Quantitative Measurement of Advances in Energy Equity: Application of Distributional Weighting

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ABSTRACT

As agencies and programs focus on measuring improvements to energy equity, both program designers and evaluators typically consider not only the distribution of investments, but also the economic utility (usefulness) of the savings that accrue to different program participants and ratepayers. Distributional weights, based on the theory and empirical evidence of marginal economic utility with respect to income, can provide a mechanism for estimating this utility.

Economists have long agreed that the utility (value) of money to a person depends at least in part on that person's income. In other words, an extra dollar has more utility (e.g., ability to purchase something of immediate use) to someone who has $100 than to someone who has $100,000. Moreover, empirical data demonstrate an "inequality aversion" in society; eliminating inequality has an explicit economic value. Building on this foundation, distributional weights have been used in other contexts (e.g., tax policy) to assess the benefits to society specifically associated with reducing inequality (improving equity). For energy programs, distributional weights offer a way to calculate and communicate the impacts of specific investments that reach underserved households.

This paper documents the economic theory and empirical research that supports the design of distributional weights for the energy context. The paper then describes the application of these weights in a tool developed to assess the equity impacts of on-bill savings in homes and communities across California. Finally, the paper notes key considerations in ensuring the effective development and use of distributional weights in different programmatic and policy contexts.

Introduction: The Limits of Benefit-Cost Analysis in Considering Equity

For decades, benefit-cost analysis has been used by analysts across federal and state agencies to determine whether government policies and programs increase the overall welfare of society. In the case of energy efficiency programs, benefit-cost analysis (or cost-effectiveness testing) is often used by regulators and evaluators to determine whether programs are justifying the overall cost of the programs to ratepayers.[2] Traditional benefit-cost frameworks applied by federal and state agency analysts and

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[2] Different versions of benefit-cost and cost-effectiveness tests are applied in different situations, and employ different constraints on which benefits and costs are included in determining the final value. Common cost-effectiveness tests used by utilities and regulators that consider benefits to program participants and others include Total Resource Cost (TRC) Test (the costs and benefits to utility system and impacts on program participants); Societal Cost Test (TRC Test impacts plus impacts on society); and Participant Cost Test (Costs and

evaluators focus on the net benefits (total monetized benefits minus total costs) or on benefit-cost ratios to provide a single consolidated value of program impacts. If net benefits are greater than zero (or if a benefit-cost ratio exceeds 1.0), a policy or program is assumed to be "economically efficient," providing an overall positive impact to society (i.e., an increase social welfare), regardless of how the benefits and costs of the policy accrue to different communities or populations.

Though it is not often stated explicitly, this focus on net benefits and positive benefit-cost ratios in traditional benefit-cost analysis is built on the "Kaldor-Hicks" criterion, which asserts that a policy or program is worthwhile if those who benefit from the policy have accrued sufficient benefits to compensate those who bear the costs (Farrow 2009).[3] That is, a policy is beneficial if the gains to the those who benefit outweigh the impacts on those whose situation worsens, because the gains will be redistributed in the economy. In practice, the beneficiaries of a policy rarely compensate those who do not benefit. For example, participants in energy savings programs (e.g., homeowners purchasing new technologies) are not likely to pass on a portion of their savings to non-participants (e.g., renters who do not qualify).[4] However, as long as overall savings are documented across the program or system, the program can pass the benefit-cost tests.

Because this traditional benefit-cost framework is unconcerned with the distribution of resources and benefits across different populations, it is not well designed to explicitly measure the value of policies that improving the distribution of resources by more equally, or more equitably, arraying benefits. It is not, however, correct to say that traditional benefit-cost analysis does not use weights. By focusing on the aggregate net benefits of policy, traditional benefit-cost analysis, in effect, *weights monetized benefits and costs equally for all segments of the population*, even when the baseline circumstances differ greatly across populations, and changes due to the program may align with (and be affected by) other important factors such as poverty or baseline exposure to negative impacts. For example, while market-rate households that upgrade appliances under a program will receive energy savings benefits, populations that do not have the financial resources to participate in programs may also be using older, less efficient appliances in the baseline, incurring higher costs than "average" to operate and, in some cases, enduring negative health effects. Installing new appliances in these households could have more significant changes on energy bills as well as greater impacts on quality of life. Finally, the dollars saved on energy and the new appliance functionality might have an impact on quality of life such as access to more nutritious food.

The equal-weight approach in traditional benefit-cost analysis effectively assumes that the economic utility from an additional dollar of income is constant across all individuals and households in all demographic groups, suggesting, for example, that a $100 increase in income is as valuable to a multi-millionaire as to someone living below the poverty line. In effect, by eliminating weighting from its equations, the traditional CBA approach *implicitly applies an equity weight of zero*.

Economists, however, have long agreed that the value of money, viewed in terms of its utility to the person holding it, depends at least in part on the person's income. In other words, an extra dollar has more utility (e.g., ability to purchase something of immediate use), and is therefore more valuable, to someone who earns $1,000 a month than to someone who makes $10,000 a month and already has accrued all necessities. Moreover, empirical data have demonstrated a broad "inequality aversion" in society; eliminating inequality has an explicit economic value. This presents both a challenge and an

benefits to program participants. Other cost-effectiveness tests focus on utility operations and rate impacts, but not on direct impacts and benefits to participants.

[3] A more rigorous, and in some ways simpler, test of a policy's economic benefit is ensuring that it is "Pareto optimal," or structured in such a way that the effects are neutral or positive for everyone. However, many regulations are designed to correct market failures (e.g., emissions or waste that is polluting communities) by increasing requirements on businesses to ensure safety or health, making Pareto optimality difficult to achieve.

[4] The argument that energy efficiency programs benefit everyone by reducing capacity costs across bills is legitimate but does not materially redistribute benefits toward non-participants.

opportunity to regulators and the administrators of energy programs, who are increasingly challenged to explicitly calculate and communicate the monetary benefits of specific investments in disadvantaged and low-income communities, including difficult-to-measure but potentially significant non-energy impacts.

One approach to this issue, building on economic theory, is to apply differential weights to monetary benefits enjoyed by populations with higher and lower income and resources. This is interchangeably referred to as distributional weighting, welfare weighting, or, as here, equity weighting.

In recent years, issues such as climate change, income and wealth inequality, access to health care and resources, and the concentration of environmental and economic burdens in communities of color and communities with limited resources have become central challenges for policymakers. In the last decade, California's Clean Energy and Pollution Reduction Act (SB 350) and Equity in Clean Energy Investments (AB 523) mandate that the state both achieve rigorous renewable energy procurement goals and ensure that at least 35 percent of the benefits of its technology development and deployment funds reach disadvantaged communities (DACs) and low-income communities. New York's 2019 Climate Leadership and Community Protection Act has a similar goal of transforming New York's energy economy, and a similar requirement to ensure that 40 percent of benefits accrue to disadvantaged communities. Most recently, the Biden White House has launched Justice40, a government-wide effort to ensure that policies pursued by the administration and government agencies are benefitting underserved communities. These high-profile laws and initiatives share a critical goal: an explicit distribution of resources to address and correct market disparities and improve energy and economic equity. In this context, measuring the extent to which policies have added value by improving this distribution is critical.

To assist this effort, distributional (equity) weights provide a method for calculating and communicating the differential impacts of specific investments in disadvantaged and low-income communities, particularly those with direct on-bill or fuel savings (i.e., measurable monetary savings) to households. This paper provides a brief overview of the theory and structure of equity weighting, and describes a method and tool developed for the California Energy Commission to help evaluate the equity impact of its Electric Program Investment Charge (EPIC) portfolio investments.

Foundations for Equity Weighting: Economic Theory and Empirical Research

Economists have long recognized that a dollar has more value – or utility – to a person or household with limited resources than to a wealthier person. In the 1960s and 1970s, economists explored the theoretical foundations of inequality measures, drawing connections between social welfare, individual utility, and the theory of choice under uncertainty (Atkinson 1970, Rothschild and Stiglitz 1972).

The Atkinson parameter and the Atkinson index. A key element in identifying the value of equity is determining how utility changes across different income groups. The formula for calculating the weights to assign to different income groups in policy analysis relies primarily on a parameter first defined by Anthony Atkinson in 1970. Atkinson's work focused on measuring income inequality so that he could compare different income distributions across regions or time periods. Noting that existing measures of inequality often gave conflicting results when comparing the same income distributions, Atkinson proposed a new measure based on the relationship between social welfare and income. Drawing from literature analyzing decision-making under uncertainty, Atkinson (1970) defined the social welfare function as "increasing and concave" with respect to income. In other words, additional resources have a smaller effect as wealth increases (Figure 1). Atkinson further proposed that the shape of the curve (the "degree of concavity" of the social welfare function) be represented by a parameter, ε, defined as "a measure of the degree of inequality-aversion—or the relative sensitivity to transfers at different income levels."[5] In other words, the higher the value of *ε*, the more the overall social welfare could be increased by transferring wealth from a high-income group to a low-income group. Atkinson was the first to suggest that social aversion to inequality might be expressed by a single parameter, laying the theoretical foundation for equity weighting.

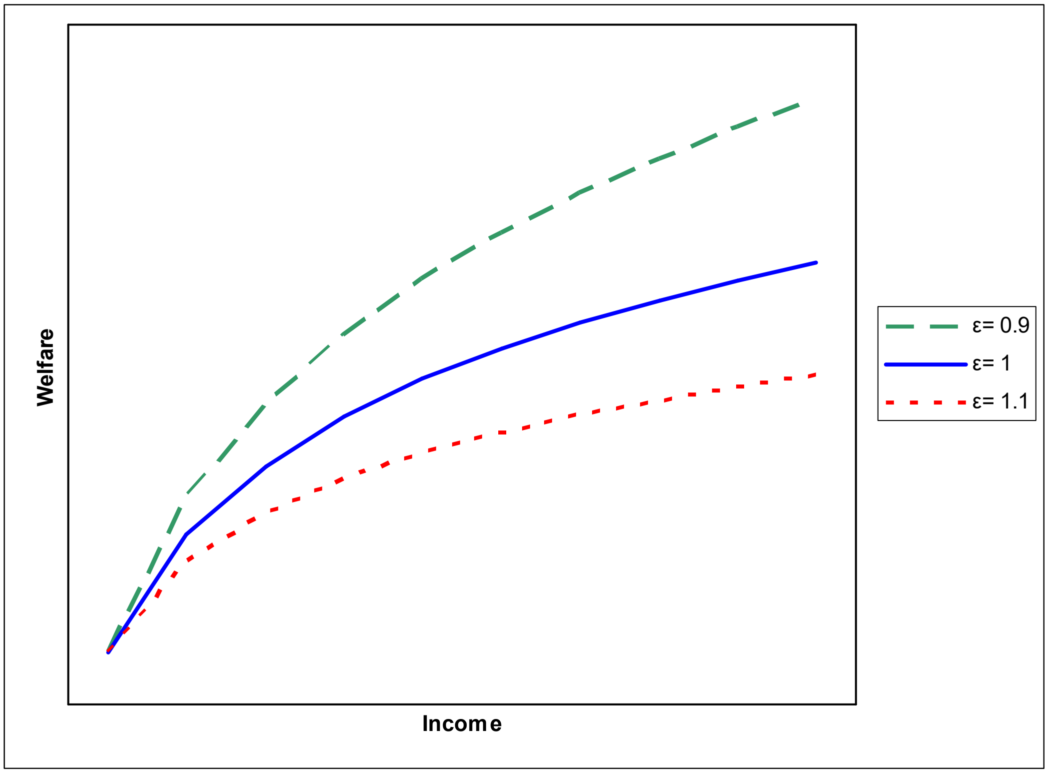

Figure 1. Welfare as a Function of Income for different values of *ε. Source:* Adapted from Atkinson 1970.

Atkinson used the inequality aversion parameter to develop an index for characterizing income inequality.[6] Atkinson's inequality index has values ranging from 0 to 1 and can be interpreted as "the

[5] Specifically, Atkinson drew a parallel between measuring social welfare as a function of a distribution of incomes and measuring individual preferences as a function of a distribution of probabilities of different outcomes. He concluded that to assume that social welfare is concave with respect to income is equivalent to assuming that a person is risk-averse. This concept will be addressed in greater detail below.

[6] To develop the inequality index, Atkinson first identified the "equally distributed equivalent" level of income (yEDE), defined as "the level of income per head which if equally distributed would give the same level of social welfare as the present distribution." The value of yEDE depends both on the degree of inequality in a particular income distribution and on the value of ε chosen, with higher ε values corresponding to lower yEDE values, all else equal. The yEDE corresponds to the amount of income that a person would be willing to accept in lieu of a distribution of incomes associated with different probabilities. Just as the certainty equivalent decreases as an individual's risk aversion increases, so does the yEDE decrease as society's aversion to inequality increases. The index is calculated as (μ= mean income for the population) (Atkinson 1970).

amount of income [in percentage terms] that could be given up but the same level of social welfare achieved if incomes were equally distributed" (Farrow 2009). Because the index value is a function of society's aversion to inequality, it depends on the value of ε chosen. The U.K. Treasury recommends using an ε value of 1.2, while the U.S. Census presents the Atkinson Index using ε values of 0.25, 0.50, and 0.75.[7]

Inequality Aversion and Utility. Atkinson's framing of the parameter ε as a measure of a society's benefit from reducing inequality has a clear logical link to the concept of equity weights.[8] However, different researchers have interpreted ε to represent different economic factors. In the literature, this same parameter has represented risk aversion, the elasticity of the marginal utility of income (i.e., how the value of a dollar changes), and the elasticity of inter-temporal substitution over time (i.e., how the difference between having something today or later changes value). Although the explanations for the parameter differ, these different interpretations are assumed to be equivalent in value and function. Researchers and policymakers seeking to identify the proper value of ε to use in weighted benefit-cost analysis have taken advantage of this equivalence assumption, drawing on empirical studies based on several interpretations of ε. While the space here is too limited to trace the different approaches in detail, a thorough discussion of the different economic approaches to the development and application of equity weighting, and the different moral and ethical assumptions that underpin the research, is provided in two 2016 articles crafted by Marc Fleurbaey and Rossi Abi-Rafeh, and Matthew D. Adler as part of a symposium on distributional considerations in benefit–cost analysis.[9]

This paper, and the method developed for examination of energy equity impacts in California, focuses on the approach to estimating the value of ε that was developed by Richard Layard, Stephen Nickell, and Guy Mayraz (Layard et al. 2008). Layard and his colleagues focused on utility, and examined patterns of wellbeing relative to income as documented in six large surveys of subjective happiness, involving data from participants over three decades (1972 – 2005) and across 50 countries. From this data set, they were able to derive an estimate of ε as the elasticity of marginal utility with respect to income.

Formula for equity weights

The generic social welfare function proposed by Atkinson provides a basis for estimating welfare weights for individual income groups. As described by Farrow (2009), integration of Atkinson's welfare function yields the following formula for estimating the marginal welfare benefit associated with a change in income:

$$(1)\quad \frac{U_i'}{\overline{U'}} = \left(\frac{y_i}{\overline{y}}\right)^{-\varepsilon} = \left(\frac{\overline{y}}{y_i}\right)^{\varepsilon}$$

Where:

$\frac{U_i'}{\overline{U'}}$ = the welfare weight for a given individual or group, or the relative marginal welfare of an individual or group, compared to the mean,

y_i = the income of a particular individual or group,

$\overline{y}$ = the mean income of the population, and

ε = the Atkinson parameter of inequality aversion.

In other words, the size of the weight to assign to a particular group depends on the group's relative income (compared to the population mean income) and a measure of society's aversion to inequality.

[7] The U.K. Treasury recommendation can be found in H.M. Treasury 2020. The range of ε values used by the U.S. Census is noted by Farrow 2009 and can be found in Denavas-Walt et al. 2009, and U.S. Census publications.

[8] Discussion continues about the correct formula for weights (See, for example, Van der Pol et al (2017)). However, Atkinson's work and related approaches remain the most broadly applied approach.

[9] The articles in the symposium are Adler (2016), which introduces distributional weights centered around the concept of the social welfare function (SWF), Fleurbaey and Rafeh (2016), which examines how distributional weights can be introduced into benefit–cost analysis, and Robinson, Hammitt, and Zeckhauser (2016), which describes the role of distributional considerations in U.S. regulatory analyses, providing context for the economic discussions. Together these articles provide a readable overview of the theory and use of equity weights.

ε as the elasticity of marginal utility with respect to income. Economists generally define social welfare (i.e., the welfare of society at large) is an aggregation of individual welfare or happiness. However, a person's total welfare is almost impossible to objectively measure. As a result, economists typically assume that it is a function of utility, defined as "a measure of the level of satisfaction or well-being arising from particular baskets of goods, or from a given money income" (Cowell and Gardiner 1999).[10]

The critical link in economics between *ε* and the marginal utility of income rests on the assumption that social welfare is an aggregation of individuals' utility functions. Again, a basic precept of microeconomics is the diminishing marginal utility of income, meaning that for every additional (marginal) unit of income (e.g., dollar) that an individual earns, the less utility, and the less satisfaction, is gained from that additional unit of income (Harberger 1978). This assumption implies that individual utility functions operate similarly to Atkinson's inequality aversion curve (i.e., the curve "flattens" at higher incomes). The change in the slope (the "degree of concavity") is defined by the elasticity of marginal utility with respect to income (as previously shown in Figure 1).

Defining *ε* in terms of utility has an clear link to equity weighting. If changes in utility decrease as income increases, policies that benefit low-income individuals more have a greater impact. A larger elasticity of marginal utility with respect to income therefore implies and aligns with a larger "inequality aversion" as defined by Atkinson, because the social benefit of increasing lower incomes will be much greater than the social benefit of increasing higher incomes.

Estimates of ε found in the literature by different methods. This paper, and the equity weighting tool developed for the California Energy Commission, employ the values derived by Layard et al. (2008). To ensure that these values are both robust and appropriate for use in the energy evaluation context, the authors conducted a broad review of the equity weighting literature and compared both the methods and results of Layard's research with the work of other researchers using other methods. This section briefly summarizes that comparison, and notes the limitations of different approaches. Importantly and somewhat surprisingly, the results of the different methods are remarkably consistent.

The methods used to estimate the value of ε depend on the definition of ε employed. Some attempt to directly measure individuals' attitudes toward income inequality through surveys, while others focus on the relationship between inequality aversion and risk aversion and estimate individuals' attitudes toward risk. A number of "revealed preference" studies attempt to estimate societal values by deriving ε from public policy instruments, such as income tax codes. Still others make use of the interpretation of ε as the elasticity of inter-temporal substitution to estimate ε based on consumption and savings behavior. A review of the literature conducted in 2011 for the U.S. Environmental Protection Agency identified a number of studies that take four basic forms:

- *Estimate of changes in "utility" and income using meta-analysis of happiness surveys:* As outlined above, the approach used by Layard et al. (2008) estimates ε by directly measuring the relationship between income and happiness on an individual level. This approach relies on a meta-analysis of existing survey data with large sample sizes to plot self-reported happiness as a function of income for large groups of people. Layard et al. (2008) analyzed several large cross-sectional surveys of happiness from over 50 countries between 1972 and 2005. The estimated elasticity based on all six studies ranged from 1.19 to 1.34, with a combined estimate of 1.26. The US-based General Social Survey, with 17,603 respondents, yielded an estimated elasticity of 1.20.

[10] While some economists have noted theoretical objections to connecting social welfare to individual utility with respect to income, much of the economics literature assumes that the concavity of the social welfare function (concave because of inequality aversion) reflects the concavity of the individual utility function (concave because of diminishing marginal utility). For example, see Layard et al. 2008 and Cowell and Gardiner 1999.

The logarithmic relationship between reported happiness and log of annual gross income appears robust from $8,000 to $100,000 (in 2004 dollars).

- *Direct surveys of attitudes toward inequality and risk:* Direct survey experiments ask participants questions designed to elicit their attitudes towards inequality or risk, depending on the approach used. Researchers then derive the value of ε implied by the survey responses. Survey approaches focus on economic concepts like income transfer ("leaky bucket") wage distribution, and risk aversion (income gambling).[11] These approaches share common survey limitations particularly variation in results around the way survey questions are framed, and limited ability to generalize.
- *Indirect behavioral evidence of substitution over time:* These studies use models of lifetime individual consumption of resources with macroeconomic data on consumption over time to estimate the way people value things differently across time (e.g., valuing something far in the future less than something near).[12] These studies rely on the interpretation of ε as a factor in the elasticity of inter-temporal substitution, rather than a factor in immediate utility.
- *Revealed social values:* A group of studies identified in the literature posit that social values—including society's aversion to inequality—are embedded in public policy decisions. These studies estimate ε by examining income tax codes, supposing that "overtly redistributive instruments" such as progressive income tax codes reveal social attitudes toward inequality (Cowell and Gardiner 1999). To infer the value of the inequality aversion parameter, researchers assume that a guiding principle, such as that of "equal absolute sacrifice of satisfaction," informed the development of the income tax code (consciously or not), and that the principle reflects—through the democratic process—values shared by society as a whole (Layard et al. 2008).[13]

The studies identified in the 2011 review reveal a range of values for *ε,* but with the exception of direct survey approaches (Layard et al., while drawing on surveys, is not a direct survey approach; the authors conducted a meta analysis of survey data that was collected for different purposes), study results fall within a range of 1.0 to 2.0, despite their different approaches and theories, and different national contexts. The 1.26 central value identified by Layard et al (2008) is generally consistent with the values found in other studies using revealed social values and behavior.

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[11] The term "leaky bucket" refers to a metaphor describing the tradeoff between economic efficiency and wealth transfers. Because of the distortionary effects of transfer policies (such as taxation), not all wealth obtained from the affluent will reach the poor, as if it were carried in a leaky bucket. A typical survey question might be, "how much loss is acceptable for a transfer of wealth from a high-income group to a low-income group?" Respondents might be asked to choose between hypothetical transfers with different amounts of losses, or to specify a dollar amount (i.e., the maximum loss that would still make the transfer worthwhile). Studies using this approach include Amiel et al. 1999 and Pirttilä and Uusitalo 2007. Wage distribution surveys (e.g., Pirttilä and Uusitalo 2007 and Carlsson et al. 2005) focus on the distribution of income among different groups, rather than transferring wealth. A typical survey question might be, "what distribution of income among various groups is preferable?" The choices offered vary by distribution of income and average income, and the respondent's choice will reflect an inherent equity-efficiency tradeoff. Lifetime income gambling (relative risk aversion) relies on the connection between ε as a measure of both inequality aversion and risk aversion. An example survey question is: "would you accept a job with a 50 percent chance of earning double your current salary and a 50 percent chance of cutting your current salary by 1/3rd?" Such surveys would present gambles with varying degrees of risk; respondents' choices provide a measure of individual risk aversion (e.g.,Pirttilä and Uusitalo 2007, Carlsson et al. 2005).

[12] Studies that use this approach include Blundell et al. 1994 and Evans and Sezer 2002. Depending on how the formula for the elasticity of inter-temporal substitution is defined, the estimates reported in these studies correspond to either ε or the negative reciprocal of ε.

[13] Studies that use this approach include Cowell and Gardiner 1999, Evans and Sezer 2004, and Evans 2005. The principle of equal absolute sacrifice of satisfaction requires that for all individuals, the difference in pre-tax utility and post-tax utility must be equal (Creedy 2006).

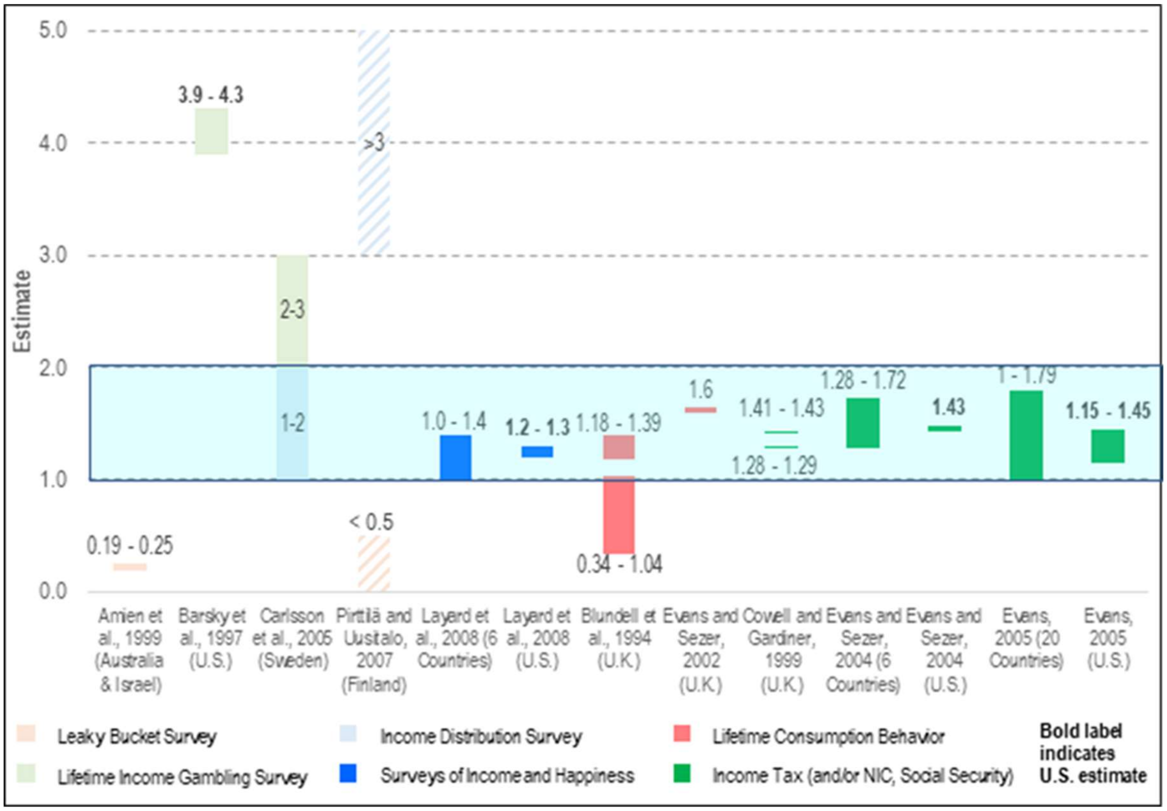

Figure 2. Estimates of ε found in the literature. *Sources:* Multiple (cited in Figure).

Application of weights: California Energy Commission's EPIC Weighting Tool

The California Energy Commission's Electric Program Investment Charge (EPIC) program invests more than $130 million annually in scientific and technological research to accelerate the transformation of the electricity sector to meet the state's energy and climate goals.[14] Under California Assembly Bill 523, the Commission must ensure that 25 percent of the technology demonstration and deployment R&D funds in the EPIC portfolio be spent *in and benefitting* [emphasis added] disadvantaged communities (DACs). An additional 10 percent of technology demonstration and deployment funds must be spent in and benefitting low-income communities.[15] The requirement that benefits accrue specifically to residents of DACs raises a number of important measurement issues related to equity, and demands that benefit-cost analysis, at a minimum, be spatially specific enough to identify impacts accruing to particular communities. Ideally, benefit-cost analysis would also capture any differential impacts and benefits that accrue when services and technologies are improved in underserved communities.

To address this requirement, as part of a broad effort to better measure and document the benefits of EPIC grants (including non-energy impacts, or NEIs), the Commission contracted with Industrial Economics, Inc. (IEc) to develop methods and tools for measuring different program impacts.

The social welfare function developed by Atkinson broadly suggests that investments in communities and households with fewer resources will have greater impacts. Ideally, these impacts could be calculated as endpoints such as improved health, but the interactions that improve quality of life are

[14] https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program

[15] California Assembly Bill 1550 defines low income populations as "those with household incomes at or below 80 percent of the statewide median income."

complex and difficult to document. For example, on-bill savings *could* in some cases be reallocated in many directions, enabling better nutrition, which can reduce health care costs, which can improve productivity and income, but absent some elusive (and comprehensive) data set, the frequency and impact of these interactions is impossible to estimate. In the absence of these types of data, equity weights provide a general sense of the comparable value of this improvement in conditions.

To provide some insight into the potential magnitude of some of these differential impacts, IEc developed a screening-level scenario tool based on Atkinson's equity weighting principle and using the research by Layard et al. (2008), assuming that the benefits of increasing income are consistent with the relative happiness that was measured in that study. The tool aims to help the Commission measure and communicate an aggregate estimate of the additional economic utility (value) of increasing energy equity in disadvantaged communities (DACs) and low-income communities in the State of California by providing on-bill savings to households in those communities.

The tool enables the user to "weight" on-bill savings estimates in different communities in the state, to examine the relative impact of existing or future planned investments. Potential uses could include program planning and targeting of future projects, or documentation and communication of the importance of existing investments that reduce costs in DACs and low-income communities.

Notably, the tool is designed to remain separate from, and *complement*, the benefit-cost analysis methods employed by the Commission, as a sensitivity analysis examining the distribution of impacts or to enable comparative assessments of investments. In addition, to limit the potential for overlap with other benefits, or oversimplified application of weighting to complex benefits such as health effects, the tool specifically focuses only on the equity impacts of on-bill savings. While equity weighting could theoretically apply to a broad range of benefits (e.g., productivity or comfort are likely to increase more where baseline conditions are worse), it is both philosophically and politically problematic to assert that avoiding health effects in one population is "more valuable" than avoiding the same health effects among a different population. The concern for "equal protection" and "equality" is often noted by benefit-cost practitioners and policymakers as a reason to avoid weighting (though again, assuming an equal weight and average impacts for all people is also assigning a weight). To avoid this concern, and because Layard's research specifically and directly considers the link between monetary status and happiness, the Commission's equity weighting tool focuses on on-bill savings.

Calculation Methodology

The tool requires only two inputs from the user: the total on-bill savings to residents across all relevant households in each project or program of interest (this value is developed using program data),[16] and the location of the project.[17] Using the median household income associated with the geographic boundary (e.g., census tract, zip code, city, or county) of the accrued on-bill savings, the equity weighting tool calculates a distributional weight multiplier for that geographic area using the following equation:

Distributional Weight Multiplier =

(1/[Median Household Income of Geographic Area of Interest/Low-Income Threshold of 80% of California's Median Income])^1.26

[16] As part of the same project, IEc developed a separate On-Bill Savings Calculator to assist CEC in identifying on-bill savings across investments.

[17] Equity-weighted project impacts can be aggregated to the program and portfolio level through simple addition, but the current version of the tool does not support a multi-location analysis.

As outlined above, the 1.26 value reflects the elasticity of marginal utility with respect to income. Mathematically, this 1.26 figure determines the relative value of distributing savings to households at or below 80 percent of the statewide median income. Because the distributional weight multiplier is exponential, the equity effect increases as household income decreases. In contrast, the equity effect of on-bill savings allocated to households above 80 percent of the statewide median income is less than one, resulting in a lower equity-weighted value than the initial on-bill savings (a lower-utility investment).

Some on-bill savings occur in multi-family homes that are not sub-metered. In these cases, the landlord, as opposed to the family, experiences the direct on-bill savings, and may or may not pass them through to the residents. The calculator therefore eliminates on-bill savings associated with multi-family homes that are not sub-metered, based on user inputs. If the user does not know the metering status of individual buildings, the tool provides default values for the proportion of sub-metered units on a census tract, zip code, city, and county level. In other words, this tool adjusts only the on-bill savings for families that directly receive the savings. This may under-count the effects of the program.

After identifying the on-bill savings accruing directly to metered households, the calculator then multiplies the distributional weight multiplier by the total annual on-bill savings accrued to households specified in the analysis.[18] The result is the total on-bill savings weighted for equity. Where a location's median household income is lower than 80 percent of the statewide median income, the equity-weighted value of the on-bill savings will be higher than the "raw value," reflecting the added utility of distributing savings to lower-income households. The effect is stronger (i.e., the multiplier is higher) as household income gets lower. Conversely, the equity weight will be less than one for areas where median household income is higher than 80 percent of the statewide median income, resulting in a lower-equity weight value than the initial on-bill savings (implying that the investment did not have the value to those residents that it might have if spent elsewhere. In addition, users can arrive at a lower-equity weight value than the initial on-bill savings if a significant portion of the on-bill savings are not directly accrued to families (i.e., on-bill savings are accrued in non-sub-metered multi-family homes where the landlord directly experiences the on-bill savings and may or may not pass them through to the resident).

To simplify the analysis, the methodology makes several assumptions. Single family houses are assumed to be separately metered and residents (whether owners or tenants) are directly billed. Multi-family buildings built before 1982 are assumed to not be sub-metered and tenants are not directly billed. Multi-family buildings built after 1982 are assumed to be sub-metered and tenants are directly billed. This tool also assumes that national-level estimates documented in Layard et al. (2008) are applicable to California. The authors are not aware of any estimates of this figure for California specifically, and to develop one could require significant time and effort.

To show how equity weighting can reveal differences in the utility of savings in different areas, Figure 3 provides example results for analysis of equal on-bill savings in households in two zip codes in California, one with a median household income of $35,985 (roughly 50% of the $71,805 state median income) and one (more famous) zip code with a median income of $173,882 (242% of the state median income). To clearly illustrate the impact of the weights, the assessment assumes that all savings accrue directly to households in each area.

Importantly, the equity-weighted results do **not** change the total on-bill savings ($1.5 million in both instances in this example) that would be included in a formal benefit-cost analysis. Instead, they provide insight into the efficacy of those investments in improving equity and utility across communities.

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[18] The tools relies on publicly accessible data, including California Air Resources Board's screening tool (to identify DACs) https://ww3.arb.ca.gov/cc/capandtrade/auctionproceeds/communityinvestments.htm, California census tract, zip code, city, and county data from California Office of Environmental Health Hazard Assessmenthttps://oehha.ca.gov/calenviroscreen/report/calenviroscreen-30, U.S. Census data on housing age, https://www.census.gov/topics/housing.html, median household income by Census tract (IPUMS NHGIS, https://data2.nhgis.org/main)

In addition, the example below provides a maximum impact; the equity-weighted value of investments in either scenario would typically be adjusted to exclude participating households that are not separately metered. For projects targeting multi-family housing, this adjustment may be an important factor; if programs are not structured to ensure that households directly receive the savings associated with energy investments, the program's impact could be limited with respect to equity, or, in a worst case, could accrue benefits only to large property owners.

General Project Characteristics	
Geographic Boundary Of On-Bill Savings	Zip Code
Census Tract	Not Selected
Zip Code	[redacted]
City	Not Selected
County	Not Selected
Median Household Income Of Selected Area	$ 35,985
Percentage of Median Household Income Relative To The State Median ($71,805)	50%

General Project Characteristics	
Geographic Boundary Of On-Bill Savings	Zip Code
Census Tract	Not Selected
Zip Code	90210
City	Not Selected
County	Not Selected
Median Household Income Of Selected Area	$ 173,882
Percentage of Median Household Income Relative To The State Median ($71,805)	242%

Results	
Total On-Bill Savings	$ 1,500,000
Total On-Bill Savings Directly Accruing to Families In Single-Family and Sub-Metered Multi-Family Housing	$ 1,500,000
Total On-Bill Savings Directly Accruing to Families In Single-Family and Sub-Metered Multi-Family Housing Distribution Weighted for Equity	$ 3,582,089

Results	
Total On-Bill Savings	$ 1,500,000
Total On-Bill Savings Directly Accruing to Families In Single-Family and Sub-Metered Multi-Family Housing	$ 1,500,000
Total On-Bill Savings Directly Accruing to Families In Single-Family and Sub-Metered Multi-Family Housing Distribution Weighted for Equity	$ 492,182

Figure 3. Illustrative results using the California Energy Commission's Equity Weighting Tool. *Source:* Adapted from tool developed by IEc for California Energy Commission, 2020.

Application and Limitations of the Equity Weighting Tool and Concept

The equity weighting tool is designed to help the California Energy Commission communicate the impact of targeted investments that specifically improve the financial circumstances of households in DACs and low-income communities. Utilities and agencies have difficulty documenting the success of programs aimed at low-income households and communities, in part because standard benefit-cost tests do not recognize the relative importance of savings to household with limited resources. In cases where an investment is unable to pass a traditional benefit-cost test, perhaps because implementation costs are higher due to aging housing stock or infrastructure, the use of equity weighting can provide an indicator of the relative impact of investments in these areas. The calculator was completed in 2020 and has not yet been explicitly used or cited by the Commission in public analyses; internal use in program design and targeting and internal communications is a more likely application.

One interpretation of the "utility" indicated by equity weighting could be that it is a general, aggregate proxy for a number of difficult-to-measure non-energy impacts explicitly associated with improved cash flow. These include impacts such as reduced shut-off and reconnection costs, reduced debt-financing costs (due to reduced need for credit cards or pay-day loans), improved nutrition, and better health (due to more consistent use of prescriptions or access to other medical needs). While the specific savings of some of these items (like utility shut-off costs) is measurable, the utility function, because it is tied to research on happiness, may capture more elusive, but critical, impacts such as the effect of reduced stress, time saved, wellness, and other difficult-to-estimate changes.[19]

A few caveats and points of emphasis are worth noting:

On-bill savings estimates weighted for equity will not replace, and are not additive to, the direct measure of on-bill savings accrued by a program, as the utility of a dollar is not the same as a factual dollar value of a benefit. Weighted benefits are therefore most readily useful as a distinct indicator of the relative impact of a set of investments.

On-bill savings weighted for equity are additive across different projects so long as the impacts on specific communities are not obscured. For instance, if two projects in disadvantaged communities produce a total equity-weighted savings of $500,000 for a $350,000 investment, it is reasonable to combine these projects in discussions of impacts on DACs. Program-level impacts considering distribution across both DACs and wealthier areas, however, can more effectively be presented separately to clarify the investments that had a positive impact on equity from those that do not.

This application of equity weighting is limited to measurable dollar savings that are intuitively comparable to explicit impact of dollars on utility, which was the focus of the Layard et al. (2008) research that is used. Other benefits such as improved health are not ideal for weighting.

While feasible, the use of equity weighting to *adjust* the core results of benefit-cost analyses is not common, particularly in the United States, though it is being discussed in the literature in some contexts such as climate change analysis that consider long time horizons (inter-generational tradeoffs) and global variation of impacts. The reasons for this typically fall into three areas:

- Philosophical and theoretical disagreements about the correct interpretation and appropriate application of different values of ε emerging from different literature (i.e., disputes about what is being measured by ε and whether it can be broadly applied to different circumstances), and
- "Equal protection" concern about economic metrics that imply (or explicitly measure) benefits such as improved health as being more "valuable" among some people than among others; and
- Limited data and significant uncertainty in some regulatory contexts about the specific populations and effects that might be subject to weighting.

A fourth, less formal reason is precedent; traditional benefit-cost analysis is the core approach recommended. While the White House Office of Management and Budget (OMB) under its 2003 Circular A-4 requires agencies to consider distributional effects, the methods are not specified:

> *Your regulatory analysis should provide a separate description of* ***distributional effects*** *(i.e., how both benefits and costs are distributed among sub-populations of particular concern) so that decision makers can properly consider them along with the effects on economic efficiency. … Where distributive effects are thought to be important, the effects of various regulatory alternatives should* ***described quantitatively to the extent possible,***

[19] As noted, the equity weighted impact estimated in the tool is NOT designed to be additive to other benefits and NEIs, in part to avoid concerns about double-counting impacts, but it is important to note that the narrow use of on-bill savings and other monetary benefits limits the potential for double counting for many NEIs. For example, the value of improved health from better indoor air quality, or improved comfort from better temperature controls, would not be affected by use of the tool.

including the magnitude, likelihood, and severity of impacts on particular groups. (emphasis added)

OMB Circular A-4 is currently undergoing review, and the COVID-19 pandemic has increased the nations' focus on economic disparities and how to correct them, but the California Energy Commissions' equity weighting tool is designed to be consistent with this core guidance, and to address the methodological concerns most often expressed by economists in applying equity weights. It aims to use specific, easily identifiable data and relationships to present separate, intuitive insights into the impacts of programs on different populations. As thinking about benefit cost analysis limitations and options for evaluation of equity continues to evolve, this approach to equity weighting represents one simple first step in a quantitative assessment of equity impacts.

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