying causes of distributional inequities, and addressing procedural and contextual inequities can play an important role in addressing distributional inequities.

Understanding Equity Metrics and How to Develop Them

What Is an Equity Metric (and What Is It Not)?

A *metric* is a standard of measurement. In the context of our work on distributional equity, metrics are measurements of how costs and benefits of a system or intervention accrue to different groups. For example, as California utilities increasingly use power outages (known as Public Safety Power Shutoffs) to manage growing wildfire risk fueled by climate change (Zanocco et al., 2021), a key question is whether the experience and costs of those outages are equitably borne by individuals and communities (Palomino and Dizikes, 2019; Sotolongo, Bolon, and Baker, 2020; Wong-Parodi, 2020). Equity metrics can help answer different questions, such as the following:

1. Is the baseline condition equitable? For instance, is the frequency or impact of power outages equitable among different groups?
2. Does a program or intervention improve equity? For instance, does an infrastructure investment to reconductor a particular line

Addressing procedural and contextual inequities can play an important role in addressing distributional inequities.

lead to more-equitable experiences of power outages between different communities? Used in this way, metrics can signal a change toward better or worse equity.

3. Is a program's implementation equitable? Are a program's resources to improve infrastructure equitably allocated to different communities?

Importantly, metrics are necessary but not sufficient to answer these questions. Metrics can highlight differences in the allocation of costs and benefits (or experiences more generally) between different groups, but not what the differences *should be*. This is determined by the "why" of equity, i.e., the goal that the organization is trying to achieve.

Finally, as we will discuss in the next section, metrics are different from *indicators*, which are the attributes of an object or a system from which conclusions on the state and quality of the phenomenon of interest can be inferred (Heink and Kowarik, 2010). In other words, indicators (e.g., economic progress) can be measured with different metrics (e.g., gross domestic product and gross national product).

Using Program Logic to Identify Equity Metrics

An organization or program's choice of metrics should be informed by its equity goals and how it intends to achieve those goals (Finucane, May, and Chang, 2021). Logic models are a useful way to describe the relationships that link a program's resources with its ultimate goals (Savitz, Matthews, and Weilant, 2017). As we illustrate in Figure 2, a logic model describes the program's inputs or resources that, in turn, enable it to undertake a set of activities that lead to some outputs that help to achieve desired outcomes.

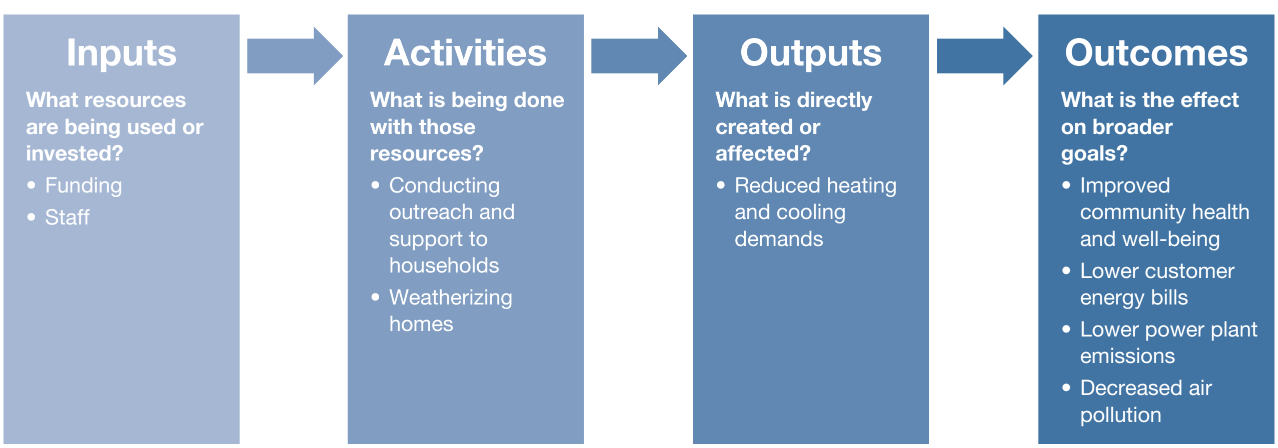
The example that follows shows a simplified logic model of a notional energy utility home weatherization program. The inputs include the program's funding and staff, which are used to reach out to households and weatherize the homes of those who have chosen to participate. As a result of these activities, participating households would have reduced heating and cooling demands. These outputs would ultimately lead to several desired outcomes for consumers, the community, and the utility, such as improved community health and well-being, lower energy bills for participating customers, lower greenhouse gas emissions, and decreased air pollution.

Such logic models as this can help identify metrics for assessing equity and other aspects of program performance. For example, suppose a utility is concerned with improving energy equity between a more vulnerable and a less vulnerable community. The utility might use several metrics throughout the weatherization program's logic to identify differences in groups' experiences and outcomes, such as

- the amount of funding or staff time allocated to each community (equity in inputs)

FIGURE 2

A Simplified Logic Model of a Home Weatherization Program



- the number of homeowners contacted through its outreach activities and the number or proportion of homes weatherized in each community (equity in activities)
- the reduction in heating and cooling needs of participating households in each community (equity in outputs)
- the health and well-being of members of each community and the cost reduction in utility bills in each community (equity in outcomes).

Our Approach to Developing Metrics for Southern California Edison

At SCE's request, we used the California Energy Commission (CEC)'s clean energy equity indicators as a starting point for developing a slate of illustrative metrics for SCE (CEC, 2018). We assessed whether each of the indicators was appropriate for SCE's goals. We asked the following questions:

1. Is the CEC indicator applicable to or can it be adapted to the utility power sector (as opposed to other types of energy systems and organizations)?
2. Is the CEC indicator relevant to the geography and conditions in Southern California and the task of climate adaptation broadly (rather than relevant only to certain types of energy projects)?
3. Is the CEC indicator well specified and does it reflect the latest research on equity?

Second, we reviewed existing federal, state, and local energy equity frameworks, plans, and programs to identify other metrics that might be relevant for SCE. Third, we assessed whether the resulting metrics in aggregate captured equity concerns throughout the logic model of climate adaptation projects. That is, does the set of equity metrics include metrics for inputs, activities, outputs, and outcomes? Finally, with SCE, we assessed the relevance of these metrics to three types of potential adaptation projects: infrastructure investments, operational changes, and custom programming.

Review of Energy Equity Metrics and Frameworks

Review of California Energy Commission's Energy Equity Indicators

California's Clean Energy and Pollution Reduction Act (SB 350) required the CEC to study challenges that low-income and disadvantaged communities face in adopting clean energy measures (California State Legislature, 2015). The CEC's energy equity indicators are aimed at tracking progress toward recommendations in the study that the CEC conducted, *Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities* (Scavo et al., 2016). The CEC worked with other state agencies and stakeholders and used the U.S. Department of Energy's Clean Energy for Low-Income Communities Accelerator (CELICA) toolkit, discussed later (U.S. Department of Energy, undated-b). The CEC identified three broad objectives for low-income and disadvantaged communities. Directly quoting the CEC's study, they are

- **Access**. Advance access to clean energy, including actions to increase the availability of product selection options, access to high-quality jobs, expansion of small business contracting opportunities, and improved access to non-debt finance offerings.
- **Investment**. Increase clean energy investment in low-income and disadvantaged communities, including technology development and demonstration funding, infrastructure investments, emergency preparedness, technical assistance, and local capacity building. Capacity building includes workforce development, small business development, outreach, and clean energy education.
- **Resilience**. Improve local energy-related resilience, defined as energy services to support the ability of local communities to recover from grid outages and enjoy affordable energy in a changing climate. Local energy resilience includes energy reliability, energy affordability, health, and safety. (Scavo et al., 2016, p. 6)

CEC's clean energy equity indicators related to each of these objectives are presented in Table 1 along with our research team's assessment of their relevance for SCE, according to the three questions listed in the prior section, "Our Approach to Developing Metrics."[2] As might be expected, many of the metrics are specifically aimed at clean energy. As noted in the subsequent section "Key Observations from the Review of Frameworks," indicators can be measured in different ways, and more specificity is needed to develop metrics from this set.

Other Federal, State, and Local Energy Equity Frameworks

We reviewed federal, state, and local frameworks, plans, and policies concerned with energy equity to identify additional equity metrics that might be relevant for developing metrics for SCE.[3] As shown in Table 2, many metrics developed by state and local governments are (or appear to be) derived from the U.S. Department of Energy's CELICA partnership, described next (U.S. Department of Energy, undated-b). A study by the Pacific Northwest National Laboratory offers an additional review of the energy equity metrics discussed in this corpus (Tarekegne et al., 2021).

CELICA-Based Metrics and Indicators

CELICA is a voluntary partnership between the U.S. Department of Energy and different state and local governments to develop strategies for addressing energy challenges facing low-income communities (U.S. Department of Energy, undated-a). CELICA partners conducted a study to identify barriers that

TABLE 1

Assessment of California Energy Commission's Clean Energy Equity Indicators

Indicator	Access	Investment	Resilience	Research Team's Assessment for Southern California Edison
High energy bills			✓	adaptable to SCE's context as *high electricity bills*
Energy efficiency: savings, amount invested, number served	✓	✓	✓	energy efficiency • not broadly relevant to adaptation projects, although it might be appropriate for some adaptation projects amount invested and number served • relevant metrics in the *inputs* and *activities* stages of the logic model, respectively
Rooftop solar		✓	✓	not broadly relevant to adaptation projects, although it might be appropriate for some adaptation projects
Electric vehicles	✓	✓	✓	not broadly relevant to adaptation projects, although it might be appropriate for some adaptation projects
Health and safety issues abated	✓	✓	✓	not a very well-specified indicator and not reflective of the latest literature, which shows that socioeconomically disadvantaged communities take longer to recover from impacts of a negative event when compared with other communities[a]
Energy resilient communities	✓	✓	✓	not broadly relevant to adaptation projects, although it might be appropriate for some adaptation projects and needs greater specificity to be used as a metric
Clean energy jobs	✓	✓	✓	adaptable to SCE's context as the number of jobs created by a project
Small business contracts	✓	✓	✓	not a measure of equity between two groups
Amount invested: innovation	✓	✓	✓	relevant to SCE's context as an investment in adaptation projects

NOTE: The first four columns are recreated from the CEC's clean energy equity indicators (CEC, 2018). The last column describes our research team's assessment of those indicators.

[a] Markhvida et al., 2020.

TABLE 2

Federal, State, and Local Documents Related to Energy Equity Metrics

Federal, State, or Local Government	Name of Report or Document Related to Equity Metrics	Source
U.S. Department of Energy	CELICA partners indicators[a]	Developed from the study of barriers that low-income and other disadvantaged communities face in accessing energy efficiency and clean energy programs
California	*Energy Equity Indicators Tracking Progress*[b]	Adapted from CELICA partners indicators and developed for tracking progress for advancing the recommendations in the SB 350 Low-Income Barriers Study[c]
Minnesota	*Energy Policy and Conservation Quadrennial Report, 2020*[d]	Adapted from CELICA partners indicators to identify barriers to clean energy adoption by low- and middle-income households and to develop strategic policies to address these barriers
Connecticut	*Connecticut Green & Healthy Homes Pre-Feasibility Analysis Report*[e]	Adapted from CELICA partners indicators; used LEAD tool from U.S. Department of Energy for increasing energy affordability of low- and middle-income households[f]
Kentucky	"Kentucky: Using LEAD Tool Data to Fund Energy Efficiency Programs Where Energy Affordability Assistance Is Needed Most"[g]	Used LEAD tool to identify areas with energy affordability needs and to promote strategic decisionmaking
New Jersey	Clean Energy Equity Act[h]	Developed to extend clean energy benefits, such as clean energy access, savings, and job opportunities to underserved communities in the state
San Francisco, California	*Advancing Equity and Community Investment in CleanPowerSF*[i]	Developed from literature review of relevant government reports and publications, interviews with community choice aggregator providers, government agencies, industry experts, advocates, and customer service data
LADWP	"Equity Metrics Data Initiative"[j]	Developed after stakeholder engagement to "track, measure, and report" the performance of different LADWP programs

NOTE: LADWP = Los Angeles Department of Water and Power; LEAD = Low-Income Energy Affordability Data.

[a] U.S. Department of Energy, undated-c.

[b] CEC, 2018.

[c] Scavo et al., 2016.

[d] Minnesota Department of Commerce, Division of Energy Resources, 2021.

[e] Green & Healthy Homes Initiative, 2018.

[f] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2020a.

[g] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2020b.

[h] New Jersey Legislature, 2020.

[i] Parsons, 2019.

[j] LADWP, undated.

low-income and other disadvantaged communities face in accessing energy efficiency and clean energy programs (U.S. Department of Energy, undated-a). They identified several major issues: housing instability, bill payment challenges, geographic dispersion, jobs and career development, access to capital, and program and policy limitations (U.S. Department of Energy, undated-d). CELICA partners then developed the indicators and metrics shown in Table 3 for measuring progress toward these goals and supporting evidence-based decisionmaking.

Some CELICA partner states, such as California, Connecticut, and Minnesota, have adapted these indicators to develop their own set of metrics and indicators. Relevant to this work is the fact that most of CEC's indicators have a direct analogue to a CELICA indicator or metric. In addition, CEC has added metrics that are specific to its clean energy

TABLE 3

Indicators from CELICA Partners

Indicator	Metrics
Energy efficiency savings	• Energy (MWh, MMcf, MMBtu) and cost savings for customers in aggregate or by low-income households served
Low-income parity	• Savings across low-income and market-rate programs (% of total savings) • Market penetration rate by income band (% AMI; % FPL) statewide and in each census tract
Participation	• Number of households served or percentage of eligible households served • Percentage of participants at various income levels (% AMI; % FPL)
Housing type	• Percentage participation by housing type (single family, mobile, and multifamily housing of different sizes and types, e.g., restricted, naturally affordable, and market-rate multifamily)
Program resources	• Total funding leveraged for energy efficiency, health and safety, and solar (by source and purpose) • Amount of investment financed (housing tax credit projects, on-bill programs, etc.)
Energy burden	• Amount that energy burden decreased (% reduction in % of income paid for energy bills) for participating low-income households
Health and safety	• Number of homes not served because of health and safety issues and percentage that receive referrals and ultimately return for service (% homes and % frequency of health and safety issues cited) • Health and safety issues abated (number of homes with % frequency issues abated)
Workforce development	• Contracts or jobs to locally owned, minority-owned, women-owned, and small businesses (number, %, or both) • Number of jobs created (by job type) • Participation of low-income residents in the energy efficiency and renewable energy workforce (number of local workers trained and number placed into energy efficiency and renewable energy jobs)

SOURCE: U.S. Department of Energy, undated-d.

NOTE: AMI = area median income; FPL = federal poverty level; MMBtu = one million British thermal units; MMcf = one million cubic feet; MWh = megawatt hour.

focus, including adoption of rooftop solar and electric vehicles. Other partners, such as Colorado, Michigan, and Indiana, have used a single indicator from this set to track the progress of their low-income energy efficiency and energy assistance programs (U.S. Department of Energy, undated-a).

Other State and Local Energy Equity Metrics and Indicators

Some state and local energy equity metrics and indicators are not directly derived from CELICA. Nevertheless, we observed that the metrics or indicators identified in these efforts also tracked closely with CELICA partners indicators. For example, the Kentucky Office of Energy Policy used such metrics as energy burden to identify areas of greatest energy affordability need and provide grants to organizations that provide weatherization upgrades and home repairs. Similarly, New Jersey is considering legislation that will use such metrics as energy burden, energy cost savings, clean energy asset ownership, number of clean energy jobs, and participation in clean energy and energy efficiency programs to ensure equitable deployment and distribution of benefits from those programs.

Utilities are also developing metrics and indicators to ensure equitable adoption of clean energy programs by the communities they serve. CleanPowerSF, a program by the San Francisco Public Utilities Commission (SFPUC), is using such metrics as the number of power and gas shutoffs, energy burden, baseload energy needs, greenhouse gas and fossil fuel emissions, the number of solar-plus-energy-storage projects in disadvantaged and energy-overburdened areas, customer trends such as delinquencies, and the distribution of renewables to guide their programs and policies aimed at reducing disparities in clean energy access.[4] From this work, we found that concepts of service interruptions and account attrition would be relevant for SCE's equity efforts.

As another example, LADWP's Equity Metrics Data Initiative is designed to "track, measure, and report on how its programs are provided to all customers and residents of Los Angeles" (LADWP, undated). It consists of 15 metrics in four categories: water and power infrastructure investment, participation in customer incentives and programs, procurement, and employment. As with SFPUC, we found metrics of service interruption (part of the investment category) particularly relevant to SCE. We determined that other energy equity metrics were already represented in our adaptation of CEC's clean energy indicators for SCE, such as participation rates and employment.

Key Observations from the Review of Frameworks

Many of the energy equity metrics and indicators (including CEC's energy equity indicators) are adapted from the indicators developed by CELICA partners. As one consequence, there is little diversity in the practical literature—it largely converges to a common set of metrics and indicators.

Second, the terms *metrics* and *indicators* are often used interchangeably in the literature, but they have different meanings. For example, some of the indicators used in the CEC *Energy Equity Indicators Tracking Progress* report, such as "high energy bills" and "clean energy jobs," would be more accurately described as *metrics* because they measure specific variables (CEC, 2018). This lack of precision can create confusion and make it more difficult to advance the field of equity assessment. For our work on behalf of SCE, we are developing metrics and therefore using the term *metric*.

Third, often what are classified as *equity indicators* or *equity metrics* are not actually used to measure equity; rather, they are developed to assess changes within a disadvantaged group, once the group has been identified as facing inequities. This is the case, for example, with the metrics and indicators developed by CELICA and the CEC. Measuring change is essential for achieving change, but, because these metrics are used to measure conditions or changes *within* a group and not differences *among* groups, they are not comparative constructs. As designed, they are *not* measures of equity. This speaks to the broader confusion in the literature and the community about what it means to *measure equity* between groups versus *measure progress* within a disadvantaged group. The two are not the same. To be clear, the issue is not with a metric itself, but whether it is used to compare groups or to measure change within a group. Therefore, the underlying concepts in these frameworks can still inform our work.

Fourth, the practical literature focuses on distributional equity with some consideration of procedural equity, but often overlooks contextual dimensions of equity. Today's inequities are the cumulation of historical conditions, and understanding the latter is essential to addressing the former. To be clear, our work is *also* scoped to distributional inequities and does not address procedural or contextual inequities.

Illustrative Set of Equity Metrics for Electricity Projects

Beginning with the metrics described in the previous section, Table 4 presents an illustrative set of metrics for assessing energy equity, applied to electricity projects for climate adaptation. The first column provides a short, descriptive name for the metric. The second column notes the broad category to which a particular metric belongs (public investment, participation, cost, etc.). It also notes in parentheticals the step in the logic model of a project that the metric addresses (inputs, activities, outputs, or outcomes; see Figure 2). The third column briefly describes the metric, and the final column provides a quantitative description of the metric. Next, we briefly discuss each metric. Our discussion is organized around the logic model steps of inputs, activities, outputs, and outcomes.

Some metrics are naturally measured at the individual level (e.g., investment per capita), others by household (e.g., energy burden), and still others at the community level (e.g., implementation cost burden). For those metrics that are not already measured at the community level, an average community measure (e.g., average energy burden of households in

TABLE 4

Equity Metrics for Adaptation Projects in the Electricity Sector

Metric Name	Category (Logic Model Step)	Short Description	Quantification
Investment	Public investment (inputs)	Monetary investment in electricity programs or projects	$ per capita
Employment	Public investment (activities)	Job or apprenticeship opportunities created by the project	Number of jobs and apprenticeships, measured as FTEs
Participation	Participation (activities)	Fraction of households (accounts) participating in electricity programs or projects	Number of participating accounts / number of total accounts
Electricity burden	Costs to customer (outputs)	Fraction of a household's income that is spent on their electricity bill	Electricity utility bill / household income
Implementation cost share	Costs to customer (outputs)	Cost is borne by a community as a share of the total community cost of a project	Cost per community / total community cost
SAIDI	Service reliability (outputs)	Average duration of interruption in the power supply, indicated in minutes per customer	Total duration of interruptions for a group of customers / number of total customers
SAIFI	Service reliability (outputs)	Average frequency of interruptions in the power supply	Number of interruptions for a group of customers / number of total customers
Account attrition because of nonpayment	Service accessibility (outputs)	Rate of electricity disconnections in territory for nonpayment	Number of electricity disconnections during the event / number during baseline
Hospitalization rates	Health and well-being (outcomes)	Percent change in ER visits and hospitalizations during a period, compared with a baseline	Number of ER visits and hospitalizations during event / number during baseline
Weighted VoLL—business	Health and well-being (outcomes)	Loss of business income, such as customers not served, disruption in digital trading, or machines abruptly closed	VoLL in $ / total income
Weighted VoLL—household	Health and well-being (outcomes)	Loss of household income because of loss of service relative to the total income of households	VoLL in $ / total income
Community benefit	Health and well-being (outputs or outcomes)	Value-added to community services, e.g., green space, cooling from reflective surfaces	$ per capita

NOTE: / = divided by; $ = U.S. dollars; ER = emergency room; FTE = full-time equivalent; SAIDI = System Average Interruption Duration Index; SAIFI = System Average Interruption Frequency Index; VoLL = value of lost load.

the community) can allow for comparisons between communities. Although the CPUC's focus is on the differences between DVCs and non-DVCs, the metrics are not particularly relevant to these groups. One resulting advantage is that the metrics are more general and could be used to compare groups defined in other ways. However, the limitation is that communities are themselves diverse, and the concerns of certain vulnerable or disadvantaged individuals or subcommunities could be overlooked, unless further care is taken to develop metrics specific to them. For example, different tailored metrics might be needed to assess equity for tribal communities or individuals with disabilities within a DVC. This is yet another reason to treat these metrics as starting points for conversations on measuring equity.

Metrics for Assessing Equity in Inputs

Investment

The first metric, investment, can help assess how investments made by a power utility or other entity are distributed among different communities. This metric corresponds to the investment indicator used by the CEC (CEC, 2018). This speaks to the equity in the inputs in the logic model and can be measured as the financial investment in the community. We suggest measuring investment dollars per capita to account for the fact that communities might have different populations. Then, the investment per capita can be compared among different communities. In addition, investment dollars per capita should be measured over time to assess how communities have been served historically and to inform any future investment.

Metrics for Assessing Equity in Activities

The metrics of employment and participation help assess equity in the activities enabled by the inputs.

Employment

Employment and other economic opportunities are an important concern in investment projects and climate adaptation efforts, and it is often a goal to ensure that such opportunities are equitably distributed (Chapman, McLellan, and Tezuka, 2016; Mohnot, Bishop, and Sanchez, 2019). The employment metric addresses how the jobs created by climate adaptation activities accrue to different communities. It can be measured as the number of jobs created or the number of FTE positions created (U.S. Department of Justice, undated). Importantly, unlike most other metrics, the distribution of economic opportunity associated with a project might not be an inherent characteristic of the adaptation project but rather a choice that the utility might make about how to fill the jobs created by an adaptation effort.

Participation

Participation measures the fraction of households (or accounts) that participate in a particular adaptation effort (Johnson and Hall, 2014). This metric is most applicable to programs in which customers can opt-in to participate, rather than projects that automatically affect customers. Significant differences in participation rates among communities can point to contextual inequities between them. For example, a lower-income community's low participation rate in a weatherization program relative to a higher-income community might reflect lower rates of homeownership in the former community and therefore a lack of agency to participate in the program. Its analog in the CEC equity framework is "Energy Efficiency—Numbers Served," but we use it here to refer to participation in any kind of adaptation program (CEC, 2018).

Metrics for Assessing Equity in Outputs

The next several metrics assess outputs of an adaptation project, i.e., the direct impacts of the activities undertaken.

Electricity Burden

The electricity burden is the fraction of a household's income that is spent on its electricity bill. This is an analog to the CEC's "High Energy Bills" metric, which we have adapted to be specific to electricity (CEC, 2018). It is an important metric because many studies show that lower-income households have a higher energy burden than other households (Golubchikov and Deda, 2012), which "can threaten a household's ability to pay for energy, and force tough choices between paying energy bills and buying food, medicine, or other essentials" (U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2018). A household's electricity burden will primarily be affected by two factors: the price of electricity and the quantity of electricity purchased. Each of these factors can be modulated by different programs or utility-related variables. The price of electricity for a household can be affected by enrollment in rate payment plans or the change of existing rates by a local public utility commission. Electricity purchase can be affected by demand-side management programs, such as utility-organized home weatherization or appliance upgrade programs. Electricity purchased can also be affected by household behavioral changes, such as turning the air conditioning up or off in the summer or reducing the use of consumer electronics. When evaluating equity, two communities could be compared by considering their average household electricity burden to assess the impacts of these programs meant to affect electricity prices or purchases.

Implementation Cost Burden

Many projects involving infrastructure have significant implementation burdens, such as road closures, eminent domain land takeovers, noise pollution, and reduced property values. These burdens might be short- or long-term, and in many cases, the siting of a project will impose these costs primarily or entirely on one community, while the benefits accrue to other communities. The negative perception of these projects (e.g., as unpleasant or even harmful to residents) can affect property values in those same communities (Rasmussen et al., 2021). Although it can be difficult to quantify the costs of these burdens in absolute terms (e.g., the cost of noise pollution), their allocation might be more straightforward. For example, if a substation is sited in a particular community, the community will likely bear all the associated implementation costs. Additionally, the converse can also be true.

System Reliability Metrics SAIDI and SAIFI

The next output metrics relate to service outages—a key concern for SCE and other California utilities and a major driver of their adaptation efforts. SAIDI and SAIFI are standard metrics often used together by the electricity sector to measure reliability (Ensto, 2016). SAIDI measures the total time that an average customer experiences a non-momentary power interruption, usually in one year, while SAIFI measures the frequency of interruptions. We include them as equity metrics because they can be used to compare reliability experienced by different groups of customers.

Although SAIDI and SAIFI measure the duration and frequency of interruptions, it will be important to use them to assess how the burden of interruptions—particularly those caused by public safety power shutoffs—are borne by different communities (Heylen et al., 2018). For instance, one community might experience 50 percent of the total customer minutes of shutoffs while making up only 10 percent of a utility's accounts. This could be a sign of underlying contextual inequities, e.g., in the maintenance of infrastructure or use of solar panels and batteries that might otherwise reduce load and make a shutoff less necessary (Gonzalez, 2021).[5]

Account Attrition Caused by Nonpayment

Although the previous metrics reflect impacts to customers of a utility, it is important to consider households' ability to be customers and receive electricity. This metric assesses account attrition caused by nonpayment of bills, which could become a growing concern if climate change results in high utility bills (e.g., for increased air conditioning; U.S. Environmental Protection Agency, 2021). It can help utilities understand how customer programming can help households afford their electricity bills and remain connected to service.

Metrics for Assessing Equity in Outcomes

The remaining metrics are useful in assessing equity in the broader outcomes of an adaptation project. In the context of equity, these are the impacts on the health and well-being of communities and the environment.

Hospitalization Rates

Although there are many ways to measure equity in health outcomes, a key metric used in the literature is the change in hospital and ER admissions during a particular period or event, compared with some baseline (Dominianni et al., 2018). For example, CEC used "asthma and heat-related illness" as two health and safety indicators in their initial energy equity tracking progress report and tracked the number of ER visits related to both diseases (CEC, 2018). There are other potential indicators, such as disruption in education or civic services, which could also be used to track well-being. Consistent with existing literature, we used short-term health impacts, such as asthma, because they are a proxy for tracking the progress in areas with deteriorated air quality because of historical inequities. Similarly, we used *heat-related illness* as a proxy for areas that face disparate impacts of a heatwave and unreliable electricity because of past lack of investment. Also, it can be argued that there is a correlation between areas with high asthma and heat-related illness and disruption in other well-being activities, such as education, because of unreliable electricity. Thus, hospitaliza-

Community benefits might include increased green space, energy savings from the use of innovative materials, and improved roads and other transportation networks.

tion rates can help in understanding the differential impact on the well-being of communities caused by unreliable electricity.

Weighted Value of Lost Load—Business

Service interruptions (measured by SAIDI and SAIFI) are important because of the impact that they have on people's lives and well-being, but these metrics do not themselves capture that impact. VoLL is typically used to quantify the cost associated with unreliable electricity and interrupted services and is measured as dollars per unit of electricity. But as explained by Markhvida et al., 2020, any measure that focuses only on the "loss of dollar value" will inadvertently undervalue the impact of such disrupting events as outages on a community's well-being. In the study, the authors took the example of postearthquake disaster recovery and argued that focusing only on the housing asset loss during disaster recovery provides an incomplete picture because wealthier households tend to be homeowners with higher-valued assets. Such asset-based focus also fails to capture any consumption and well-being loss, such as loss of labor income, loss of savings, need to relocate during housing repair, and other predisaster socioeconomic factors. Similarly, focusing only on VoLL does not help in evaluating the differential impact of unreliable electricity and outages on certain communities and businesses within those communities.

This metric captures differential impacts of unreliable electricity and thus quantifies the economic impacts faced by a business because of outage as a percentage of the total earning of said business. Examples of economic impacts are customers not served, disruption in online business activity, and wear and tear in machines and other production infrastructure because of abrupt shutdowns. The economic impacts are normalized against the earnings of the business and can help evaluate whether a certain type of business is bearing the disproportionate impact of unreliable electricity.

Weighted Value of Lost Load—Household

This measure complements the previous one, quantifying the impact of unreliable electricity on the household. Such impacts might include "lost wages and other income, interruption of educational and health services, disruption caused by temporary or permanent relocation, and decreased consumption" (Markhvida et al., 2020).

As explained earlier, focusing only on the "loss of dollar value" undervalues the impact of unreliable electricity on the community's well-being (Markhvida et al., 2020). For example, disadvantaged households usually cannot mitigate the impacts associated with unreliable electricity and they might take longer to recover from any setback when compared with wealthier households. Weighted VoLL—household captures the differential impact of unreliable electricity on households as it is normalized against the household income and can help in understanding the issue of inequitable distribution of the impacts of unreliable electricity.

Community Benefit

This last metric measures the value added by the project in the community and could be thought of as an inverse of the implementation cost share, which measures the value lost by a community. Community benefits might include increased green space, energy savings from the use of innovative materials, and improved roads and other transportation networks

(U.S. Department of Energy, Office of Minority Business and Economic Development, 2017).

How Should These Metrics Be Used?

There are at least three ways to use such metrics as these to assess equity implications of adaptation projects. The first is to consider whether a project itself is equitable. Are the benefits and costs of the project distributed equitably, or is an already vulnerable community disproportionately bearing the costs of an adaptation program while realizing little of its benefits?

The second is to consider the project's impact on inequities. For example, does a project reduce the existing disparity in energy burden between two communities? For such assessments, the metrics can be used to measure change—e.g., what is the average electricity burden in a community before and after an intervention? Does an intervention improve equity, have no impact on equity, or make inequities worse? Such changes can be estimated *before* a project to anticipate its impact and prioritize against other options; *during* a project to monitor progress and course correction; and *after* a project to evaluate outcomes.

The third is to use these metrics to assess the equity of a portfolio of projects or interventions. Doing so can reduce the expectation or requirement that every project address equity, which might simply not be possible, while enabling an organization to know whether it is making progress toward equity overall.

In addition, for any application of these metrics, it is important for utilities to engage with local community members (e.g., through community-based organizations) and particularly vulnerable communities that they seek to support. Such participation is part of the fourth parameter of equity, which asks, "how are these issues of what, who, and why decided, and by whom?" (McDermott, Mahanty, and Schreckenberg, 2013).

Discussion and Conclusions

As the United States pursues decarbonization through the expanded electrification of the economy and dispatch of low- and zero-carbon technologies—while also adapting the energy system to a changing climate—concerns of how these changes affect historically vulnerable and underserved communities might grow. Energy equity is increasingly being studied as a formalized concept, and policymakers and utilities are turning to the literature to understand concepts of equity and to measure equity in their own work.

It is evident from our literature review, however, that there is a great deal of confusion in the literature. First and foremost, there is confusion about what equity is and is not. Much of the practical literature on equity frameworks focus on distributional and procedural inequities while omitting contextual inequities. In this report, too, our scope is on measuring distributional equity, and we necessarily leave assessments of contextual equity in the hands of the users of this work.

There is also confusion about what it means to *measure* equity, in at least two ways. The practical literature, including literature aiming to assess equity, often focuses on measuring progress *within* a disadvantaged group rather than between groups, the latter being essential for measuring equity. In addition, there is confusion about such terms as *indicator* and *metric*, which add to difficulties in robustly measuring equity.

In this report, we have laid out key concepts and definitions around what equity is and how to measure it, which we hope will reduce some of the confusion. We have also offered a partial process for developing equity metrics that we hope energy utilities and policymakers can use to begin considering the impacts of climate adaptation projects on different communities.

Importantly, these metrics should be used as a starting place from which to engage communities in conversations about equity and how to consider impacts and trade-offs between different adaptation projects. Metrics should also be exercised through case studies and demonstrations. They can and should be adapted and new metrics could be added to account for the specific characteristics of projects or communities. And, as noted in the first section, these distributional metrics should be accompanied by careful consideration of procedural and contextual equity, which together will paint a more complete picture of equity in climate adaptation.

Notes

[1] CalEnviroScreen is a mapping tool developed by the California Office of Environmental Health Hazard Assessment that "helps identify California communities that are most affected by many sources of pollution, and where people are often especially vulnerable to pollution's effects" (California Office of Environmental Health Hazard Assessment, 2021).

[2] CEC's framework uses the term *indicators* but contains a mix of indicators (e.g., for energy efficiency) and metrics (e.g., for high energy bills).

[3] Our review is not intended to be comprehensive; rather we concluded our search when new literature no longer yielded new concepts. It is possible that certain equity metrics might not have been captured in our literature review, particularly as this field is evolving rapidly. Thus, we characterize our findings as an illustrative baseline from which electricity equity indicators should be developed.

[4] SFPUC is different from the CPUC, which is also based in San Francisco, California.

[5] Note that Public Safety Power Shutoff outages can be caused by many conditions, such as heat-driven infrastructure failures or shorts caused by sagging power lines. Some might be climate-related while others are not. As noted previously, measures of distributional inequity might not reveal a cause for the inequity. Studies of procedural or contextual equity can shed light on the underlying causes.

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About This Report

Social equity has become a key concern among many public agencies. In 2020, the California Public Utilities Commission (CPUC) adopted Decision 20-08-046, *Decision on Energy Utility Climate Change Vulnerability Assessments and Climate Adaptation in Disadvantaged Communities*. This ruling requires the utilities to engage disadvantaged vulnerable communities (DVCs) and assess their vulnerability to climate impacts. It also requires utilities to evaluate how their climate adaptation efforts can promote equity among DVCs and non-DVCs. Southern California Edison (SCE), the sponsor of this work, is one of several investor-owned utilities regulated by the CPUC that must adhere to this rulemaking.

In response, SCE has begun to develop an equity framework in which energy-related equity metrics will be used to evaluate the equity of adaptation projects. SCE asked the RAND Corporation to assist by developing an illustrative set of context-specific equity metrics that SCE could then build on and incorporate into its ongoing work toward climate adaptation. This report describes RAND's work and the resulting metrics.

These metrics can help inform utility regulators and electricity utilities as they begin grappling with energy equity. It offers a straightforward methodology and a starting set of equity metrics that are intended to be adapted to different contexts.

Community Health and Environmental Policy Program

RAND Social and Economic Well-Being is a division of the RAND Corporation that seeks to actively improve the health and social and economic well-being of populations and communities throughout the world. This research was conducted in the Community Health and Environmental Policy Program within RAND Social and Economic Well-Being. The program focuses on such topics as infrastructure, science and technology, community design, community health promotion, migration and population dynamics, transportation, energy, and climate and the environment, as well as other policy concerns that are influenced by the natural and built environment, technology, and community organizations and institutions that affect well-being. For more information, email chep@rand.org.

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