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One metric to rule them all: A common metric to comprehensively value all distributed energy resources

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ABSTRACT

Traditional energy and demand savings metrics for distributed energy resources (DER) do not accurately describe the value of DERs to meet future energy needs, minimize grid investments, maintain reliability, and reduce greenhouse gasses. This problem is exacerbated in an increasingly renewable grid in which DER impact varies significantly with time and location. Moreover, different DERs are also valued using disparate metrics; this fragmented DER valuation and procurement creates process and economic inefficiencies. A new path forward is the Total System Benefits metric (TSB); the TSB aggregates all electric system benefits, and relevant environmental externalities that accrue to DERs. The TSB is the only metric that comprehensively values DER's to meet future electric system needs and environmental policy goals. This common metric will enable electricity planners, regulators, utilities, and implementers to best deploy and track DER to meet electric grid and environmental policy needs. This paper explains why the TSB is the right metric to value all DER, data requirements to develop the TSB, how to express DER in terms of the TSB, and lessons learned so far from California's implementation of the TSB.

1. Traditional DER valuation metrics need to evolve

Utility funded distributed energy resource (DER)[1] programs are currently planned, implemented, and regulated separately on a per-DER basis. Moreover, the metric to value each DER is different and usually energy based. For example, state regulators have separate processes to set goals for acquiring cost-effective energy efficiency in annual energy savings (CPUC, 2021a; Puget Sound Energy, 2017); separate proceedings to set goals for demand response programs in terms of coincident demand reductions (CPUC, 2021b, 2021c); and separate goals for electrification programs in terms of budget spend or total equipment installed (CEC, 2022) or greenhouse gas (GHG) reductions (Wang and Menonna, 2020.).

Economy-wide decarbonization relies on (1) producing electricity from renewable and zero-carbon resources, (2) electrification of fossil fuel end-uses, and (3) matching electric demand with renewable supply through storage and demand side-management solutions such as efficiency and demand response. Moreover, this needs to be accomplished through a mix of resources to minimize the total cost of building out this decarbonized grid and ensure electric service reliability. This presents many challenges for traditional means of valuing energy efficiency and demand response (Rosenow and Eyre, 2022.).

There are two problems with the current paradigm. First, energy-only valuation metrics don't capture the full suite of policy benefits that DERs provide to get to a decarbonized grid cost-effectively. Second, fragmented DER valuation and procurement creates inefficiencies by artificially siloing DERs, prohibiting optimal deployment, and creating unnecessary administrative burden.

The holistic metric proposed in this paper solves the comprehensive valuation problem and makes significant headway toward solving the fragmentation problem.

1.1. *Existing energy based performance metrics don't accurately describe DER contribution to least cost-decarbonization*

As renewable penetration on the grid increases, the value of DERs - to avoid energy, capacity, carbon, transmission & distribution investment deferrals - becomes increasingly time dependent. When low operating cost renewables are on the margin, wholesale energy prices are low and there are less carbon savings to be had; when traditional fossil-fired generation is on the margin, both wholesale energy prices and carbon savings are greater (CAISO, 2016). Moreover, as supply side means of integrating intermittent renewables, such as storage or peaker plants, are expensive, DERs can integrate renewables and avoid overbuild of capacity-only resources. This benefit of avoiding capacity is temporal as well. Finally, DERs can help defer transmission and distribution investments if they reduce electricity demand at the right times and the right place.

Traditional energy metrics, like annual energy savings for energy efficiency measures, don't capture this temporal variation. The examples in Appendix A illustrate that using energy as a performance metric for energy efficiency inaccurately describes the value energy efficiency

[1] In this paper, DERs refer to all load modifying (energy efficiency, demand response), distributed generation, and distributed storage resources.

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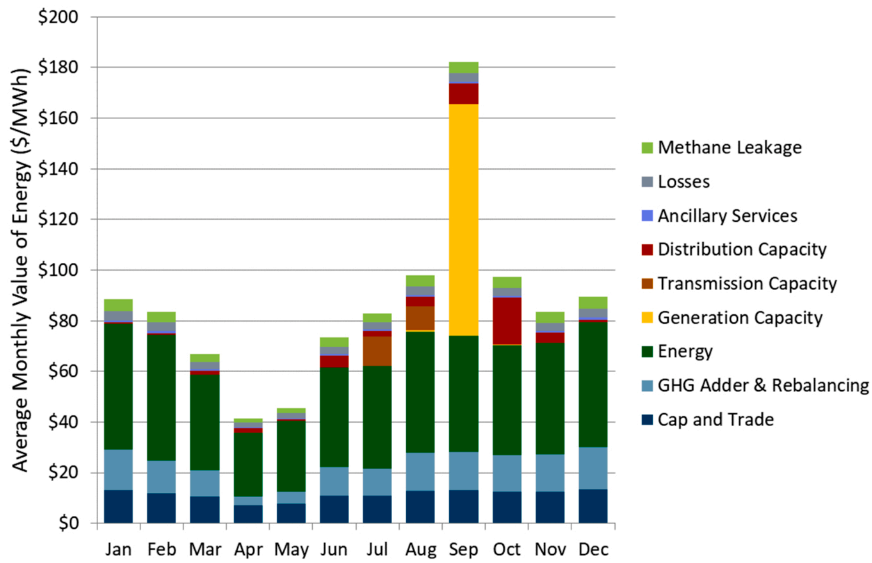

Fig. 1. Monthly variation in levelized average avoided costs.

provides to meeting energy system needs and carbon reduction policy goals. The two examples, one specific to California and one for the pacific northwest, illustrate that although the same set of cost-effective energy efficiency measures can be applied in varying configurations to meet annual energy savings targets, the total electric grid and carbon benefit from these differing implementation configurations could vary by a factor of three or more. This is because the value of energy savings in both California and the northwest varies significantly with time.

Traditional energy savings metrics also cannot describe whether the net impact of electrification is beneficial. Electrification reduces carbon emissions by shifting load from carbon intensive fuels to an increasingly clean electricity grid. Energy efficiency and demand flexibility are valued because they reduce electricity generation and demand; building electrification on the other hand reduces fossil fuel use and increases electricity use. The net impact of building electrification is thus the difference between the value of gas savings and the increase in electric consumption.[2] Some jurisdictions value this impact in terms of GHG savings, but that ignores the impact that changing electricity and gas demand due to electrification has on energy prices, capacity needs, and transmission and distribution infrastructure (NRDC, 2020.).

1.2. Fragmented DER valuation and procurement creates inefficiencies

Fragmented DER procurement, each with its own methods of measurement and valuation, causes at least three inefficiencies: it leads to incomplete valuation of DERs. It prevents multiple DERs from competing to provide value and thereby it also ignores the interactive effects between multiple DERs. DER fragmentation also causes unnecessary administrative burden.

The same distributed resource can achieve multiple ends and should be valued accordingly. For example, a heat pump water heater can be used to electrify gas end uses (decarbonization and energy efficiency), it can be applied as an upgrade to an inefficient electric water heater (energy efficiency), and it can also be applied to shift load by pre-heating water in line with electric grid needs (demand flexibility/load shifting). Similarly, a smart thermostat can reduce electric demand during times of supply constraint (demand response) and reduce annual energy consumption (energy efficiency.) Including these technologies into energy efficiency-only programs, for example, means that they will be valued by planners and implementers for their annual energy savings contribution only.

Fragmented DER implementation also prevents multiple DERs that provide the same value from competing against each other (IPI, 2019 at 25); by doing so it also fails to account for the interactive effects between DERs. This leads to missed opportunities and/ or unnecessary spending.

For example, if the objective of a regulatory planner is to cost-effectively avoid the need for building new capacity and to reduce total energy use, then that planner could apply energy efficiency, distributed generation, and demand response in various combinations to meet that goal. Ideally a planner would define the total need and let providers of different DER compete to meet that system need in a least cost-manner. Moreover, the adoption of one type of DER impacts the incremental value of other DERs. For example, if energy efficiency does not fulfill its load management/ demand reduction obligations, the need for incremental demand response will increase. And conversely, if energy efficiency over-achieves its load management obligations, incremental demand response isn't needed to the same extent.

Finally, implementing DER through separate and unrelated initiatives leads to added administrative burden and inefficient implementation. This is because there is a lot of overlap between the customers that each of these DER are separately marketed to and the energy and policy benefits these DER procurement programs target (ACEEE, 2020). Integrated deployment of DERs can also reduce soft costs by offering customers a one-stop shop for demand side management technologies and may also help customers identify the best combination of solutions given personal preferences and budgetary constraints.

2. Utility avoided costs are the foundation for comprehensively valuing DERs

Utility avoided costs are the bedrock for determining cost-effectiveness of DER. They represent estimates of costs avoided by the utility when a DER either generates or reduces demand for a marginal unit of energy. These should include all relevant utility system costs and utility system related policy compliance costs that would be incurred by the utility in the absence of demand side savings or generation. Avoided costs are also often referred to as the DER value stack or total value of DERs (Lazar and Colburn, 2013; New York State Public Service Commission (PSC), 2022).

For example, in the absence of a distributed resource that produces

[2] Similarly transportation electrification impact can be described as the difference of the impact between gasoline savings and increase in electricity consumption.

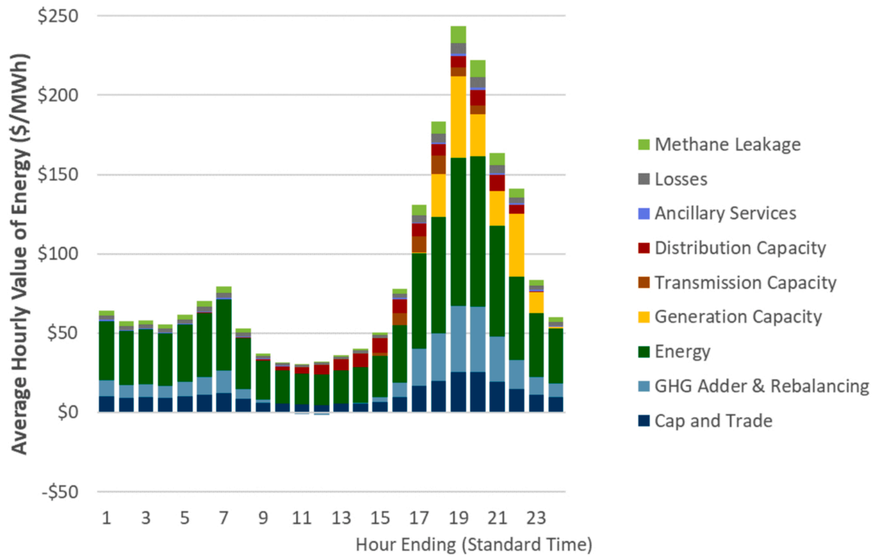

Fig. 2. Hourly variation in annual average avoided costs.

carbon free electricity at 6 PM on a September weekday, the utility would have to purchase additional electricity from the wholesale market to deliver to customers. The associated costs that the utility avoids because of that clean distributed resource include the short run costs of purchasing electricity through the wholesale market, the potential long-run costs of expanding grid capacity, and the cost marginal emissions. These avoided costs are dependent on when and where the distributed resource saves or produces electricity.

Fig. 1 shows the average economic value of all the benefits of energy efficiency for each month of the year in California including the value of marginal GHG reductions. Fig. 2 shows the economic value of benefits from saving energy in each hour of the day in California as represented by California's avoided costs. Each hour's value is the average value for that hour across all days of the year.

These avoided costs illustrate how the value of saving energy varies significantly with time, especially in an electric grid with high renewable penetration. When renewable resources are at the margin, the value of avoided energy is low because of the minimal cost of renewable electricity generation and avoided emissions value is zero.

As these figures show, traditional energy savings metrics are incomplete because resource planners solve for a wide range of energy system and policy needs (such as reduced carbon emissions, avoided capacity, etc); and because the total value of energy savings varies significantly by time of day and season and also with a DER's lifetime.

3. A new path forward: total systems benefits

To resolve these shortcomings, a better DER valuation metric is the total system benefits (TSB) metric. The TSB is calculated by multiplying the DER load-shape by the hourly avoided costs through the DER's effective life.[3] To the extent that the avoided cost calculator accounts for the various benefits of energy savings and how they vary with time, illustrated via Figs. 1 and 2 above, the TSB will capture the complete value stack of DER.

$$TSB = \int_{t=0}^{t=n} (loadshape \times avoidedcosts)dt$$

This simple formula can be applied to all DER. For energy efficiency measures, this is the sum of the product of a measure's load-shape and its time varying avoided costs through a measure's lifetime. For a demand response event, the TSB is equal to the product of the load-shape of the event and the applicable avoided costs. The TSB for electrification measures is the sum of the gas TSB (due to decreased gas use and related emissions reductions) and the negative electric TSB (due to increased electric use and related emissions increase). This same formula can be applied to distributed generation, storage, and other DERs.

Appendix B shows the TSB calculation for a hypothetical energy savings measure with and without load shaping capability and illustrates how the TSB can quantify and explain the full suite of benefits of different types of DER through the above formula.

The TSB can also be thought of as the numerator, or the lifetime benefits of DER, in traditional cost effectiveness tests (CPUC, 2001). The TSB is not completely novel. It is an aggregation of existing performance metrics; its application to set goals and track performance of DERs is novel. Inputs necessary to calculate the TSB exist in all jurisdictions where regulated utility demand side programs exist.

The TSB represents the aggregate value a DER provides toward meeting energy system needs (energy, demand/ reliability, transmission & distribution capacity) and related energy sector policy goals such as GHG reductions. This holistic metric thereby describes the full value of a DER toward achieving a reliable, least-cost, and decarbonized grid. For example, the TSB represents the aggregate value a smart thermostat provides as a demand response and an energy efficiency measure; it also accurately describes the value heat pump water heaters can provide for electrification, demand response and energy efficiency.

The TSB can be used to set goals for all DER and thus helps break down DER-specific silos. By setting one goal and by providing a common metric to value multiple DER, resource planners can now encourage competition between all DER to meet energy system and carbon reduction needs most cost-effectively and can account for the interactive impacts of different DER. As explained next, the TSB has been implemented on a limited basis in California to describe goals for energy efficiency, some demand flexibility measures, and some electrification measures. Its broader application is yet to be tested.

Moving to the TSB to describe DERs has many other practical advantages.

Setting goals and valuing measures in terms of a TSB helps develop a

[3] For dispatchable demand response initiatives the lifetime is equal to the number of demand response events being analyzed.

technology neutral priority order for DER procurement to meet grid needs and carbon reduction goals.[4]

DERs can now be combined and compared to offer more expansive programs as they now have a common unit of valuation. It also makes cost-effectiveness determinations easier and more intuitive. If the TSB for a DER measure, program, or portfolio is greater than the costs to acquire it, then that DER measure, program, or portfolio is cost-effective from a utility's perspective.

3.1. Developing DER goals in TSB

There are two general methods for setting goals for DER through the TSB that are within scope of existing regulatory and utility planning processes. Most planning processes determine goals in two ways: (1) through an integrated resource plan, a co-optimization model of all resources a utility should acquire to meet future energy needs and policy goals, or (2) through a potential model, which forecasts DER adoption to determine feasible programmatic goals for cost-effective DER procurement.

If an IRP process is being used to set DER adoption goals then the TSB can be calculated by taking the difference between total utility spending in a no DER scenario and total utility spending in which DER are co-optimized with supply side resources. This difference between the two values will provide the marginal value of future DER adoption value in dollars.

If a potential model is being applied then, the TSB can be estimated by multiplying (1) the utility avoided costs with (2) each DER load-shape being analyzed and with (3) the quantity of cost-effective DER selected by the model. (DOE, 2020).

3.1.1. Data necessary to develop TSB goals

The TSB is an aggregation of various inputs and its usefulness and accuracy is a function of the veracity of its inputs. No new data incremental to those already applied to determine DER procurement goals, evaluate their impact and cost-effectiveness are necessary to develop the TSB. Moving to the TSB, however, does underscore the importance of two categories of inputs that may be overlooked due to focus on annual energy savings in existing processes. The first category are DER measure characteristics and the second are utility avoided costs.

The DER measure characteristics that are necessary to fully realize the potential of the TSB are primarily the DER impact load-shape and how long a DER is expected to be active (e.g., the effective useful life (EUL) for energy efficiency and distributed generation or the number of events for demand response initiatives).

As the TSB intends to capture time varying impacts of DER, it is important that time-varying DER load-shapes are as accurate as possible. Similarly, because the TSB aggregates the impact of a DER through a DER's lifetime, an accurate estimate of EUL of energy efficiency and distributed generation measures is necessary. Although both of these inputs are necessary to estimate DER cost-effectiveness, due to the primary focus on annual energy and demand savings targets not much resources are spent researching and updating load shapes and EULs. Any errors and uncertainties that exist within these inputs flow through to cost-effectiveness estimates as well. Moving to the TSB highlights the importance of and encourages research on these inputs. This will also reduce any inaccuracies that exist in cost-effectiveness analysis.

Avoided costs are the backbone of any DER cost-effectiveness evaluation and also the backbone of the TSB metric. It is essential for any DER planning process, whether it is based on the TSB or not, to start with comprehensive and time varying avoided costs. This is especially important in regions with clean energy policy and high renewable penetration where the value of avoided energy, capacity, and carbon emissions vary significantly with time (per Figs. 1 and 2 above.).

Avoided costs should describe the incremental short and long-run impacts of marginal change in energy consumption. These should include all relevant energy system costs and energy system related environmental and other policy compliance costs that would be incurred by the utility (and borne by its customers through their utility bills) in the absence of a demand side initiative.[5] These avoided costs are dependent on when and where the distributed resource saves or produces electricity.

Avoided costs should be time varying and, to the extent feasible, account for geographic variation of the energy system. These avoided costs should include a valuation of environmental externalities that a utility is legally obligated to account for.[6] In California, for example, hourly avoided costs include a monetary value of greenhouse gas emissions aligned with the costs of complying with California's energy sector greenhouse gas reduction goals.

3.2. Implementing the TSB metric in California

In March 2020 the California Public Utilities Commission (CPUC) solicited stakeholder feedback on what metric or valuation framework should be used to value energy efficiency and electrification in California considering the multiple objectives of these measures including greenhouse gas reduction, energy conservation, and grid benefits (CPUC, 2020).

After reviewing party comments, the CPUC adopted the TSB metric to value energy efficiency as a resource through a subsequent decision based primarily on comments filed by the Natural Resources Defense Council (NRDC) (CPUC, 2021d).

The CPUC Decision required that the TSB metric be phased in over a three year period; and they required the California investor owned utilities (IOU) to start tracking the TSB metric parallel to energy savings goals in the meantime and to apply it for developing their portfolios. The CPUC developed a TSB target through their most recent potential study; this target is inclusive of energy efficiency, electrification, and some demand response measures. The TSB has already led to planning improvements.

The CPUC has also started using TSB to track goals and IOU accomplishments toward this goal. This provides the IOU program administrators freedom to trade off different measures to best achieve these goals (CPUC, 2021f) and enables initiating building electrification efforts through the energy efficiency portfolio. The IOUs have reported in their recent energy efficiency program filings that the TSB metric has made planning for multiple resource procurement goals - energy, demand, and carbon savings - more efficient (e.g., PG&E, 2022). Marin Clean Energy (MCE) has applied the TSB to develop innovative pay for performance programs that incentivize customers to adopt DERs that help meet California's carbon reduction and reliability needs (in addition to all other services that DER provide) (St. John, 2021).

The TSB has also helped program administrators evolve program offerings to changing grid needs. For example, the CPUC released a ruling soliciting requests for special demand side management programs

[4] Two measures with the same annual energy savings contributions can have very different energy and carbon reduction benefits based on each measure's location and loadshape/ time varying impact as illustrated in Appendix B.

[5] For example, in the absence of a distributed resource that produces carbon free electricity at 6 PM on a September weekday, the utility would have to purchase additional units of electricity from the wholesale market to deliver to customers. The associated costs that the utility avoids through that distributed resource include, at minimum, the cost of purchasing electricity, the cost of any additional strain on the transmission and distribution grid, the cost of procurement of clean supply side resources to meet state carbon reduction goals, and the costs with resource adequacy contracts.

[6] The TSB can also be modified to develop a societal metric instead of a utility system metric by including a broader set of costs and benefits alongside utility avoided costs.

Filing ID	Measure Application	TRC	Scenario 1			Scenario 2			Scenario 3		
			Quantity	Annual Energy Savings	Benefits	Quantity	Annual Energy Savings	Benefits	Quantity	Annual Energy Savings	Benefits
SCE-2020-001121	Residential Smart Thermostat Heat Pump	1.97	55	8,350	$ 6,533	1	152	$ 119	260	39,471	$ 30,884
SCE-2020-001108	Faucet- Kitchen Aerator- 1.5 gpm- electric-AR	10.35	61	8,243	$ 4,096	1	135	$ 67	40	5,405	$ 2,686
SCE-2020-001106	Efficient Showerhead- Electric- 1.25 gpm	3.62	57	8,254	$ 3,823	1	145	$ 67	40	5,792	$ 2,683
SCE-2020-001252	Faucet- Kitchen Aerator- 1.5 gpm- electric-AR	17.38	52	8,431	$ 4,189	1	162	$ 81	40	6,485	$ 3,223
SCE-2020-001037	Interior LED Lighting - To-Standard Practice interior	2.67	8000	8,000	$ 3,073	16600	16,600	$ 6,376	40	40	$ 15
SCE-2020-001440	2 x 4 LED New Luminaire rated greater than or equal to 125 LPW and < 140 LPW	1.36	1040	8,497	$ 7,880	1	8	$ 8	5200	42,484	$ 39,400
SCE-2020-001401	(1) 48in T8 Lamp LED replacing (1) 48in T8 Linear Fluorescent	1.47	449	10,776	$ 2,897	1	24	$ 6	40	960	$ 258
SCE-2020-001009	Interior LED Lighting - To-Standard Practice Interior	2.84	8000	8,000	$ 3,075	16600	16,600	$ 6,381	36	36	$ 14
SCE-2020-001031	Agricultural pump system overhaul - retrocommissioning	1.18	8000	8,000	$ 1,048	16600	16,600	$ 2,175	40	40	$ 5
SCE-2020-001194	Process Motor - VFD	1.41	8000	8,000	$ 1,542	16600	16,600	$ 3,200	40	40	$ 8
SCE-2020-001150	HVAC - energy management system (EMS)	1.93	8000	8,000	$ 1,542	16500	16,500	$ 3,181	40	40	$ 8
SCE-2020-001144	Economizer - air side	1.24	8000	8,000	$ 1,542	16500	16,500	$ 3,181	40	40	$ 8
Total			49,714	100,550	$ 41,241	99,406	100,026	$ 24,841	5,856	100,833	$ 79,191

Fig. 3. California example: three feasible paths to meeting a cost-effective annual energy savings target. each scenario results in very different total benefits.

to meet California's summer evening capacity shortage needs. However, no special carve-out was needed to focus energy efficiency programs to meet this goal (CPUC, 2021e). This is because capacity shortfalls lead to higher avoided energy and capacity procurement costs that is reflected in CPUC's regularly updated avoided costs; as the TSB is an aggregation of these avoided costs values, program administrators are naturally incentivized to target energy conservation in capacity shortfall hours because the TSB goal incentivizes them to target hours with highest utility avoided costs. Energy savings in these hours provides much greater TSB than in other hours. Thus focusing effort toward the most beneficial conservation measures.

4. Conclusion

In an increasingly renewable grid, the value of DER varies with time. DERs are more valuable when thermal generation is on the margin and when the grid is capacity constrained. The value of these resources is also dependent on its location.

The TSB is the only metric that comprehensively values all demand side management measures' ability to meet future energy system needs (energy, capacity, transmission & distribution, etc.), environmental policy goals,such as greenhouse gas reduction goals, and environmental externalities (such as air pollution reduction). The TSB is thus necessary for states with climate goals that require inclusion of environmental impacts in energy planning and procurement.[7]

All DER can be expressed and valued through the TSB, which helps to break silos between energy efficiency, demand flexibility, distributed generation, storage, and electrification. Setting and tracking goals through the TSB provides demand side program planners and implementers the information necessary to optimize deployment of distributed resources. TSB is flexible and it represents the evolving need of the grid; e.g., in a high renewable grid the TSB will help focus demand side measures on those hours where polluting resources are on the margin and to integrate intermittent renewables.

The TSB has been implemented in California primarily for energy efficiency and electrification measures. Lessons learned in California will help further inform the development and implementation of the TSB metric.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A

Existing Energy Based Performance Metrics Are Incomplete: An Illustration through Energy Efficiency Measures

Energy savings goals for demand side programs are typically set in terms of annual energy savings. To ensure that these savings are beneficial to the grid, regulators require savings from utility funded programs to be cost-effective. The problem with setting goals in terms of cost-effective annual energy savings is illustrated here with the help of two theoretical examples, first using energy efficiency data for California and then for the Pacific Northwest.

These two examples, each from a different region, illustrate that this issue isn't specific to any one region; the findings and recommendations of this paper are germane to regulators of energy efficiency programs across the country.

Fig. 3 presents a list of twelve cost-effective measures currently offered in California, their cost-effectiveness ratios calculated through the Total Resource Cost (TRC) test, and three scenarios through which these measures can be implemented, in differing quantities, to reach a hypothetical annual energy savings goal of 100,000 kWh. Also presented in Fig. 3 are the total benefits accrued through each measures' lifetime. This value of total benefits is the economic value of the energy system needs met by energy efficiency and the monetary value of the policy

[7] For example, the draft scoping plan in NY to meet the Climate Leadership and Community Protection Act (CLCPA) includes a benefit-cost analysis that recognizes that improvements in air quality, increased active transportation, and energy efficiency interventions generates health benefits ranging from approximately $165 billion to $170 billion. Reduced GHG emissions avoids the economic impacts of damages caused by climate change equaling approximately $235 billion to $250 billion. The combined benefits range from approximately $400 billion to $420 billion. Moving to the TSB will help account for these benefits of DERs.

Sector	Measure Application	TRC	Scenario 1 Quantity	Scenario 1 Annual Energy Savings	Scenario 1 Total Benefits	Scenario 2 Quantity	Scenario 2 Annual Energy Savings	Scenario 2 Total Benefits	Scenario 3 Quantity	Scenario 3 Annual Energy Savings	Scenario 3 Total Benefits
Residential	Starting February 2018_Front Load_CEE Tier 2_Electric DHW_Electric Dryer	6	80	16,960	$ 41,077	0	-	$ -	155	32,860	$ 79,587
Residential	Retail_Any home_Any Electric_1_50 GPM	16,263	115	16,675	$ 28,014	0	-	$ -	15	2,175	$ 3,654
Commercial	Double Row T12 _High Power LED_Outside Refrigerated Space_HVAC Interaction	2	98	16,464	$ 4,359	160	26,880	$ 7,116	0	-	$ -
Residential	Tier2_indor2_HZ1_gas_0-55gallons	1	11	17,017	$ 17,255	32	49,504	$ 50,197	1	1,547	$ 1,569
Residential	Level 2 Networked to Level 2 ENERGY STAR Networked BEV & PHEV	9,999	370	15,910	$ 10,819	550	23,650	$ 16,082	0	-	$ -
Residential	Existing Single Family Home HVAC Conversion - Convert FAF wo/CAC to Heat Pump - Heating Zone 1	1	4	18,400	$ 34,739	0	-	$ -	14	64,400	$ 121,587
Total			678	101,426	$ 136,263	742	100,034	$ 73,396	185	100,982	$ 206,397

Fig. 4. Pacific Northwest example: three feasible paths to meeting a cost-effective annual energy savings target. Each scenario results in very different total benefits.

goals met by energy efficiency such as reducing carbon emissions.

Each of these three scenarios are feasible ways to get to an annual energy savings goal of 100,000 kWh cost-effectively. However, each scenario results in a different total system and climate benefit from energy efficiency. Scenario 1, which gets to the annual savings goal through an even distribution of energy savings among the measures, results in benefits of $41,224 to California's energy customers. Scenario 2, which focuses on measures that have lower relative benefits, gets to the goal of 100,000 kWh while resulting in benefits worth $24,841. Scenario 3, which focuses on measures with higher relative benefits results in getting to the annual energy savings goals and benefits worth $79,191. So, although each scenario represents a feasible way for programs to meet their goals, the resulting benefits that accrue to Californians from these three scenarios vary significantly: approximately by a factor of three.

Fig. 4 applies six common cost-effective measures, developed by the Regional Technical Forum, to construct a similar example for the Pacific Northwest. Each scenario presented in Fig. 4 shows a cost-effective way to get to an annual energy savings goal of 100,000 kWh. But the total benefits associated with each scenario varies significantly. Scenario 1 gets to the annual energy savings goal through equal savings contribution from each measure, Scenario 2 focuses on measures with lower relative benefits, and Scenario 3 focuses on measures with higher relative benefits.

The result is similar to the result of the California example. Energy efficiency goals can be met cost-effectively, but the total amount of benefits that Pacific Northwesterners get from energy efficiency could vary by a factor of three. This shows that if energy efficiency measures are correctly prioritized by program administrators and implementers, Pacific Northwesterners can get three times the amount of benefits from energy efficiency in the form of lower electric rates and less carbon emissions than a scenario in which these measures aren't correctly prioritized.

These examples illustrate that expressing energy efficiency goals in terms of annual energy savings with a cost-effectiveness requirement does not provide the right signal for program administrators and implementers to get the most out of energy efficiency. The effects of this issue have been felt by some resource planners and stakeholders who note that energy efficiency procurement does not have enough meaningful measures that save energy at the right time and for many years.

Hour	M1 (Energy Savings)	M2 (Energy Savings + Load Shift)
1	10	2.1
2	10	2.1
3	10	2.1
4	10	2.1
5	10	2.1
6	10	2.1
7	10	2.1
8	10	2.1
9	10	2.1
10	10	2.1
11	10	2.1
12	10	2.1
13	10	2.1
14	10	2.1
15	10	2.1
16	10	2.1
17	10	40.0
18	10	40.0
19	10	40.0
20	10	40.0
21	10	40.0
22	10	2.1
23	10	2.1
24	10	2.1
Total	240	240

Fig. 5. Measures M1 and M2 have the same annual energy savings, different loadshapes.

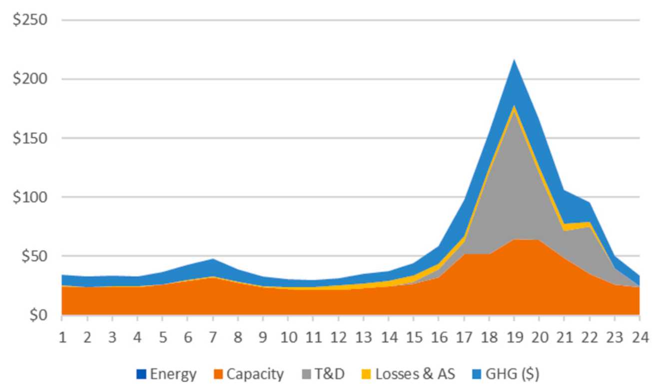

Fig. 6. California levelized hourly average avoided costs ($/MWh).[81]

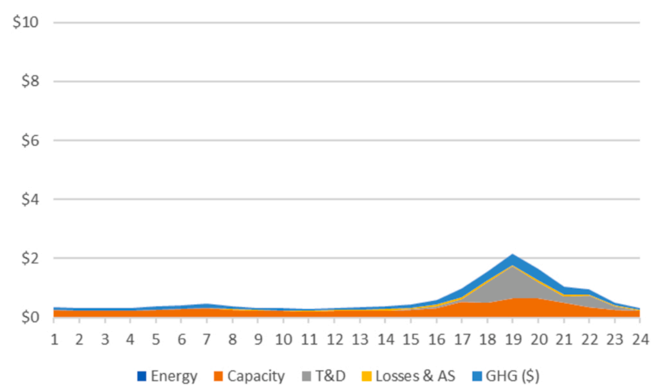

Fig. 7. M1 Hourly TSB (Total = $15).

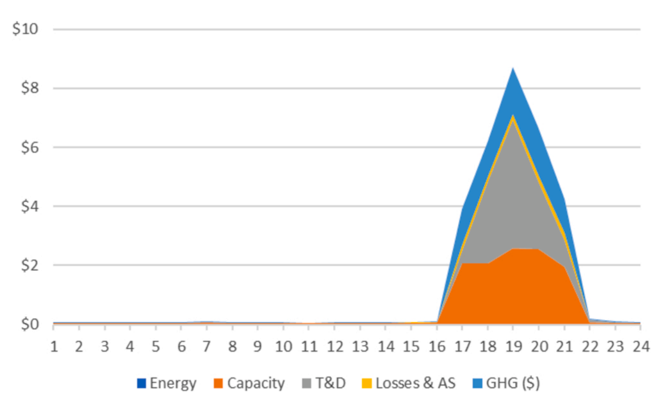

Fig. 8. M2 Hourly TSB (Total = $30).

Appendix B

Detailed TSB Calculation Example

Fig. 5 presents the average hourly impact for two measures that have the same annual energy savings (240 kWh.) Measure M1 is an energy efficiency measure that saves a constant amount of energy in each hour of the year. Measure M2 adds smart controls to M2 to shift load in line with grid needs. Both measures have a one year measure-life.

Fig. 6 presents the levelized average hourly avoided costs ($/MWh).

The TSB for both measures can be determined by multiplying hourly savings by hourly avoided costs. These are presented in Figs. 7 and 8. The TSB for M1 is $15, the TSB for M2 is $30.

The TSB for M2 is $15, that for M2 is $30 even though they save the same amount of annual energy. This example illustrates the following:

- The TSB values those measures that save energy when it is most valuable to the grid
- The energy savings value of both measures is 240 kWh; the demand value of M2 is intuitively greater than M1, the TSB explains exactly how much.
- The TSB is capable of describing the combined energy and load-shifting value of each measure. So, for example, the TSB will capture the total value realized by a heat pump water heater with load shifting capability.
- The TSB also explains the relative value of each measure's stream of benefits.

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