



WHITE PAPER

The State of Equity Measurement

A Review for Energy-Efficiency Programs

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Introduction

To support contemporary efforts among energy-efficiency programs in their consideration of equity and its measurement, this paper explores the discourse around equity, and explores definitions and measurement schemes for equity in service fields beyond energy-efficiency. The authors review scholarly and policy sources to describe the state of equity's measurement among advocates and policy analysts in general and in each of these fields to advance a preliminary theoretical approach toward equity measurement in energy-efficiency and related energy-services.

The review finds that the state of equity definitions and subsequent measurement—qualitative and quantitative—varies across sectors but has advanced considerably. Equity's analytical and practical uses continue to evolve, but six dimensions emerge from the contemporary literature that are relevant to energy efficiency programming:

1. Understanding the **historical legacies** of disparities in which an intervention—be it a specific service, program, agency, or institution—is implicated.

Description: Equity at any point in time is the aggregation of past actions and outcomes that resulted in disparities. The original disparity and its effects may persist. The community that was negatively affected by a past disparity may also connect all programs governed by similar service structures as part of the same system that caused the disparity regardless of whether an individual program was responsible. For example, racist clinical health trials, housing and school segregation, and gender bias in employment have histories that inform groups' perceptions of those institutions. A program's new actions are viewed as contributions to that system, and opportunities for equitable amends.

Measurement: Historical accounts, ethnographic study, community discussions and qualitative data collection can document past disparities and grievances to create a record of local events or actions that led to current disparities or perceptions of disparate treatment and possible numbers of households or individuals affected.

2. Having a **detailed awareness** of populations that were affected by past disparities and of new populations that may be negatively affected by planned interventions.

Description: The identification of demographic and behavioral groups in the general service area that are of interest is an essential step toward measuring differences between them in

relation to a service. This step involves quantifying group numbers and locating them geographically, starting with the groups identified in the historical analysis.

Measurement: General population data for traditionally defined protected classes and income are a common starting point. Relevant data differentiated by these groups should then be collected in relation to the service in question (e.g., total energy consumption, energy intensity, or other energy condition). Similarly identifying information for an intervention’s eligible, applicant, and recipient populations is also needed to assess representativeness compared to the general population. These sets of information can then be used to analyze disparities in an intervention’s inputs, activities, outputs, and outcomes.

3. Including the **perceptions and insights from all** recipients or stakeholders at all levels of intervention design, staffing, management, and execution.

Description: This procedural dimension of equity has to do with the inclusiveness and representativeness of a service’s administration. Steps for defining the dimension include ensuring that populations from potentially disadvantaged groups are at the table in designing an intervention through active community engagement, but also that they are proportionally represented or overrepresented in an intervention’s management, staff, and contractor and consultant pools.

Measurement: Simple quantitative measures of community engagement representation and program staff and management rolls can determine proportional representation in employment and community participation. Qualitative assessments of engagement quality, the incorporation of stakeholder feedback, and hiring processes round out the measures.

4. Ensuring that the processes for eligibility and application for a service are not exclusionary—that is, that **access is equitable**, not discriminatory, and fair.

Description: Voluntary services often involve procedures that target certain consumers at the exclusion of others, intentionally or unintentionally. The methods and media for targeting and recruiting individuals can be scrutinized, and resulting application and approval rates can confirm any access disparities.

Measurement: Marketing and outreach activities can be assessed qualitatively for inscribed bias, and measured quantitatively through expenditures rates and media hits across groups. Numeric measures for the proportions of applications and approvals can be compared to those

in the general population. Finally, process assessments of access procedures and materials may uncover other qualitative barriers to equitable entrée into programs.

5. **Differences in service outputs** can indicate underlying disparities between groups' needs or constraints in relation to an intervention, or in the intervention's design.

Description: Outputs are typically defined as measures of an activity's progress and completion. A service may be implemented in a qualitatively different way to one group than another, or may not account for ways in which one group needs a qualitatively different treatment. In either case, this variance may potentially result in differences in completion rates and quality and, later, in outcomes.

Measurement: Qualitative monitoring of service provision and the inspections of final services can reveal potential differences in service delivery across groups. Satisfactory inspections and project completions may also yield attrition rates that reveal differences between groups.

6. All things being equal, a service may produce desirable or unintended **disparate impacts** between groups despite purported equal access and treatment.

Description: Most services intend to alter a specific fundamental outcome for their recipients. Overall building performance and utility bills in relation to an energy efficiency program, for example, may be an indicator of differences across groups' interactions—that is, service impacts—which can be wholly or partially attributable to the service or intervention itself.

Measurement: Outcome measures can be collected through primary data collection (inspections, surveys, etc.) or secondary collection (such as utility data), though both are intensive. Measuring impact through experimental or quasi-experimental evaluation with comparison groups is even more exhaustive.

Equity is a complex goal. Measurement is a first step toward taking the needed actions to achieve it and, fortunately, it is a step for which a robust volume of literature, practice, and advocacy provides precedent. This body of work is far from conclusive and definitive. However, the six dimensions outlined in this report and examples from other sectors' application of them lay out a wide range of reasonable options. Programs may opt to focus on a handful of these measurement strategies depending on the resources and data available to them. However, the selection of measures should always be revisited and questioned since inequity can arise from a wide range of decisions, actions, and omissions.

I. Equity Dimensions

Social programming of all stripes has adopted the rallying cry for *equity* in relation to race, income, home tenure, age, physical challenge, and other demographic traits. Energy provision is no exception despite the seeming fairness and rate-neutrality of energy delivery and corollary activities including residential energy-efficiency audits, appliance and equipment rebates, and retrofits. Indeed, the need for—and, in some cases, requirement to—serve all populations in a bounded territory has surged across providers in all sectors, be they public, quasi-public, private, and civil. Questions about equity in services have especially arisen regarding publicly owned or regulated utilities and their different components, decisions, and actions. The five-year-old Flint water crisis, for example, is the most egregious product of inequitable utility service treatment in recent history.

There are many ways in which considerations of justice and injustice have been defined legally and ethically in ways that are reasonably applicable to the energy sector (Sovacool and Dworkin 2014, 2015). Yet, there are also material and political reasons why that application is topical. The current impetus for equity inquiry comes as much from the realization that some populations are often “energy poor,” “energy insecure,” or “energy burdened” (Hernández 2016), as from the gaps in access and treatment that certain groups face to reap all potential energy service benefits (Reames 2016). As energy-efficiency advocates have noted, there is a need “to ensure that low-income communities and communities of color benefit from a clean energy economy.”

A handful of scholars have begun outlining how equity and its related goals (especially justice) may manifest in the broader energy public-industrial complex (Jenkins et al. 2016), including the effects of mining for fossil or nuclear fuel or the siting of energy production facilities. This theoretical work has moved the narrative forward, but has yielded little practical and industrial application—especially in the subset of energy efficiency actions and advocacy. Despite efforts to target some key groups such as renters (Philbrick, Scheu, and Brand 2016; Ross, Jarrett, and York 2016) to date, though, providers’ success in this endeavor has been modest at best (Frank and Nowak 2015).

But, what does equity mean? This chapter focuses on the contemporary discourse surrounding social and economic equity in the broader terms, to then establish a framework for what it might mean to different stakeholders in the energy service community including community activists, the general energy utility or service customer population, energy program professionals, and independent scholars.

The authors broadly define an “intervention” as a system, institution, a program, or a service or a combination thereof except when purposely distinguished; for example, the offering of water

conservation techniques is a discrete intervention but implicates a bigger program (the water conservation service provider) or institution and system (the water utility and its investors, employees, governing bodies, and regulatory framework). As the following discussion reviews, this holistic approach is critical to identifying structural inequity or the deep-seated perceptions of inequity in a service or by a service provider—even when the intervention appears neutral on its face.

Definitions

Equity—the current operational term for social and economic policy and public programming—dates to the social justice movements of the 1960s (Frederickson 1990). Since then, there have been various definitions of equity that often overlap with comparable ideas, such as “diversity,” “inclusion,” “representation” or “representativeness,” “fairness,” and “equality.” These terms are more nuanced than equity’s textbook definition: “justice according to a natural law or right” and “freedom from bias or favoritism.” Despite the complexity of the term’s modern use, clarifying concepts emerge. Each of four underlying concepts implies an additional consideration for equity measurers, as noted below.

Equity is historical parity, not just current equality. Both descriptive studies of justice and quantitative empirical analysis of disparity have struggled with how equity is qualitatively different from previous concepts. First, equity, in its current use, is emphatically distinguished from equality. The former term is associated with the equal provision or dosage of a service devoid of context regarding past difference in service provision or current disparities of need or capacity. For example, the same rate fee for use of a water utility service regardless of a person’s background would be considered equal treatment. In contrast, equitable actions attempt to redress past wrongs as well as current differential gaps with the assumption that the gaps are a symptom of a longer-running, chronic condition. Inequity is cumulative, and equity, therefore, cannot be achieved through one singular action.

Many scholars and advocates have argued that equity inquiry must look at the historical legacies that explain current gaps in power and access, into the institutional and systemic rules or procedures that perpetuate the gaps, and the identification of the relevant group’s less-quantifiable, underlying access challenges—for example, poverty or institutional distrust (Annie E. Casey Foundation 2014). Inequity is a social or economic condition that is the aggregate of past and contemporary exclusions and disparities for a group, and equity is the removal of those and rectification of those differences and reparation of their effects. Justice is achieved, in theory, through the correction of legacy burdens (that is, past disparities) that manifest in the present imbalance.

In the water example, a sliding scale of fees or an additional set of services such as a subsidy, direct assistance, or water conservation provisions dependent on a person's financial conditions or the water utility's possible history of discrimination may be an appropriate equitable action. For providers, then, the concept challenges the idea that there is any one metric for which current data can be collected that can reasonably account for the ways equity or inequity plays and has played out for all the groups in question. Aggregate or composite measures are also insufficient in that they do not specify the past mechanism or contemporary action that result in disparate outcomes. Rather, indicators of past and present service must be assessed beyond basic equality in service receipt to paint a picture of equity.

Equity is measured for specific populations—including protected classes or just groups with shared characteristics—for whom there is a relevant and reasonable past or current disparity in treatment. Because equity as an operational concept has tracked along justice as a legal and policy movement in the US, the evolution of equity definitions has tended to align with federally defined protected classes since the 1960s' civil rights era, which currently are race, color, religion or creed, national origin or ancestry, sex, age, physical or mental disability, and veteran status. Anecdotally, public-sector programs' most commonly selected characteristics for data collection, measurement, and analysis are race or ethnicity, gender, income, age, and location. Location is often used as a proxy for race and income through secondary data, as well. These categories faced or face some overt disparity or discrimination that led to their legal protection. In some services at the subnational scale, other group classes have more recently been qualified as requiring equitable rebalance, e.g., sexual orientation and gender identity.

Still other demographic categories outside these legally defined protections—namely, income—have also played an integral role in equity advocacy in the public policy sphere because of a perceived unfairness or injustice. In the water services analogy, regressive water fees would be an example of income-based inequity. Other qualifiers such as housing tenure, education, employment, rurality or urbanity, and household composition have also been employed as categories of interest by public and semi-public service providers for either demonstrable disparities or perceived injustice in treatment. Residential location is also used as a proxy for other characteristics, such as race and income.

Equity measurement is multifaceted and cannot be reduced to a single construct. When presented with the concept of equity, scholars' and evaluators' primary questions center around whether there are existing measures in place and, if so, if any one operational construct is most valid. Construct validity is defined as the highest approximate truthfulness or correctness of an inference to ensure that what is being measured by a specific metric is equity, and not a different concept. If many measurement constructs and actions are needed as noted above, operationalizing equity is even more complex.

While fields such as housing segregation, health status differences, and educational performance disparity have moved the science of measuring equity forward, there are still disparities in other functions or activities that can be measured—and that may ultimately explain why outcomes differ between groups. Indeed, exclusion, discrimination, and disparity can arise at any stage or combination of stages in the exchange between an institution or service and the individual or household experiencing the disparate treatment.

As such, no single quantitative measure has been proposed that works for every type of institutional or service activity or for every group. In some cases, descriptive disparities are sufficient while others require multivariate statistical regressions that control for other potentially contributing or intervening factors to determine whether a disparity is present. In most cases, some historical and qualitative data should supplement measurement for context. For providers, different measures apply depending on the nature of the intervention and the population in question.

Equity *can* be measured—just not by one metric alone. Assessment of the individual disparities that sum to inequitable conditions must occur for each relevant group and at each point of an intervention’s causal chain, from inputs such as an intervention’s founders, investors, supply chain, and staff to outcomes (for populations intended to be served. An important corollary to this pattern is that the subsequent application of any kind of disparity- or equity-related metric has been relatively agnostic about which groups should be studied by which measures.

In theory, inequity in treatment and outcome could play out in all ways for all groups and should be measured comprehensively. In practice, there is a specificity to unjust treatments for certain groups that implies that certain kinds of measurement methods are more appropriate for certain kinds of disparities. The identification of multiple metrics for different aspects of an intervention that are relevant to different groups requires keen insights into both the intervention and the populations. In the water utility example, current disparities in pricing, cutoffs, and assistance lend themselves to basic descriptive metrics, while the provision of a typical service (e.g., maintenance of healthy water mains) or of a voluntary service (like water conservation retrofits) require geospatial analysis.

Equity should be measured for each component along an intervention: development, implementation, quality, and outcome. Equity policy scholarship has attempted to qualify what and how disparities arise along different points of exchange between an intervention and the population being served. Most of the literature has converged on a few key intervention stages, but categorized them in slightly different ways. For example, in 2000, the National Academy of Public Administration (NAPA) defined four possible components of social equity analysis:

- **Procedural fairness.** NAPA interpreted this component in relation to due process and equal protections, but others have expanded on its implications for inclusion, ranging from establishing which groups are relevant in relation to an intervention’s potential equity, documenting the structures, institutions, and systems around the intervention and their historical inclusion or exclusion across the groups, and documenting power relations and authority within them, such as leadership, fiduciary and governance controls, and so on. “Guaranteeing all a place at the table” is a common expression of this expanded notion of procedural fairness.
- **Distribution and access.** This is defined as equity in the availability of services or benefits and can be depicted as either equal access to all populations, including the removal of any financial, perceptual, or behavioral barriers that any one group may face. Equitable interventions also may result in the creation of services or benefits targeted exclusively to groups that have been identified as facing or having faced access problems. The purpose of equitable actions is to “promote equal distribution, compensatory redistribution, and efforts to correct past discrimination, depending on the nature of the problem being addressed” (Svara and Brunet 2005).
- **Quality.** This equity component addresses the process of providing services and benefits to ensure consistency (i.e., equality) or to provide enhanced services for the groups identified as particularly disadvantaged.
- **Outcomes.** Since the goal of most social policy and program interventions is to have an impact on broader life outcomes, differences in outcomes across groups must be quantified—controlling for other contributing or intervening factors.

Combined with the two additional insights from more recent equity inquiry regarding historical disparities and the appropriate identification of populations of interest, these four categories help to further articulate dimensions of equity beyond scholarly categories and into practical, operational definitions that can be interpreted by practitioners and to which institutions can be held accountable. The authors of the current paper put forth six dimensions of equity discourse and their application to interventions of all types (i.e., institutional practices, public policies, or program services) to explore the state of equity measurement. The disciplines and subfields that form a scholarly basis for the dimensions are summarized in Exhibit 1.

EXHIBIT 1

Theoretical Background for Equity Dimensions

| Dimension | Concept | Theoretical sources |
|---------------------------|--|---|
| Historical legacies | Equity is measured cumulatively. Current perceptions of equity implicate past disparities, discriminatory practices, and exclusion. | Sociology and psychology of race, ethnicity, and gender; legal, regulatory, and industrial history; science, technology and society studies; developmental education and psychology |
| Awareness of populations | Equity is measured for relevant populations. Measurers should identify and focus on both the demographic or behavioral groups in a region that have been historically treated unequally, and those who may be at a unique disadvantage in relation to the service or institution in question. | Public health; public policy analysis; government and political science theory; gender, race, and queer studies |
| Inclusion of other voices | Equity is measured at different points in an intervention's life, starting with design and staffing. Equity is inclusion during the conceptualization, design, and monitoring of a program, service, or institution. This "procedural fairness" includes full and sustained engagement with community members as well as leadership and employment that is representative of the community. | Public administration; organizational management; social welfare; participatory planning and engagement (urban planning) |
| Access discrimination | Equity is measured by the ability of different groups of interest to become aware of, apply for or request, and access a service. Services must be available and practically tenable to all groups equally, or specifically targeted at one group that suffers from other inequitable actions. | Legal and regulatory theory; civil rights history; communications and marketing |
| Output differences | Equity is measured by the quality and completion of a service. In many cases, different groups receive disparate treatment consciously and unconsciously. For example, the quality of service, customer satisfaction, or basic completion or performance may vary. | Housing discrimination history and sociology; social determinants of health (public health); educational finance and teacher quality; environmental justice scholarship |
| Disparate impacts | Equity is measured by disparities in the desired outcomes across groups of interest. Most services are intended to produce a specific social, financial, or physical outcome. | Sociology and anthropology of segregation; Public policy analysis |

Measurement Dimensions

Historical Legacies

By the above definition, equity requires an understanding and redressing of past instances of structural injustice and chronic unfairness (Jones 2000; Fullilove 2016). This analysis extends beyond a group's

relationship to the specific intervention since other negative experiences with the institutional or systemic structures in which the intervention exists may precede and inform that relationship. The new interventions should speak to the record of that direct interaction at a minimum. This subsection refers to the need to answer the questions:

- What is the past historical treatment of different groups (for example, by race, income, or household composition) by service providers and institutional authorities for different groups in a specific place?
- Are there any perceived injustices or differences in past treatments that shape these groups' perceptions of institutions today?
- Do these perceptions inform institutional relationships today?
- This first dimension of equity analysis is measured largely through qualitative means, unless sufficient historical data exist in relation to a group and the proposed intervention. Practitioners, then, must give thought to whether their interventions acknowledge and address past inequity—both in relation to their specific institution in which the intervention is administered or to that community's treatment by institutions in general. Understanding the historical context around which an institution functions is a critical step toward identifying any group that may suffer or benefit from disparities in current and future treatment—regardless of whether the subject institution played an intentional role in past disparities.
- Where neither the institution nor any related provider of the same intervention were involved explicitly or tacitly in creating disparities, this analysis will serve to provide helpful context for identifying groups that may be suspicious of institutions for other reasons. In cases where the institution or intervention providers have played an intentional role in disparities, the onus for remedial interventions is even stronger.

Awareness of Populations

The current state of interactions and uptake across different groups reflects a wide range of previous and concurrent decisions and actions—many of which are not obvious. Historical precedents always influence current structural disparities. Yet, there are also ways in which the nature of the intervention may simply not be matched to the behaviors, needs, and actions of groups. For both cases, a keen awareness of the groups is in order. Questions to be asked are as follows:

- Which populations are of interest—either because of historical evidence or anecdotal experience—to equity advocates in a specific place in relation to an intervention?
- How does the intervention in question consider or document them in relation to potential disparity in service access?
- Current demographic considerations and intervention providers’ or programs’ attention to them are a basic condition of this dimension. Identifying the groups that may not be accessing services requires understanding the current population breakdown by characteristics traditionally associated with inequity in modern America (e.g., race, gender, income, and age), but could also involve other traits and behavioral difference that limit a potential recipients’ access.
- Access to other related interventions, for example, may be one overlapping characteristic; federal weatherization programs, for example, are meant to improve the energy performance of low-income households. Language, rurality, physical challenge, internet bandwidth and use, household composition, housing tenure, household-head work schedules, inability to pay a large upfront fee—these are all potential barriers to access as well, though they likely correlate with other factors. A potential intervention must be aware, then, not only of the groups of interest but also of the relevant and competing interventions in which those groups may be participating.

Inclusion of Other Voices

Equity advocates frequently note gaps in programs’ staffing, supply chains, leadership, and advisory or regulatory entities as causes of unfair or inequitable conditions particularly regarding race and income in relation to service area demographics (Bradbury and Kellough 2011). Further, the exclusion of representative voices from the recipient community of interest limits both the quality of the intervention (including how the need is defined and how the program interventions is designed) and the community’s buy-in to the eventual program—whether that exclusion is intentional or an oversight.

Questions on how to measure these indicators relate to representativeness and inclusion, such as:

- Does the composition of all operational and governance entities associated with the intervention reflect or proportionally represent the communities being served?
- What methods are employed to accurately include and substantively address the perspectives and needs of all groups in decision-making processes?

A combination of descriptive quantitative measures (e.g., racial composition of staff or suppliers and contracted business owners in comparison to the general population) as well as a qualitative scale for procedural reviews (quality of feedback and input into program offerings and their implementation designs) could be employed.

Access Discrimination

Historically, many access disparities fall along traditional classifications. Though often regulatory or ethically defined, discrimination still occurs in numerous private interactions; in housing, for example, mortgage lending and realty are still known areas in which both explicit discrimination and implicit bias still occurs. These practices reflect the persistent effect of past segregationist policies (such as the racial correlation to housing tenure or the costs of basic service). Questions that lead to measurement include:

- Are there differences in service application and receipt across groups beyond intention?
- How do current application, eligibility and other access channels influence service provision?

Intentional differences in service and treatment can be meant to positively redress inequity, such as a group receiving a different type of service better suited to their needs. However, such interventions can also exacerbate inequities if not designed well. For example, a low-income energy retrofit program may not adequately reach out to and make interventions convenient for most of a region's low-income households.

- Monitoring marketing materials and media through indicators like user-identifiable screen views or "source of information" questions on customer service surveys can help identify how service users differ from non-users. The absolute and proportional institutional spending of marketing dollars to different groups in the same intervention, or across interventions or programs established just for those groups, could also be an indicator of disparities in access. Non-users need to be identified and consulted to better understand overlooked factors that may explain output and outcome differences.
- Yet, not all access differences are bad. Conscientious and thorough scrutiny of the proposed intervention's access may also reveal intentional eligibility differences. For example, one intervention may be designed to uniquely target an underserved population and, consequently, have intentionally different eligibility requirements. This is inherently the case with a utility's low-income household energy efficiency program.

Output Differences

The satisfactory completion of an intervention is an output that is distinct from simply being eligible for, applying to, or being approved for it. There are many ways in which the output can vary inequitably. For example, similarly eligible applicants may be treated differently or may receive an inferior product or service as part of the intervention. The applicants may face delays or additional costs, ultimately forcing them to withdraw from the intervention altogether.

There have been clear disparities in treatment and outputs documented in other sectors, such as different mortgage terms for equally qualified applicants of color, inferior curricula being implemented in schools in low-income neighborhoods, different apartments being shown to prospective tenants reliant on housing assistance, or disparate rates of medical treatment based on gender. Output differences can directly indicate discriminatory practices and as such, are a good starting point for equity measurement. Questions regarding the output dimension of equity measures include:

- Are there differences in service use, duration, and satisfactory delivery—e.g., does a group receive the same service as others?
- Do a group's final participation rates (that is, the rate at which the intervention is documented as complete) mirror its application rates for the intervention? Are there service rules or procedures that might explain these differences?

The quality of service may vary between groups because of implicit biases among program or contractor staff, even if the participation numbers reveal equitable service receipt. For example, differences in customer service treatment or in the physical delivery of a service against a set standard of performance may occur. Variance in completion rates and in indicators of satisfactory completion across groups are straightforward measures of output differences. Among the first measures, comparing the output rates to the access rates is a helpful exercise for quantifying attrition. Parsing out data from physical inspections or customer satisfaction survey responses by group traits can provide insight into the differences in the quality of outputs.

Disparate Impacts

Unintended discriminatory effects can also be measured by differences in mid- and long-term outcomes. Though possibly not deliberate, these effects are also a legally upheld expression of the absence of equitable action. From recent environmental justice and fair housing verdicts, the case for

addressing the unintended consequences of actions is legally binding and requires a very nuanced set of measures.

Outcomes are the conditions that an intervention intends to change. Outcomes are typically more fundamental states or program objectives than outputs, which are measures of activity performance. In energy efficiency programs, for example, the purchase of LED lights is an output while household electric bills, home energy intensity, or utility peak energy use may be outcomes that the intervention seeks to change. In this case, outcomes can include additional benefits from a service like health improvements. A series of questions can help determine the variations in outcomes and an intervention's role in impacting them:

- Are the outcome changes attributable to participation in the intervention?
- Are there persistent differences in the intended outcomes and benefits from an intervention across groups—e.g., does a participating specific group benefit in the same way as other participants?
- When combined with the effects of other interventions, are there differences in the outcomes and benefits across groups to which a specific intervention significantly contributes?

Indicators for program outcomes as defined by basic theories of change or logic models are common starting points for articulating differences in conditions for different groups of interest. For example, baseline energy use, costs, and intensity are common conditions that an energy-efficiency or renewable-energy service seeks to alter. These indicators are often measured as trends over time, or in pre-post snapshots in relation to a new intervention. Ideally, the outcome indicator is identified at the “awareness of populations” stage of equity assessment.

Other outcomes beyond those directly expected by an intervention may also be considered. For example, changes in energy costs are often associated with energy-efficient interventions. Consequently, life outcomes such as the financial benefits from increased energy savings, the health benefits of improved housing quality, and the societal and employment benefits of improved human productivity may reflect an institution's or program's mission in implementing interventions beyond the immediate practical outcomes of focus. Interventions with these types of far-reaching financial and social conditions also speak to more fundamental equity issues in communities.

Differences in outcomes, though, are not necessarily measures of the effects attributable to a specific intervention. A wide number of other factors may be intervening or contributing to the outcomes across different groups, and their effects need to be isolated and reduced in analysis for the

specific intervention's impacts to be measured. Impacts—the difference in outcomes that can be attributed to an intervention—require extensive analysis. Consequently, outcome studies are more common than impact studies.

In summary, the contemporary discourse around social and economic equity provides new ways of thinking about and studying fairness and justice across an intervention's context, development, activities, and results. The discussion is complex. Ultimately, though, the start of any equity conversation today requires sensitivities to the groups that may be disadvantaged on the one hand, and a keen insight into the institutions and interventions on the other. This robust knowledge provides the foundation to clearly, practically, and effectively measure and address equity.

II. Equity Measurement Examples

As the overall definition of equity evolves, addressing equity for any specific intervention has taken many forms. Yet, a review of how and why specific measures of equity have played out in other areas unrelated to energy efficiency reveals strong commonalities and converging approaches.

Select Service Areas

The authors chose four service areas to shed additional light on equity measurement. Several criteria were considered to select these four areas. First, the authors sought out fields in which a public or semi-public service is provided or implied; the interplay between a service intervention and a life outcome could then be analogous to energy efficiency programs. The authors also intentionally excluded other energy-related services such as renewable energy installation programs since a fundamental conceptualization of equity in this paper has been that the institutions, systems, and structures in which an intervention lies must be part of the equitable analysis. The authors also looked for service areas from which there has been a recent history of advocacy, legal, and regulatory efforts in promotion of equity so that definitions and operationalized concepts of the equity could be identified. Lastly, the authors selected service areas that have also advanced some amount of scholarly effort toward measuring equity to date so that the authors can present quantitative and qualitative measurement approaches. This criterion excluded many household public services such as water delivery or waste water management for which advocacy and scholarship are just emerging.

The authors considered several potential subject areas, social institutions, and industrial sectors, such as: employment (particularly, disparities by gender and race across industries and occupations), financial services (e.g., access and use between banked and unbanked groups, typically dictated by income), criminal justice policy (such as racial profiling, incarceration rates, and sentencing disparities); and economic investment (geographically dictated levels of public and private financing and business growth which typically correlate with race and income); among others. Ultimately, the selection of four areas is limited and non-exhaustive of all efforts that could be classified as equity measurement.

- Regardless, four subject areas stood out as having extensive documentation in practice and more rigorous scholarly exploration. Definitions, practices, and measures are reviewed for:
- **Housing.** Rigorous measurement of housing equity began soon after the passage of the 1968 Fair Housing Act after centuries of institutionally sanctioned discriminatory practices. Since

then, a variety of analytical methods have been employed to look at housing discrimination rates on one hand, and their consequent geospatial segregation effects on the other. The field of housing equity has arguably been the site for the most advanced measurement, analysis, and policymaking in the US because of the numerous public and market practices that contribute to disparities, and the many life outcomes associated with the disparities' persistence.

- **Health.** Health care access, disparate treatment, and health outcome disparities have been the focus of equity in this field since the blatant racism of clinical trials like the Tuskegee Syphilis Study in 1932 and persistent disparities in women's health research and service treatment. As opposed to housing equity, however, the causal relationship of actions leading to equitable access, program design, outputs, and outcomes has been more complex given the number of intervening factors related to predisposition, behavior, and environmental causes in addition to institutional health care and related services and offerings. Health equity measurement, then, continues to evolve.
- **Education.** Educational equity measurement is a conceptual hybrid of the strategies employed for housing and health both because of the spatial overlay of educational services (like housing) and their public and private funding sources (like health). In contrast to those fields, there has been a concerted effort to have "color-blind" service delivery that prohibits basic population awareness, let alone measurement and analysis of it. Regardless, disparities in access to certain educational opportunities (such as honors or advanced placement courses and secondary education), outputs (enrollments and degrees), and outcomes (employment and income) persist.
- **Environment.** The environmental justice movement has been at the foreground of the equity conversation regarding point-source pollution, air and water quality, and land conservation efforts as well as, more recently, disaster recovery assistance (UCC 1987, Bullard 1990). While disparities in the negative effects from environmental conditions have been this field's focus, an increasing body of work also looks at differences in access to positive environmental amenities, such as tree canopies, green buildings, and parks. When it comes to measurement, the movement has pursued many options, some of which are qualitative histories as well as longer-term life outcomes like health disparities. Environmental equity provides a useful subject case both because of its topical relationship to energy equity but also because its metric tools call into question the way that equity does or does not measure historical disparities.

In each area, the authors review equity definitions and measures with a focus on the points of equity measurement—history, group definitions, design and staffing, access, participation outputs, and outcomes—that are most robust.

Housing

Overwhelming evidence suggests a significant association between place of residence and numerous other life outcomes, such as individual health and well-being, and the amount of available educational, economic and social opportunities (Jacobs 2011; Herbert et al. 2013). Low-income neighborhoods in the US are more likely to be occupied by people of color and feature older and substandard housing; to be located near amenities such as high-achieving schools, public parks, and grocery stores; and to have higher levels of pollution and other health hazards; all of which drive down home values (Massey et al. 2003). Conversely, high-income neighborhoods are more likely to be predominantly white and appear on the opposite end of the spectrum regarding the previously listed social characteristics.

The present-day spatial distribution of these neighborhood types and the resulting inequities are not random. Instead, they are largely a result of discriminatory housing policies that funneled African Americans and other communities of color into undesirable neighborhoods, limiting their opportunity for economic and social growth (Massey and Denton 1988; Geronimus 2000). The legacy of these policies continues to have a differential impact on white communities and communities of color. The passage of the Fair Housing Act of 1968, which ended the legal discrimination in housing practices, prompted the desire to measure equity in the housing sector to track the success of this seminal legislation and uncover procedural and access disparities.

A few historical inquiries detail past institutionalized housing discrimination and their subsequent effects on community formation and disparities in physical and economic resources (Rothstein 2017). Equity has recently been defined by housing scholars in terms of housing discrimination (an access discrimination) and geographic segregation (an output difference). Discriminatory practices with regard to lending, rental inquiries, physical accessibility, and “redlined” home purchases have been documented over time (Galster 1999; Ross and Turner 2005; Aranda 2019). This work has demonstrated numerous categories of populations that have or continue to suffer from discriminatory housing access practices; groups include traditionally protected classes (race, physical ability, and nationality) and housing-specific traits or behaviors (sources of income).

By far, however, the bulk of studies related to housing equity have focused on the measurement of outputs—namely, the location and quality of housing across different groups. There are many interrelated indicators for housing disparities, such as housing tenure (ownership vs. rental vs. homelessness), housing unit value, and housing quality. These measures tend to have an underlying geospatial component. For tenure, for examples, barriers precluding African Americans across the income spectrum have resulted in gaps in access to homeownership (Jackman and Jackman 1980;

Massey 1987; Massey and Denton 1988). Consequently, homeownership rates are much higher for white Americans than non-white Americans (Long and Caudill 1992; Flippen 2001). For this reason, homeownership rates have been used as a proxy to measure housing inequality.

Like homeownership rates, the demographics of renters and the homeless have also served as a useful measure of housing inequality. With the assumption that households that are not homeowners either reside in rental housing or are homeless, the gross number and percentages of certain demographics (race, income, education, etc.) within the population of renters and the homeless have also been used as a proxy to measure housing inequality.

Home values—measured by tax assessment, comparable sales listings, or actual sales—are another output indicator of housing inequality. The value of a home is determined by a combination of several variables, including size and layout, but much of a home’s worth is determined by its location. Locational segregation, then, can also be assessed through disparities in these values. Similarly, physical quality is another major determinant of home value, but that is also an independent indicator of inequity. Quality is a subjective concept and thus has been difficult to both define and measure. Still, researchers have used housing age and housing conditions as proxies for quality (Friedman and Rosenbaum 2004). Studies have shown that low-income households and people of color are more likely to occupy older and substandard homes.

Ultimately, all these indicators have been analyzed as measures of the degree of segregation (Flippen 2004; Dwyer 2007). Massey and Denton’s 1988 paper organized the developed measures of segregation into five categories: evenness, exposure, concentration, centralization, and clustering. More information about these measures can be found in Appendix 1. Measures of residential segregation have been used primarily to measure housing inequality in owner-occupied housing, but the same principles can also apply to rental housing. Apartments and other rental houses that occupy good locations have traditionally been highly segregated as well because of both discrimination against people of color and the unaffordability of units to people of color, who often have lower incomes and less wealth. For example, some studies examining the distribution of Housing Choice Voucher Programs have utilized the index of dissimilarity to measure potential segregation (Galvez 2010; Horn et al. 2014; Metzger 2014).

In all cases, the above measures of housing equity focus primarily on monitoring the outputs of housing markets and the outcomes of housing policies, namely segregation, and the impact of various service interventions to increase access to the housing market (e.g. reduce discriminatory practices).

Health

Achieving equity has been a core principle of health at least since the founding of the World Health Organization (WHO) in 1948. However, equity has been broadly defined: “all persons [should] have fair opportunities to attain their full health potential, to the extent possible” (Braveman 2006). These definitions are aspirational goals more than they are operational constructs that can guide how to measure and track equitable health

Despite this, some researchers have attempted to develop an operational definition of health equity that would enable measurement and tracking (Wagstaff and van Doorslaer 2000; Braveman and Gruskin 2003; Oliver 2004). Braveman (2006) defined equity as “the absence of systematic and potentially remediable differences in one or more aspects of health across populations or population subgroups defined socially, economically, demographically, or geographically,” and an equitable action as the “minimizing of avoidable disparities and its determinants—including, but not limited to health care—between groups of people who have different levels of underlying social advantage.” The definitions point to the use of comparisons to measure and track differences in health conditions—typically focused on existing trends in rates of disease or symptoms of poor health (Penman-Aguilar et al. 2016).

Life expectancy, although it can be indicative of other impacts, is one of those measures. Calculating life expectancy requires a robust system that collects various demographic, lifestyle and health information including age at death. With accurate data, health professionals can predict how long an individual can expect to live based on their demographic, lifestyle, and health profile (Arias et al. 2017; National Center for Health Statistics 2017). Other methods of determining and tracking health inequities include prevalence and incidence of specific health outcomes, conditions or diseases as well as statistical methods such as risk ratios, odds ratios, rate ratios, hypothesis testing, and regression that allow for direct comparisons of health outcomes between groups (Oakes and Kaufman 2016).

In addition to signaling health inequities, these various output and outcome condition measures also inform efforts to address identified inequities. Conclusions drawn from these measurement techniques help to gather information on the intervention type, the target population, intervention length, and resources needed. For conditions that have safe and effective treatments, for example, there is presumably a strong and significant association between health condition and the provision of health care.

Researchers have suggested that access to health care should be, above all else, distributed proportionally based on need (Porter 2010; Soni and Foot 2010). Margaret Whitehead, in the early

1990s, characterized equity in health care as “equal access to available care for equal need, equal utilization for equal need, and equal quality of care for all.” (Whitehead 1992). Consequently, much of the health care delivered around the world is more highly correlated with income and other socioeconomic identifiers than with need.

Largely, it has been difficult to define both access and need in the context of equity in health care (Oliver 2004). For many, access is simply the absence of barriers. The most significant barrier to accessing health care among many is cost. In most countries that do not employ a universal health care system, health care access is directly associated with the ability to pay. For much of the population with the lowest income, the cost of care surpasses their ability to pay, impeding access to quality health care and introducing inequities into the system. Horizontal and vertical equity have been proposed as concepts that enable the measurement and tracking of equity in access to health care and in health care financing. Horizontal equity is the notion that individuals with equal ability to pay contribute an equal amount for equal levels of care (Wagstaff and van Doorslaer 2000). In contrast, vertical equity refers to the notion that individuals with unequal ability to pay will contribute proportionally unequal amounts of money for care.

Methods similar to those in housing such as the Gini coefficient have been proposed to measure horizontal equity in health (Wagstaff and van Doorslaer 2000). The Gini coefficient can be interpreted in a health care context as the degree to which inequality exists in the amount that individuals can spend on health care services. Methods such as Kakwani’s progressivity index, which calculates the extent to which a financing source differs proportionally to the source’s income, have been proposed to measure vertical equity in health. More information on these measures can be found in Appendix 1.

Oliver and Mossialos discussed four dimensions of health care need in a 2004 article that sheds light on service access and eligibility: 1) normative need, 2) felt need, 3) expressed need, and 4) comparative need. Normative need is determined by an expert when compared to a standard, felt need is defined by individual want, expressed need is the action stimulated by felt need, and comparative need is characterized by the want of a service that other people have received. Differences between a physician’s definition and the patient’s definition may arise, so determining an individual’s actual level of need in a health care setting can be difficult.

While access and need have been important in discussions of health care equity for decades, more recent trends in the sector point to a third component: health care quality. In the United States, studies indicate a correlation between cost and both access and quality of care. In practice, this means individuals who have a greater ability to pay often have greater access to better quality of care. This

concept has been also been difficult to define though the literature suggests quality sits at the intersection of safety, effectiveness, and patient satisfaction (Campbell et al 2000.; Brook et al. 2000; Burstin et al. 2016).

Safety alludes to the ability for interventions or treatments to do no further harm to the patient and can be measured through an assessment of that patient's health status to ensure that they are not sicker after the treatment than before. How effective a treatment is at meeting the needs of the patient emerges from the literature as a critical component of quality. (Hanefeld et al. 2017) Measurement of effectiveness varies depending on the health condition being treated. Finally, patient satisfaction is conceptually easy to understand but is largely subjective. A treatment can be both safe and effective but considered to be a failure if the patient is not satisfied with the outcome. For example, the safest and most effective treatment for the flu virus is to take ibuprofen and wait it out. However, there are documented cases where flu patients have pressured physicians to prescribe antibiotics because they think have an infection instead. To capture patient satisfaction, there has been a push among both health care providers and government officials for patients to fill out surveys after treatment, which contributes to our understanding of patient satisfaction and health care quality.

Another categorization for measures of health care quality have emerged: structural, process, and outcomes quality. Structural measures capture information about the setting in which care was given (Brook et al. 2000; Soni and Foot 2010; Porter 2010). Examples of structural measures include the number of hospital beds and the nurse-to-patient ratio. Process measures give insight into how care was provided; these measures feature a comparison of the care provided to standards, guidelines, and procedures of care that are developed based on the strength of evidence compiled in the literature. For example, the length of time a patient should remain in hospital observation after heart surgery is a standard determined by the literature. Finally, outcome measures depict what happens to the patient resulting from care and are the most promising given their direct relationship to the goal of health care, which is to improve health outcomes. Readmission rates, repeat prescription requests, and patient surveys are the most used methods of measuring outcomes.

Again, these metrics represent imperfect measures of health care quality as there is no single established method of capturing the entirety of health care delivery or the numerous other social and environmental factors that shape health (Jacobs 2011; Woolf and Braveman 2011). An individual may need more health care depending on where they live and how educated they are, yet may also receive worse health care because of these same factors. Therefore, some suggest that equity measurement efforts should also include the disparities in the related determinants of health (Fawcett et al. 2010).

Strategic program design and deliberate outreach and recruitment efforts can overcome these barriers, but an intimate understanding of the barriers is often essential in developing innovative solutions that maximize the benefits to the community (Sadana and Blas 2013). As such, there has been a focus in public health to ensure that members of the community are at the table when it comes to making program decisions that will impact their communities—that is, procedural equity. Efforts to measure program design have focused on representation of community members in decision making conversations, although defining “representation” has proved to be difficult.

In sum, most of the equity measurement techniques in the health sector have been focused on disparities in general conditions and health status, differences in service interventions in terms of health care quality, and on the analysis of service population in terms of who has access to quality health care. There have also been conversations around equity in program staff and leadership in terms of improving the spatial distribution of health care practitioners within the health care industry, such as the relationship between the density of doctors and nurses and the demographic makeup of the surrounding community (Rosenthal et al. 2005).

Education

Education is often considered one of the most important determinants of life outcomes. The literature largely points to education as a key predictor of household income and wealth accumulation. Disparities in the access to quality education among communities are tied to income status and racial identity. These differences, in turn, result in divergence in income and other outcomes (Thattai 2001; Chemerinsky 2003; Sawhill 2006; Noguera et al. 2016;). Like housing inequality, the disparities that plague the education system are rooted in a history of physical segregation.

Despite the Supreme Court ruling in *Brown v. Board of Education* that prohibited systematic segregation in the education system, many schools remain segregated to this day (Noguera et al. 2016). Disparities in educational outcomes are often referred to as the achievement gap, the education debt, or the opportunity gap and are measured by the proportion of demographic groups that can reach specific milestones in education, such as high school graduation and college enrollment.

Educational outputs are common and tend to be more straightforward. The most well-known of these output measures are attendance rates, graduation rates, grade point averages, and standardized test scores. Several indices have been attempted, such as the Academic Equity Scorecard, the Attainment Equity Index, and the Educational Equity Index. Information on indices is found in Appendix 1. Each measure provides insight but is individually insufficient for assessing educational equity.

For example, public school attendance is largely associated with a community's demographic makeup. Most communities in the United States were highly segregated during the rise of public education, resulting in highly segregated schools. Public schools also remain largely funded through local property taxes (Reschovsky and Knaff 1977; Noguera et al. 2016).

Consequently, the literature in this field also points to "inputs" as a sign of disparity. Educational inputs refer to the resources that are available for groups of students and their schools. For example, because white Americans often had more valuable homes and paid more in property taxes than African Americans, there has been a substantial disparity in public school funding between schools in predominantly white neighborhoods and schools in predominantly African American neighborhoods, and in overall educational quality in turn (Chemersinsky 2003). The most common method of measuring resources has been examining spending per pupil (Ruggiero et al. 2002; Toutkoushian and Michael 2007). This measure assumes that more spending equates to more available resources and, in turn, better educational attainment. Since it is standardized by student population, this measure can be used to compare single schools, school districts, cities, or any other jurisdiction. Program inputs are a new subject for consideration in our categorization, but one that relates especially to access and output dimensions. The equation for per-pupil spending can be found in Appendix 1.

Per pupil spending is a useful measure but has some limitations. With this measure, it is assumed that investments are being made in the same resources and that these resources have the same relative impact. For example, School A could be spending a most of its funds on teachers, while School B could spend its funds on technological advancements. Both could have a positive impact on outcomes, but their marginal benefit could differ. Secondly, per-pupil spending is also insensitive to the type and level of student need and its historical evolution.

To assess the equity of educational inputs, horizontal, vertical, and categorical equity measures have also been used. The Gini coefficient has been the most common measure of horizontal equity. In the education sector, the Gini coefficient is an indicator of horizontal equity in the degree that schools of the same size and demographic makeup also have the same budget amounts.

Vertical equity in this context refers to a measure of the proportional distribution of school budgets in a district or jurisdiction among schools that vary in size and that are independent of demographic makeup. This has been measured using basic statistical methods such as ratio analysis, correlations, regression, and elasticity. Categorical equity is the idea that the necessary services or treatment should be delivered regardless of ability to pay (Ruggiero et al. 2002). Categorical equity, or wealth neutrality, is also measured using the basic statistical methods correlation, slope, and elasticity. More specifically,

these methods measure the relationship between a school's ability to pay and the services that are provided at that school.

Another resource input, where equity has been explored, is in the distribution of quality teachers. It is a widely-accepted notion that student achievement and the success of a school is dependent, at least in part, by the quality of teachers on staff. Several studies, measuring teacher quality by degrees and qualifications, found that lower-income students are more often taught by teachers with weaker qualifications than higher-income students (Carroll, Reichardt and Guarino, 2000; Clotfelter, Ladd, Vigdor, and Wheeler, 2007).

In sum, educational equity measurement techniques have been developed and utilized to assess output disparities in terms of student achievement, but also to measure input differences in service in terms of the quality of education, program design in terms of resource allocation, and program staff and leadership in terms of the distribution of quality school teachers.

Environment

Environmental equity has traditionally been defined as the equal distribution of both the benefits and burdens relating to the environment. Leading up to the 1960s Civil Rights Movement in the US, it became clear to many African Americans, particularly in the South, that their communities were bearing a large portion of the burdens, while being denied many of the benefits of subsequent environmental protections (Bullard 2018). This led to the formation of the environmental justice movement, grounded in the premise that every individual has the right to a safe and healthy environment and aimed at promoting environmental equity.

Early work in the environmental justice movement focused on describing the historical location and placement of point source pollution and other environmental health hazards. African Americans were systematically forced to live in disadvantageous areas that were either already plagued with or would eventually be subject to the placement of polluting factories, landfills, and hazardous waste sites. As such, these communities were, and many still are, forced to contend with resulting poor air and water quality as well as exposure to environmental toxins and other hazards that significantly compromise the health of community members.

The Environmental Protection Agency's Environmental Justice Screening Tool and the Centers for Disease Control and Prevention's Environmental Health Tracking Network both include numerous indicators of environmental health hazards predominately through exposure rates by geography and, in

turn, demographic and income characteristics. This includes indicators for air quality, drinking water quality, toxic substances, climate change, lead poisoning, cancer, pesticide exposure, and more. The State of California developed a similar resource, the “CalEnviroScreen,” but indexed all exposures to a single score by census tract, summing overall pollution burden by population characteristics. In most cases, these and related measures primarily describe exposure differences or geographic distributions of communities in relation to specific toxic point sources.

Over time, the environmental justice movement has evolved to also advocate for increased access to positive amenities for disadvantaged communities. Some studies point to inequities in the transportation system, revealing differential access to public transportation as well as disproportional exposure to air pollution for communities of color. In addition, there is also evidence suggesting African Americans are more likely to live in food deserts, impeding their ability to eat healthy foods. More recent studies show there is also a disparity in African Americans’ access to public land such as parks and other recreation centers that promote healthy behaviors (Nicholls 2001; Lindsey et al. 2001; Maroko et al. 2009; Walsh-Dilley et al. 2016).

New work in environmental justice has identified different procedural inequities as well as new environmental conditions for study. In the former, for example, there is a new focus on the low representation of different racial groups in large environmental organizations (Taylor 2015). In the latter, there is much growth in the environmental justice movement to advocate for climate justice in the form of beneficial climate mitigation strategies, such as energy-efficiency, green jobs, and renewable energy sources in disadvantaged communities (Reames 2016), and climate adaptation actions (including defensive infrastructure, hazard mitigation, and preparedness resources).

The climate justice movement and the prolonged recovery efforts in post-disaster areas have sparked the desire to measure resilience and improve disaster preparedness in at-risk communities. Several measures of community resilience have surfaced over the last couple decades (Sherrieb et al. 2010; Bullard and Wright 2012). While many of the specific measures differ, it is clear from the literature that researchers believe that a community’s ability to be resilient is determined by a substantial number of factors related to the persistence of structural and institutional disparities.

While environmental equity measurement has been centered around disparities in exposure to environmental health hazards, conversations around the remediation of these hazards have addressed equity in program design, program staff and leadership, intervention options and populations served in preliminary and exploratory ways. There has been an emphasis on making sure that communities are involved in making decisions on strategies to remediate and redevelop toxic land such that community

members can benefit from the restoration. However, it is not clear that specific measurement techniques have been developed sufficiently for environmental program areas.

Summary

Though disparate and unevenly distributed across interventions, scholarship in each of the four areas described above has moved the capacity and quality of measurement techniques forward. These closely follow the measurement dimensions referenced in the general equity literature and are mapped below and in Exhibit 2 to summarize the key lessons from above.

Historical Legacies

For all four subject areas, there have been extensive historical descriptions of disparities in institutional treatments and service provision to different groups. The range of places, times, and disadvantaged groups that are studied varies widely, however. Studies have tended to follow major national policy and legislation, particularly around civil rights legislation starting in the 1960s. In some cases, the historical disparity has been stark and egregious such as through purposeful discrimination. In others, the disparities have been more subtle but harmful nonetheless. In all cases, one past incident of significant inequity can inscribe itself into longer-term inequitable treatment and outcomes, and into a group's perceptions of related interventions and of the underlying institution for some time.

Awareness of Populations

Race, gender, and economic status continue to be the starting characteristics for most analyses of disparity and inequity in the four service areas examined in this report. However, the evolution of civil rights discourse in the US as demonstrated by legislation like the 1990 Americans with Disabilities Act, and with the increasing quality of data and analytical techniques, has uncovered other individual, household, and community traits worth exploring. For example, receipt of public assistance, sexual orientation, household composition, and gender identity are increasingly considered as classes that may suffer from disparate treatment. Variations in health and environmental risks have expanded the scope of population groups suffering from potential disparities to include the elderly, physically challenged, and youth, for example, as well as rural and urban households' differential exposures to negative environmental interventions and the absence of positive ones.

- Two recent analytical approaches add to how we can measure equity. First, the expansion of granular, identifying data has heightened practitioners' and scholars' awareness of the intersections across demographic and related characteristics. Contemporary equity scholarship is conscious of "intersectionality" and how overlapping or aggregated inequity is more complex than the treatment of a singularly and traditionally defined group. Second, a wealth of new ethnographic and behavioral research methods has supplemented geographically determined demographic data sources. This work has helped establish behavioral traits as much as innate identify differences as being potential contributors to the perception of, access to, and participation in services. Both trends suggest new terms and methods for exploring equity in energy efficiency programs.

Inclusion of Other Voices

Across all four areas, there has been an increasing volume of work looking at the demographic representativeness of internal staffing, leadership, and corollary fiduciary stakeholders (such as subcontractors and consultants) in relation to the community served. Health (e.g., doctor populations) and education (teachers and principals) have especially been the focus of inclusive equity, though housing and environmental professionals have received some recent attention as well. In all cases, measures of organizational inclusion tend to equate proportionality with equity.

Regarding practices for inclusiveness among the external community (i.e., community engagement in the design and development of interventions), measurement has been much less straightforward. For non-voluntary services, attempts to document the perceptions and voices of disadvantaged groups are rare beyond advisory boards and focus groups, and, therefore, there have been few opportunities or strategies to measure them qualitatively.

Access Discrimination

There are significant differences in how access equity is measured across the four service areas, ranging from variations in program spending, distributional benefits, and other "inputs" for services deemed to be public goods or rights (such as public education or environmental amenities), to qualitative differences in information provision, personal treatment, and offered options for voluntary services (such as home purchases). Measurement generally focuses on documented disparities in access procedures (such as prohibitive fees, language barriers, or information media) and consistency or compliance with regulations. For voluntary services, inconsistencies in the application of eligibility

requirements (such as charter or private schools) or the requirements themselves could limit access to whole groups.

Output Differences

All four services tended to focus on output or participation measures as the primary measures of equity, if not the only ones. There are numerous reasons for the reliance on outputs and descriptors of participation. First, the data for these tended to be readily available and quantifiable across groups. Second, these measures provide straightforward depictions of disparities that can be easily communicated within an organization and to the communities it serves. Third, these measures are often used to signal that other disparities exist, such as long-serving structural problems or access challenges. Although output or participation differences do not explain the causes of pre-existing disparities or define the impact of any intervention on them, they are used as a helpful indicator.

The complexity of output measurement varies, from basic proportional differences (e.g., different hospitalization rates, school test scores, or toxin exposure rates across groups) to more complex spatially defined differences (segregation indices in housing). In health and education, service quality disparities have also been a focus, necessitating additional measures of quality to monitor disparities in their use and participation.

Disparate Impacts

Service quality also plays a role in defining differences in outcomes, particularly where sufficient data are available to define whether a group's access to certain services (such as high-performing schools) result in equitable outcomes. Because outcomes are reliant on so many factors beyond participation in any one service or offering, though, few programs have undergone the level of measurement, data collection, and analysis necessary to explain differences in outputs or outcomes except where indicators are readily available, such as: housing costs and values; chronic disease rates; or graduation patterns. Even then, the ability to trace the outcome to specific inputs or activities is challenging.

Longer-term impacts that have been assessed in housing and environment include health effects and, in education, financial wealth. However, impact analysis is rare—and impact analysis focused on equity disparities is even less common.

Exhibit 2 provides a summary of the lessons for equity measurement across the four service areas. This review suggests that the bulk of equity measurement has occurred in two of the six suggested

equity dimensions: historical legacies and output differences. First, there is a robust qualitative scholarship on *historical legacies* from incidences of blatant disparity, discrimination, and inequity in all fields. Invariably, this work implies that the past incident has repercussions for contemporary politics, social relations, and economic conditions. Second, *output differences* between groups are common measures for determining underlying disparities.

One explanation for the proliferation of output measures is that they are typically indicators of simple general conditions, such as rates of homeownership, mortality, graduation, and park use. In turn, they become consciously monitored indicators of an intentional intervention such as a housing counseling program, a clinical drug test, an improved school curriculum or reduced park fee policy. These indicators are often basic frequency or rate calculations—e.g., X percentage of all homeowners are African-American, or Y percentage of white households are homeowners while Z percentage of African-American households' own homes. Output measures rely on data that are also relatively easy to collect, analyze across groups, and communicate to lay audiences. However, they do not explain how, why, and to what longer-term consequence an inequity exists.

EXHIBIT 2

Equity Measures and Their State of Analysis in Four Service Areas, by Equity Dimension

| Dimension | Housing | Health | Education | Environment |
|----------------------------------|---|---|--|---|
| Historical legacies | Numerous histories documenting segregationist practices, as well as accounts of the effects of racial segregation and gender roles on housing design and quality. | Histories of different treatment in medical trials, regular treatment, and in group-specific conditions have been written for women and groups of color. | Schooling access, segregation, and quality disparities have been historically documented, particularly in relationship to housing segregation. | Environmental justice scholarship has focused on legacy pollutant source locations and effects and, more recently, environmental amenity access. |
| Awareness of populations | Race and income are the primary focus of geographic segregation, while gender and physical ability have been explored in design. | Race, gender, and income have been a focus, particularly regarding access to and quality of treatment. Also, health-defined classes (e.g. chronic disease or mental health issues). | Race, income, and gender are common focuses of educational equity, along with certain educational groups (like special needs populations). | Environmental effects on disparate populations have been studied primarily in relation to race. |
| Inclusion of other voices | Some study on participatory decision making and charrettes related to housing development, and marketing focus groups for consumer preferences. Little on inclusion in institutions' staffing. | Demographics of medical professionals have been increasingly studied. Nascent civic participation scholarship in health policy and interventions. | Demographics of school boards, principles, and teachers are studied extensively, but much less on representation in educational policymaking or interventions. | Recent demographic studies of environmental scholars and advocacy groups have been published. Some study of organizing among environmental justice groups, as well. |
| Access discrimination | Many housing studies explore discriminatory realty, rental, mortgage lending, and appraisal practices defined by fair housing law. | Income-based access issues (especially around health insurance) and the geographic distribution of health facilities add to historic racial and gender discrimination. | School segregation, busing policies, and entrance exams have been studied. Resource differences (public school finance and extra-institutional supports) are recent measures. | Most environmental equity scholarship has been focused on disproportionate exposure to negative services rather than access to positive ones, though recent study on disparate access to amenities (parks, tree canopies) exists. |
| Output differences | Disparity in homeownership rates and residential location patterns is well documented. The bulk of equity-related measurement in housing is in this dimension, with segregation being the key output. | Birth, disease, and mortality rate differences are a common area of health measurement, along with health behaviors in relation to a treatment. These indicators are common health equity measures. | Enrollments, academic tracks, disciplinary actions, diploma and degree completions are frequent outcomes of interest that are common measures for tracking general educational equity. | Pollutant exposure rates, park usage, geographic distances to amenities, financial barriers to recreation, and hazard vulnerability measures have all been introduced. |
| Disparate impacts | Health and wealth outcome disparities due to housing have been well documented. Impact studies have focused on housing tenure categories (homeless, assisted, burdened, etc.). | Health conditions or outputs are typically outcomes of other areas. Few impact studies except for clinical drug/procedure trials or public campaigns. Contributing factors complicate outcomes. | Employment and income are measures used to distinguish primary, secondary, post-secondary, and workforce educational programs. | The health outcomes and property costs of negative environmental exposures are the more common impact indicators. |

III. Relevance to Energy Efficiency

The review of equity measurement in different service areas treats each area as if it were a single contained system. In that system, multiple actors working across a pool of programs and agencies provide various interventions to different groups. In turn, those interventions are governed by a relatively consistent set of rules and practices. The reality, of course, is vastly more complex. The end consumer, individual, or household understands this complexity but their perceptions of any new intervention is still colored by their past and current relationship to the whole system.

The authors impose a similar frame on the residential energy sector in this paper. Indeed, the energy utilities, suppliers, producers, distributors, consultants, regulators, retail vendors, and other related energy service providers have historically been viewed as a governmental-industrial complex—an aggregate institution—since its inception in modern history (Hughes 1993).

As such, the energy sector can and must be assessed from an equity perspective across a system greater than any one intervention. However, the capacity of a single provider or intervention—namely, a voluntary energy-efficiency program—to improve the overall system’s equity is obviously limited. To that end, the authors look to the range of equity definitions and measurement techniques described in this report to suggest relevant and practical approaches for further exploration.

Historical Legacies

Diving into archives to perform a rigorous historical analysis of different communities’ relationships with energy providers in a specific geography are typically beyond the scope of a provider, public or otherwise. Electricity production and delivery over the last 150 years has had a complex and uneven history across communities despite the apparent neutrality of current fixed utility fees and rates. However, there are time- and cost-effective ways of exploring and understanding historical relationships that may shape participation differences in energy-efficiency programs.

For example, there may be documented cases in which the energy institution itself played a role in creating disparity, such as in the mass displacement of a community for energy production or transmission facilities, underservice or under-maintenance of a power grid or distribution lines to a neighborhood or town, disproportionate energy shut-offs to certain demographic groups, or intentional past discrimination in hiring and business supplier selections. These may be recorded through existing

historical monographs about groups, by local community historians and librarians, in lawsuits and utility commission settlements, or by simply asking leaders among the communities in question.

Measures of the past injustice (e.g., households affected in total numbers and in proportion to their overall population in the community) may be available. Though this exploration may conjure fears of liability or rekindling past grievances, the lack of attention to past injustices could worsen the reception to current and future program offerings.

Awareness of Populations

A historical review of energy services will ideally identify populations that have been underserved or negatively served and provide some insight into the types of services that could repair those relationships. In some cases, though, there may be no documented cases or perceptions around past inequities regarding energy services or institutions. In this case, a general knowledge of disparities in life outcomes (income, health, educational attainment) from other public sources such as the US Census and Energy Information Administration, energy use data from state and local governments, utility commissions, or utilities themselves can lay the groundwork for a more purposive review of service delivery types.

A critical resource for this exploration includes a focus on the collection of data from publicly funded energy service providers, such as the location and household demographic data of recipients of local weatherization community services and Low Income Home Energy Assistance Programs. These provide a wealth of information regarding the range of energy services that may be used by the populations targeted by the energy-efficiency program beyond general demographic information. Where granular information is not available, information aggregated at higher geographies can be used as a proxy.

The identification of any household-level information that describes the relationship between energy services and groups with the service population is potentially useful. Regarding populations of interest, providers should begin with fundamental demographic distinctions—such as race and income—as a reasonable start. Multiple and reasonably relevant demographic groups (such as multifamily versus single-family residential occupants, and owners versus renters) should be considered for more advanced equity analysis.

Inclusion of Other Voices

Like all other service areas, the demographic representativeness of professional program staff, program consultants and supply chain providers, and leadership in comparison to their service population is typically one method for assessing equity from the standpoint of public perceptions and potential bias. Measuring representativeness is a common and simple statistical feat.

Collecting data on the representativeness of voices in designing the program's interventions is another, though more complicated, opportunity to measure and assess equity. In this case, qualitative measures about the quality of engagement (e.g., the level of input and influence on program changes) must supplement quantitative measures of representativeness. Typically, this is measured as the proportionality of individuals providing input compared to the general population—though overrepresentation of certain groups may be preferable. In some cases, program eligibility or requirement such as upfront costs can change based on this inclusiveness.

Access Discrimination

Programs could review the eligibility requirements and procedures by which they currently market, solicit, recruit, and process applicants to identify potential differences in program receipt. In some cases, culturally appropriate materials, messages, and recruitment practices can be more effectively employed if market surveys or focus groups denote a difference in perceptions or reactions. The program's own monitoring systems may also note attrition along the access continuum from marketing, through application and approval, and measure execution.

Where sufficient numbers of participants from different groups exist in the program's pipeline, paired-testing techniques such as those used in housing and employment discrimination testing may also be used to reveal differences in call-backs and other customer service, application, and approval techniques, along with customer feedback. In all cases, tying perception and access data to as many demographic, geographic, and other identifiers as feasible can help make this analysis more accurate and the measurement of disparities more robust. Programs should prioritize the collection of information on the communities perceived to be disadvantaged historically.

Differences in the implementation of a specific intervention—for example, longer outreach and engagement periods for the elderly or households with children—could improve uptake rates for underserved populations. However, providing different levels of implementation where they are not warranted could exacerbate outcome disparities. Focus groups and surveys are ways of assessing

appropriate difference in implementation before the intervention is launched, and customer satisfaction surveys are often ways to measure the appropriateness of differences after.

Other measures such as program spending for different participants across all service programs or offerings can also describe how an organization's efforts limit access.

Output Differences

General energy use patterns across different groups are a well-studied phenomenon. The more complex equity analysis involves an assessment of participation rates across all interventions to better understand how the local energy system supports different communities and the incremental contribution of any specific intervention. Ensuring a breadth of interventions for different populations' needs can help overcome some of the population barriers that lead to disparate treatment effects since, in the aggregate, certain populations are better served by different interventions.

This analysis requires measurement of the proportional participation for (1) all offerings in total against the full population and group proportions; (2) clusters of offerings that are equivalent or similar in terms of their intensity of implementation by participant groups; and (3) individual offerings as measured by proportions of all eligible participants. In many cases, extensive demographic data are not available for participant analysis because of perceived access barriers—though simple program testing can determine whether these barriers are real and, if so, whether demographic information can be collected at other points in time through surveys, program agreements, or related administrative data.

Outcome Disparities

Outcome measurements are already known among energy-efficiency programs and are typically measured in terms of proportional participation rates for individual offerings or services, such as fuel types; energy costs, savings, and consumption; and energy burdens. Measuring the final expected objectives (e.g., lower energy consumption or intensity for serviced households) across the service population as well as the eligible population against the overall eligible population are ways that disparate impacts can be studied and eventually reduced. In this case, ongoing energy data for all program participants is required along with subgroup demographic and geographic information.

Practical measures of outcome disparities can compare mean outcome differences between the participants among the groups of interest because of all energy-efficiency services, since multiple offerings can contribute to the same outcomes.

Summary

Possible applications of equity measures from other service areas in the world of contemporary energy-efficiency programming will vary widely based on numerous factors. Local pre-existing geographic and income disparities will determine the context into which energy-efficiency interventions are introduced, as well as the potential benefits that could be accrued across groups. Ideally, those benefits would accrue to those groups that have been historically disadvantaged in the program's service territory. Or, at the very least, programs should seek not to exacerbate the groups' disadvantages. A summary of preliminary suggestions for how the six dimensions of equity relate to energy efficiency is provided in Exhibit 3.

The range of concepts and their relevant measures, however, requires some qualification. Collecting data and assessing them for the full range of measures across these measurement dimensions is time intensive and can be costly. There may also be legal, regulatory, or programmatic reasons for not collecting detailed information about participant households or the energy performance of their housing.

Measurement must start somewhere. Starting with existing data sources and easily calculated measures is reasonable, but intentionally avoiding the measurement of activities or groups that are likely locations of inequity is unscientific and unethical. Attempts to measure equity comprehensively must be matched with efforts to overcome these data collection and analysis barriers through program and methodological innovations. Ultimately, equity measurement requires honest and holistic reflection.

Equity measurement must also be intentional. This white paper should not conclude without also giving thought to the overarching purpose of measurement. Measurement may be performed for the simple purpose of monitoring conditions over time. Yet, equity measurement is inherently less passive. Equity measurement is actionable. If inequity is assessed through the tools of measurement, the need to redress it is imperative. Consequently, the omission or inability to inquire and observe where and how disparities surface across all the dimensions presented here should not lead to inaction.

EXHIBIT 3

Equity Dimensions and Energy Efficiency

| Dimension | Hypothetical inequity examples | Possible equity-related measurements | Data sources and methods |
|----------------------------------|---|---|---|
| Historical legacies | <ul style="list-style-type: none"> Takeover of tribal land to build hydroelectric dam Siting of transmission substation in low-income community Poor maintenance of electric distribution lines in African-American communities | <ul style="list-style-type: none"> Recorded incidences, policies, or programs leading to inequitable or disparate conditions in relation to energy systems and institutions Longitudinal differences in energy use or intensity across groups | <ul style="list-style-type: none"> Documented histories Oral histories Focus groups Past administrative or policy data. |
| Awareness of populations | <ul style="list-style-type: none"> No familiarity with local Weatherization and LIHEAP recipient rates Lack of tailored programs for groups with different energy-use needs No exploration of energy behavior variations | <ul style="list-style-type: none"> Basic community demographic and composition by race, income, and other relevant factors Energy consumption patterns by group Housing quality status by group Participation in any energy program across groups | <ul style="list-style-type: none"> General tabulations of local populations of interest Secondary Data Sources (Energy Information Administration, American Community Survey) Proprietary Data Sources (Utility records) Customer surveys |
| Inclusion of other voices | <ul style="list-style-type: none"> Lack of community representation on governing boards All white staff No process for representative community engagement in designing EE program | <ul style="list-style-type: none"> Proportion of staff, contractors, and program leadership demographically in relation to service population Representativeness of population input for intervention design | <ul style="list-style-type: none"> Staff, leadership, and governing bodies' recruiting, hiring, and retention records Focus group consent and surveys |
| Access discrimination | <ul style="list-style-type: none"> Different electric rates across groups Expensive or burdensome EE program participation costs English-only outreach materials for a multilinguistic community Single-family homeowner only program | <ul style="list-style-type: none"> Cost accessibility sensitivity tests Media hits for marketing materials by viewer demographic Eligible populations as proportion of service population | <ul style="list-style-type: none"> Access or application process analysis for a specific service Marketing "hits" Disparities in access rates against the proportions in the general population or the targeted groups. |
| Output differences | <ul style="list-style-type: none"> Completed EE-intervention households not reflective of eligible population Participation rates across all EE programs not reflective of general population Targeted program resources not commensurate with population size | <ul style="list-style-type: none"> Attrition records from application to completion of intervention Proportional differences between completion rates and eligible or general population (and proportion of subgroup) Implementation fidelity | <ul style="list-style-type: none"> Monitoring data Appliance purchase records Inspection data Paired-test findings |
| Disparate impacts | <ul style="list-style-type: none"> Household energy burdens vary across groups Energy poverty behaviors persist Health benefits from EE programs accrue to certain groups only | <ul style="list-style-type: none"> Energy use or intensity Household utility savings Peak load contributions Frequency of specific energy-related behaviors | <ul style="list-style-type: none"> Utility data Household survey |

Appendix A. Measurement Practices in Other Services

The following discussions elaborate on some of the statistical methods introduced in Section II.

Housing equity measures

Measures of evenness assess the differential spatial distribution of two given social groups. Maximum evenness occurs when every area contains an equal proportion and spatial distribution of both social groups, while an uneven area is one where the residents of the two groups are completely separated (Massey and Denton 1988). There are several methods of measuring unevenness, of which the index of dissimilarity is the most common. This index measures the proportion of the minority group that would have to change their place of residence in order to achieve the theoretical maximum of evenness (Clark 1986; Massey and Denton 1988; Sander 1997; Burton 2003; Krivo and Kaufman 2004; Anacker et al. 2017). The Gini coefficient, the entropy index, and the Atkinson index are also methods of measuring evenness.

All four of these measures have values that range from zero to one (Massey and Denton 1988). Only the Gini coefficient and the Atkinson index meet each of the four criteria developed by Schwartz and Winship to assess the robustness of inequality indices. The criteria include the principles of transfers, in which the measure captures all spatial transfers and not just the transfers from overrepresented areas to underrepresented areas; compositional invariance, in which the measure is insensitive to the relative number of minority individuals; size invariance, which means that the measure is unaltered when multiplied by a constant; and organizational equivalence, in which the measure remains the same even when units of the same minority composition are combined. Understanding the impact of the above criteria is not particularly relevant for this discussion. However, it is useful to note the various considerations when developing indices/measures of inequality.

$$\text{Index of dissimilarity: } D = \frac{\sum_{i=1}^n \{t_i | p_i - P|\}}{2TP(1-P)}$$

t_i and p_i are the total population and minority proportion of area unit i , and T and P are the population size and minority population of the whole area, subdivided into n areal units.

$$\text{Gini index: } G = \sum_{i=1}^n \sum_{j=1}^n \left[\frac{t_i t_j | p_i - p_j |}{2T^2 P(1-P)} \right]$$

t_i and p_i are the total population and minority proportion of areal unit i , and T and P are the population size and minority population of the whole city, subdivided into n areal units. t_j and p_j are the total population and minority proportion of areal unit j .

$$\text{Entropy: } E = (P) \log\left(\frac{1}{p}\right) + (1 - P) \log\left(\frac{1}{(1 - P)}\right)$$

Entropy represents the degree of racial and ethnic diversity within a city and/or areal unit. The entropy index is the weighted average deviation of each unit's entropy from the citywide entropy. The above equation depicts a city's entropy.

$$\text{Atkinson index: } A = 1 - \left[\frac{P}{1 - P} \right] \left[\sum_{i=1}^n \frac{[(1 - p_i)^{1-b} p_i^b t_i]}{PT} \right]^{1-b}$$

b is a shape parameter that determines how to weight the increments to segregation. For $0 < b < 0.5$, areal units where $p_i < P$ contribute more to segregation. For $0.5 < b < 1.0$, units where $p_i > P$ contribute more to segregation. b is set by the analyst depending on how they view each population group's contribution to segregation. The default b is 0.5, which assumes that each population contributes equally to segregation.

Exposure, the second category of measures of segregation, examines the degree of potential contact or possible interaction between the minority and majority populations. Exposure has been conceptualized as the likelihood of the minority and majority sharing the same neighborhood and serves as an attempt to capture the experience of segregation. The isolation index and the interaction index are two measures of residential exposure. The former measures the degree of isolation of one social group degree, while the latter measures the degree of exposure of that social group to another. Both indices have a range between zero and one and are interpreted as the probabilities that contact will be made between members of two or more groups. When measuring two groups, the sum of the probabilities of all groups will equal one. In measures of exposure for 3 or more groups, the sum of the probabilities will only equal one after the isolation index is added as well.

$$\text{Interaction index: } {}_x P_y^* = \sum_{i=1}^n \left[\frac{x_i}{X} \right] \left[\frac{y_i}{t_i} \right]$$

x_i , y_i , and t_i are the number of X members, the number Y members, and the total population of unit i , respectively. X represents the number of X members citywide.

$$\text{Isolation index: } {}_x P_x^* = \sum_{i=1}^n \left[\frac{x_i}{X} \right] \left[\frac{x_i}{t_i} \right]$$

x_i and t_i are the numbers of X members and the total population of unit i , respectively. X represents the number of X members citywide.

Also, important in the discussion of examining residential segregation is the degree of concentration among minority and majority members. Concentration as a measure considers the relative amount of physical space occupied by both the minority and majority populations. For example, one city may be considered more segregated than another, despite their having equal proportions of minority members (evenness) and equal spatial distribution (exposure), because the minority populations occupy less physical space within the area. Duncan, Cuzzort, and Duncan (1961) proposed a

measure, delta, that assesses the number of minority members that would have to move to achieve equal density of minority members of all spatial units. Ranging from zero to one, delta measures the absolute geographic concentration of the minority group irrespective of the concentration of the majority group (Massey and Denton 1988):

$$\text{delta: } DEL = \frac{1}{2} \sum_{i=1}^n \left| \left[\frac{x_i}{X} - \frac{a_i}{A} \right] \right|$$

X is defined as the number of X members citywide and x_i is defined as the number of X members per unit i . A represents the total land area of the city, and a_i is the land area of unit i .

The fourth category of residential segregation measures is centralization, or the proximity of a social group to the urban center. For decades, central city areas were undesirable and thus minority populations often settled into these areas in large concentrations. More recent migration into central cities in the form of gentrification has altered this notion. Regardless, centralization remains a useful measure of segregation because income and wealth differences among racial and other social groups impact who can live in the rapidly growing and increasingly unaffordable urban centers. The most widely used measure of centralization is the number and proportion of a social group residing within the boundaries of the city. However, this measure has been criticized because city boundaries are often variable and politically driven. Another measure is the relative centralization index, which varies from -1.0 to +1.0. Positive values of this index indicate that the minority group has more representation closer to the city center than the majority group and vice versa for negative values. A value of 0 indicates that both groups have the same spatial distribution relative to city center.

$$\text{Total group population that live within the city boundaries: } PCC = \frac{x_{cc}}{X}$$

x_{cc} is the number of X members living within the boundaries of the central city.

$$\text{Relative centralization index: } \left(\sum_{i=1}^n X_{i-1} Y_i \right) - \left(\sum_{i=1}^n X_i Y_{i-1} \right)$$

n represents the number of areal units. X_i and Y_i are the respective cumulative proportions of X 's and Y 's population in tract i .

Clustering is the last category of residential segregation measures and refers to the degree to which unique collections of a single social group are both adjacent to one another in space and not separated by collections of other social groups. There are several measures of clustering including the measure of

absolute clustering, which utilizes a contiguity matrix to determine whether two spatial units are neighboring; a spatial proximity measure, which examines the average proximity among members of the same group and among members of a different group; and a distance-based interaction index, which attempts to adjust for evenness and exposure.

$$\text{Absolute clustering index: } ACL = \frac{\{[\sum_{i=1}^n (\frac{x_i}{X}) \sum_{j=1}^n (c_{ij} x_j)] - [\frac{X}{n^2 \sum_{i=1}^n \sum_{j=1}^n c_{ij}}]\}}{\{[\sum_{i=1}^n (\frac{x_i}{X}) \sum_{j=1}^n (c_{ij} t_j)] - [\frac{X}{n^2 \sum_{i=1}^n \sum_{j=1}^n c_{ij}}]\}}$$

c_{ij} is the element in a contiguity matrix that equals 1 when units i and j are adjacent and 0 if not. c_{ij} may also be represented as the negative exponential of the distance between the centroids of areal units i and j ($c_{ij} = \exp(-d_{ij})$). x_i and x_j represent the number of x members in areal units i and j . t_i and t_j are the total population in areal units i and j .

$$\text{Average spatial proximity between members of group } X: p_{xx} = \sum_{i=1}^n \sum_{j=1}^n \frac{x_i x_j c_{ij}}{X^2}$$

c_{ij} is represented as the negative exponential of the distance between the centroids of areal units i and j ($c_{ij} = \exp(-d_{ij})$). x_i and x_j represent the number of x members in areal units i and j . t_i and t_j is the total population in areal units i and j . X is the total number of individuals in group X .

$$\text{Average spatial proximity between members of group } X \text{ and } Y: P_{xy} = \sum_{i=1}^n \sum_{j=1}^n \frac{x_i x_j c_{ij}}{XY}$$

c_{ij} is represented as the negative exponential of the distance between the centroids of areal units i and j ($c_{ij} = \exp(-d_{ij})$). x_i and x_j represent the number of x members in areal units i and j . t_i and t_j is the total population in areal units i and j . X is the total number of individuals in group X .

$$\text{Distance - adjusted interaction index: } DP_{xy}^* = \sum_{i=1}^n \frac{x_i}{X} \sum_{j=1}^n \frac{K_{ij} y_j}{t_j} \text{ where } K_{ij} = \frac{\exp(-d_{ij}) t_j}{\sum_{i=1}^n \exp(-d_{ij} t_j)}$$

i and j represent members of areal units i and j . t_j is the total population of areal unit j . x_i and y_j are defined as the number of group X members in areal unit i and the number of group Y members in areal unit j . $\exp(-d_{ij})$ is the negative exponential of the distance between the centroids of areal units i and j .

Health equity measures

The Gini coefficient and the Kakwani index represent examples of how equity is measured in the health sector. The Gini coefficient can be interpreted in the health sector in several ways including the distribution of access to health services and the distribution of health care payments. The Kakwani index measures how progressive a health care system is by measuring the proportion of health care payments to income.

$$Gini: G = \frac{1}{2I^2\mu} \sum_{i=1}^I \sum_{j=1}^n |h_i - h_j|$$

h represents the average access to health services, I is the total number of groups, and μ is the mean access to health services for all groups. i and j represent population groups i and j .

$$p_k = C_{pay} - G_{pre}$$

G_{pre} is the Gini coefficient for pre-payment income, and C_{pay} is the concentration index for payments, which measures the cumulative proportion of the population compared to the cumulative proportion of health care payments. A system is considered progressive if the proportion of health care payments grows in proportion to income growth.

Educational equity measures

Spending per pupil is a common method of examining equity in the education sector. For equity to be achieved, schools, school districts, and other jurisdictions should allocate resources depending on the number of students and irrespective of demographic factors such as income and race. The Academic Equity Scorecard incorporates measures of access, retention, institutional receptivity, and excellence, to examine equity in higher education (Hao 2002) as they are apportioned across racial and ethnic groups. The range of possible values for these measures runs from zero to infinity with a score below 1.0 signaling underrepresentation, above 1.0 indicating overrepresentation, and 1.0 equaling perfect equity. (Bensimon et al. 2003).

The Attainment Equity Index was developed based on a Gini coefficient model to assess whether the range of exam grades among students in a school was distributed proportionately based on the distribution of the groups being compared (Kelly 2012). The Educational Equity Index (EEI) was created in 2004 to compare equality of educational opportunities, particularly in higher education systems of the US and Canada (Usher 2004). EEI measures the distribution of socioeconomic status by comparing the students' SES (using father's highest education level as a proxy) to the overall SES of the population.

$$Spending\ per\ pupil = \frac{amount\ of\ resources}{total\ number\ of\ students}$$

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He has coauthored three papers on energy efficiency: “Energy Efficiency as Energy Justice: Addressing Racial Inequities through Investments in People and Places” (*Energy Efficiency Journal*, 2019), *De-weathering through Weatherization: A Conceptual Application of the Weathering Hypothesis to the Household Energy and Stress Nexus* (ACEEE Summer Study on Energy Efficiency in Buildings, 2018), and *Achieving Health and Social Equity through Housing: Understanding the Impact of Non-Energy Benefits in the United States* (Green & Healthy Homes Initiative, 2017). He was named one of the 2018 Linda Latham Scholars by the American Council for an Energy-Efficient Economy for showing promise in the energy efficiency field. Lewis has also conducted extensive research on the potential for healthy homes interventions to prevent in-home falls among older adults, both improving resident health and reducing the related health care costs. Lewis is dedicated to improving the health and well-being of vulnerable populations through fostering a healthier environment. He graduated from the Columbia University Mailman School of Public Health’s Department of Environmental Health Sciences in May 2018 with a certificate in molecular epidemiology and was recognized as one of the university’s top graduates in the 2018 graduating class.

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