Updating Energy Efficiency Research and Evaluation for Continued Socio-Environmental Relevance

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ABSTRACT

Making energy efficiency again the core of social sustainability and climate change mitigation requires significant changes to current evaluation beliefs, practices, and policies. Changes needed to align evaluation with today's context and needs are covered.

It is imperative to align energy efficiency efforts to social sustainability and climate change mitigation. This requires a review of current energy efficiency evaluation to align with today's relatively mature energy efficiency market; where more data availability and analytics open new opportunities for programs and evaluation; and where efficiency needs to integrate with renewable supply options.

This work draws mostly on the author's three-decade experience with publicly funded energy efficiency interventions to share critiques of core beliefs and offer better practices to develop more effective and relevant energy efficiency efforts. For example, can we accurately assess program specific impacts or determine "net" savings in today's context? Can evaluation instead enable energy efficiency to co-exist with the design and implementation of broader efforts that foster socio-environmental sustainability?

Policy and programmatic evaluation changes that result in relevant, cost effective, and more interesting energy efficiency for society are discussed. These changes will maximize the value of energy efficiency for goals such as mitigating climate change, resolving constrained electric grid areas, flattening the "duck curve", enhancing local economies, or others.

The paper will enable those involved in policy design, regulation oversight, design and implementation, and/or evaluation/research to get more value from evaluations. It will help address mostly self-imposed constraints to enable us to maximize the benefits from energy efficiency efforts.

INTRODUCTION

The imperative to mitigate climate change in today's relatively mature energy efficiency market and Internet of Things (IoT) context requires modernizing energy efficiency interventions and the research and evaluations that provide feedback to keep the interventions relevant and successful.[1] Past experience provides important lessons that need to be incorporated into future research agendas and intervention evaluations to enable the design and implementation of successful, cost-effective energy efficiency efforts.

It is crucial that we quickly align energy efficiency and its research/evaluation to move from mostly a stand-alone, relatively small and siloed effort, to put it front and center in the transition to a grid edge world.[2] In this near future we will see an energy system that is increasingly electrified, with prosumers[3], bitcoin-enabled transactional markets,[4] and IoT enabling full participation by everyone (Sioshansi 2017). The future will also offer through IoT

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[1] Relevant examples of IoT include thermostats, electronic appliances, lights in homes and businesses, electric machinery, electric vehicles, among others, whose operations can be monitored and controlled via the internet; offering opportunities to modulate demand automatically as needed by the wider electric grid.

[2] The "Grid Edge" refers to technologies and business innovations that enable modulating supply and demand close to the end-consumer. Examples include PVs, energy storage, smart thermostats and appliances, building controls, automated demand response, big data analytics, integrated system planning, consumer analytics, virtual power plants, and demand or supply modulating aggregator companies participating in wholesale markets. (see: https://www.ase.org/blog/so-what-exactly-grid-edge-thing-anyway).

[3] "Prosumers" here refer to customers who also generate electricity; usually from rooftop PV systems.

[4] "Bitcoin-enabled transactional markets" are where customers can buy/sell electricity directly between customers using cryptocurrency payment systems whose low transaction cost allow for relatively small money exchanges.

enabled sensors, richer data streams that through big data and machine learning analytical methods, will result in evaluation capabilities that we can only dream about right now—making impact evaluation much less uncertain, more focused on summation of individual savings and less on samples and statistically significant, but not necessarily accurate, results (Golden, Scheer and Best 2019; Sliger and Colburn 2019).

The paper starts by highlighting lessons learned in the evaluation and implementation of energy efficiency programs (mostly in California). The intent is to share useful practices identified across three decades of involvement in energy efficiency research and evaluation, to help energy efficiency promoters and practitioners focus their limited research and evaluation resources in areas most relevant to what is needed today and in the near future, to fully tap the opportunities energy efficiency offers to mitigate climate change and to address other salient energy issues. The paper concludes with ideas of where research and evaluation will have the most value going forth.

A BRIEF HISTORY OF ENERGY EFFICIENCY EVALUATION

Early efforts to improve the efficient use of energy focused mostly on promoting conservation measures (e.g., campaigns that stressed turning off lights and televisions when not in use), as there were few technical energy efficiency measures available in the marketplace. With the energy crises of the 1970s and rising concerns about local pollution, efforts to enhance the efficiency of energy use led to policies promoting energy efficiency – mostly by building codes and, initially, by motor, A/C and refrigerator appliance standards. Limited rebate programs were instituted to help defray higher initial capital costs of more energy efficient technologies. Data on consumption patterns, the efficiency of energy-using technologies, and energy efficiency opportunities were scarce.

Evaluating accurately the energy savings of these early efficiency efforts was important for at least two reasons: first, as a "proof of concept" that energy efficiency programs could deliver energy savings, and second to help design cost-effective, future interventions. Evaluation of energy savings also was easier as there was a higher signal-to-noise ratio: for example, homes had energy-using equipment where the replacement of less efficient technologies with more efficient ones (compact fluorescent lamps (CFLs), insulation, and higher performing air conditioners (A/C) and refrigerators) resulted in clear, measurable energy savings. Given the higher first capital cost of the more energy efficient technologies (e.g., CFLs typically cost $10-20 each compared to incandescent bulbs at 25 cents or less), it was important to evaluate and confirm the expected savings to ensure that the promotion of these more energy efficient technologies was a cost-effective proposition for consumers and rate-funded energy efficiency programs. Initial efforts also had fewer concerns about how much of the observed energy efficiency uptake would have happened anyways, absent the energy efficiency interventions, since it was understood that the energy efficiency interventions were helping markets for efficient products and services develop and mature, enabling these technologies to move from early adopters to early majority and, later, to the rest of society. Therefore, early estimates of net savings[5] (by assessing mostly through self-report surveys of how many of the energy efficiency program participants were free riders) were assumed to be generally accurate.

Over the following four decades, the continuous promotion of energy efficiency has led to a more mature energy efficiency marketplace, with a multitude of technological and programmatic offerings, and much heightened awareness and understanding by consumers of these options. This social investment has resulted in a broad market of energy efficiency products and services, in the midst of a heightened societal understanding, awareness, and interest in addressing air quality and climate change. This is also coinciding with the digitalization of society which is opening new opportunities for further pursuit of more energy efficiency and evaluation of programs by taking advantage of IoT enabled opportunities to modulate and track demand changes.

The multitude of actors in the more mature energy efficiency market is making energy efficiency program and portfolio impact evaluation harder by increasing the noise and reducing the signal: for example, the savings from today's energy efficiency improvements are mostly marginal compared to existing energy efficient products. In particular, the savings in going from an air conditioner model of SEER 5 to a SEER 10 performance is more impactful (especially when coupled to a home with a less efficient building shell of single-pane windows and no attic or wall

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[5] "Net Savings" are defined as the actual energy savings that can be attributed to the energy efficiency intervention. They require estimating what would have happened absent the intervention, also known as the "counterfactual". See: https://www.energy.gov/sites/prod/files/2015/01/f19/UMPChapter17-Estimating-Net-Savings.pdf.

insulation), than going from a SEER 10 to a SEER 12 air conditioner (coupled to a home with double pane windows and with attic and wall insulation). Also, today, customers are more aware of their energy efficiency options, and they are bombarded with advertising to be environmentally conscious (especially with regards to climate change). Finally, today, there are many programs offering energy efficient products and services to customers. The many synergisms across energy efficiency efforts, and the multitude of advertising, limit significantly the ability of evaluations to directly attribute savings to a specific intervention (hence, the signal is being overwhelmed by the noise). Not only is the accuracy of these energy savings impact evaluation increasingly uncertain, but they detract limited research and evaluation resources that could be deployed in other activities with higher societal value.

The energy efficiency research and evaluation paradigm and activity has not kept up and adapted to the changes in the marketplace. There still is too much effort focused on confirming energy savings claims from specific energy efficiency measures, programs and portfolios. At its core, research and evaluation of energy efficiency interventions should be based on a broader societal perspective that incorporates a multitude of prioritized goals, and not just seek to respond to a limited set of regulatory oversight needs. Today, not enough research is carried out to better understand how to best align energy efficiency interventions to reducing greenhouse gases and other air emissions, optimize locational and temporal impacts[6] of these, and whom to partner with to get an optimal uptake of energy efficiency products and services for an integrated, sustainable energy sector.

LESSONS FROM THE PAST FOR THE FUTURE: WHAT WORKS, WHAT DOES NOT

As noted in this section, it is important to draw upon past experience to develop new institutional set-ups and integrated research agendas, as well as to improve the value for energy efficiency interventions.

Institutions Matter

The institutional set-up that funds, designs, operates, and carries out formative and summative research[7] to enable ongoing improvement and alignment with societal changes is very important. Consequently, it is important to clarify the roles and responsibilities for the institutions involved to enable them to work together in an effective way, with low transaction costs[8] to all (particularly to market trade allies[9] and targeted customers). Who funds these efforts and where do those funds come from? Who decides and/or reviews how the funds are used? Ideally these aspects are done in a transparent way with input from all interested stakeholders (policymakers, regulators, civil society, businesses, academics and others).

Research and evaluation institutional set-ups need to ensure quality, high ethics, transparency, and adaptability, so that these are able to provide effective, timely, and actionable feedback to energy efficiency interventions and their stakeholders.

Often, today's research and evaluation efforts are undertaken by parties not involved in the design nor implementation of the energy efficiency efforts. Though this helps reduce concerns about conflicts of interests—particularly with energy savings impact assessments done by third parties to confirm intervention claims – it also makes it harder to provide effective feedback mechanisms from evaluators to implementers. One approach that has worked is to have evaluation teams (either internal and/or external) embedded within the design and implementation teams. Another useful tool has been the development of evaluation protocols and frameworks that describe who carries out evaluations, how they in turn are subject to public scrutiny, how evaluation findings are

[6] The value of energy efficiency interventions varies both by geography and the moment at which it can change demand. More societal net benefits would result from focusing energy efficiency interventions in areas or times that avoid expensive grid upgrades.

[7] Formative research offers information useful in the design and improvement of the activities involved in an energy efficiency intervention. Summative research estimates the impacts of the energy efficiency intervention. Together they help design better interventions and track their implementation and success.

[8] "Transaction costs" refer to expenses (both monetary and non-monetary-e.g., time and human capital) that are required to carry out an activity. Examples can be the time and effort it takes to gather information, the expense incurred in tracking activities or bringing a good to market.

[9] "Market trade allies" refers to manufacturers, wholesale and retail vendors, and installation contractors who make, sell and install/service energy efficient products and services.

considered by implementers, and what are the best practices for evaluating energy efficiency programs (CPUC 2004, 2006; Li, Haeri and Reynolds 2018; EVO 2016, 2019).

Independent forums that enable public discussions on research and evaluation issues, methods, areas to research, and dissemination of results are very useful. They lead to a better use of the research and evaluation resources available and help improve data accessibility and analytical methods, provide higher credibility to the results, and enhance use of evaluation findings by energy efficiency intervention designers and providers. By drawing on a broader range of expertise, the results are also deemed more credible by the rest of the energy stakeholders and enhance energy efficiency's standing and support as an effective resource. Examples of some useful institutions providing these forums are the California Measurement Advisory Council (has a repository of research at Calmac.org), the California Regional Technical Forum (develops savings values for energy efficiency measures at CALTF.org) which drew from the longer experience of the Regional Technical Forum of Northwestern USA (see https://rtf.nwcouncil.org/, that not only sets energy efficiency savings values but also includes energy savings evaluation methodologies), and more recently, USDOE's Uniform Methods Project (https://www.energy.gov/eere/about-us/ump-home where evaluation methodologies are described). Other useful forums are evaluation conferences such as the International Energy Program Evaluation Conference (see IEPEC.org), the International Energy Policy & Programme Evaluation (see IEPPEC.org), and the Energy Evaluation Asia Pacific Conference (see energy-evaluation.org), as well as variety of conferences hosted by the American Council for an Energy Efficient Economy (see ACEEE.org) and the Alliance to Save Energy (see ASE.org). Multilateral banks such as the Interamerican Development Bank (see IADB.org) have also published primers to disseminate best practices.

Integrate Developmental, Process, Impact and Market Assessments/Characterizations for Providing Best Feedback

Energy efficiency interventions success will be enhanced if they draw on four key types of evaluations: 1) Developmental; 2) Process (Formative); 3) Impact (Summative); and 4) Market Assessments or Characterizations. Each is described below to highlight how each offers value to enhance the design and implementation of energy efficiency interventions.

<u>Developmental evaluation</u> "is an approach to understanding the activities of a program operating in dynamic, novel environments with complex interactions. It focuses on innovation and strategic learning rather than standard outcomes and is as much a way of thinking about programs-in-context and the feedback they produce." (see https://censemaking.com/2011/11/19/what-is-developmental-evaluation/ or Patton 2011). The intent is to help stakeholders develop interventions towards a broad goal (e.g., climate change mitigation via enhanced and strategic uptake of energy efficiency), where the path is one that will develop as you go along. It is useful at identifying all key stakeholders, assigning correct roles to them, and finding low-transaction-cost ways for them to interact to move towards the goal in a more cost-effective way. It is ideal for early design and for ongoing feedback to interventions.

<u>Process evaluations</u> examine how well an intervention is being carried out, usually contrasting actuality with as-designed. Process evaluation confirms that the activities envisioned in an intervention's program theory or logic model[10] are indeed carried out effectively and helps identify bottlenecks and gaps that are hindering project success. Process evaluation also seeks to understand how well the interventions are aligning with the intended participants needs.

<u>Impact evaluations</u> seek to confirm the savings ascribed a-priori to a specific energy efficiency measure, program and/or portfolio of programs. They typically are carried out at the end of a program cycle. A better practice is to seek to do them concurrently with program implementation, to offer faster feedback. Quarterly evaluations that leave some extra funding to adjust samples to improve their representability with the entire participating population seem to work best. These also work better when done in conjunction with process evaluations—as they draw data from samples – and by drawing from the same sample, reduce costs and interviewee tiredness (where it

[10] "Program theory or logic model" are descriptions of the activities envisioned in a program that lead to the hoped-for result. Program theories use "if this, then .." statements to explain the elements of a program; whereas logic models show these in graphical form. (See: http://www.evaluatod.org/assets/resources/evaluation-guides/logicmodel-8-09.pdf)

is harder to get survey respondents). This approach will enable the evaluators to not only measure savings, but also concurrently get a better understanding as to why the results are what they are. Impact evaluations are best used for helping to improve implementation targeting to those measures that offer the highest value.

Often, in the United States, impact evaluations are used to assess performance payments to implementers, often resulting in costly, wasteful, lengthy fights between implementers and their funders and overseers. This struggle sometimes reduces trade allies' interest to work with the energy efficiency programs. Worse, impact evaluation results on specific energy efficiency measures are used sometimes to adjust promised incentive payments to participants. Since the adjustments often reduce these incentive payments, the participants not only are subjected to lengthy delays in getting the incentive payment, but also to multiple evaluator data requests, interviews and site visits, but worse, then paid significantly less than promised, making them have to find internal funds to make up the gap to pay for the energy efficiency measure. This can lead to significant customer and vendor disinterest in future energy efficiency program participation. As pay-for-performance programs[11] become more common, the issue of how to deal with incentive payments when savings are less than expected and avoid customer and/or vendor disengagement is one that has yet to find a good resolution.

Another important aspect that needs more attention with impact evaluations is the need to find ways to better ascertain accuracy. Too often the results use statistical precision and assume it means the results are also accurate. This is particularly problematic when the sample drawn for the analysis may have questionable representativeness of the broader participant and/or non-participant market. Representative samples are harder to get for agricultural and industrial customers due to the way they uniquely operate and use the equipment; in addition, their more heterogeneous and complex decision-making processes make it difficult to find similar customers.

Market assessments and/or characterizations help identify where untapped energy efficiency opportunities lie and how to best tap into these occasions. Market assessments are crucial for establishing goals (usually via energy efficiency potential studies), and they provide key information for the development of program theories and logic models that form the backbone of any program design and evaluation.

Integrating the efforts of developmental, process, impact and market assessment/characterization evaluations and research is crucial to developing effective, timely, actionable, useful feedback to energy efficiency portfolio and program design and implementation. This is not an easy task to accomplish, but is helped by having the independent forums mentioned earlier to help design, carry out, and assess the research.

Program tracking data, which are useful, do not by themselves provide the wealth of knowledge on what to do next. Tracking data only alert implementers on how well a program is doing versus expectations for such metrics as participation numbers or savings per participant or energy efficiency measure. To better decide how to improve results, it is necessary to draw findings from the results of developmental, process, impact and market assessments.

Very useful as well is having researchers and evaluators work in tandem with the design and implementation teams. By being part of these teams, evaluators can provide guidance on what data will be useful to collect, ascertain and enhance the quality of that data, and through ongoing analyses, enable design and implementation teams to get actionable and timely feedback for ongoing program enhancement. Through this "embedded" engagement, evaluators and researchers enhance the credibility and the value that design and implementation teams ascribe to their work – a win-win situation for all.

Time To "Believe Again" And Fully Value Energy Efficiency Interventions

Despite energy efficiency's track record of success over the past 40 years, it is still seen as unreliable by some in the energy industry and consumers who favor more visible and easier to meter supply side options. Energy efficiency evaluation, though tasked with accurately estimating savings, has furthered this supply-side bias by subjecting efficiency claims to conservative biases and often reducing claimed savings results, due to a long-held concern of overstating energy savings. There are two main reasons for this:

[11] "Pay-for-performance" programs base payments to contractors on the energy savings (or other stipulated goals) achieved, and not on activities carried out.

(1) Energy efficiency is "invisible": Given the "invisibility" of energy savings from energy efficiency (as it requires using a counterfactual whose validity is always questionable), energy efficiency proponents and their evaluators erred on the side of conservative approaches to estimating energy savings and financial benefits deriving from these energy efficiency interventions.

(2) Social cost of not having enough electric supply is much higher than having too much: Most early energy efficiency interventions focused on saving electricity, and it was important that any electricity savings be conservative; as over-stating these savings and then not having enough supply was much more expensive to society (e.g., blackouts and brownouts) than under-stating these savings and having over supply.

These factors have led evaluators to be conservative in their impact energy savings assessments, to ensure there was a high likelihood that the savings were higher than claimed and never over-stated. This bias is reflected in both gross and net energy savings assessments. In gross savings assessments, when confronted with a range of possible values for the parameters being used to determine savings, evaluators tend to use the lower values or discount projects that do not follow program rules, even if the project saves energy. For net savings assessments, the focus has been on subtracting "free riders," and very seldom are significant efforts carried out to assess and count "free drivers" or "spillover"[12]. Furthermore, using the "industry standard practice"[13] as the counterfactual baseline, evaluations were already subtracting the "free riders" and thus, did not need to have a further net-to-gross (NTG)[14] factor applied to the gross savings value (Ridge 2013).

This bias toward under-estimating savings from current interventions not only undervalues energy efficiency programs today, but also under-values future energy savings and changes to the market place, as it results in an inaccurate counterfactual baseline that already includes some of today's spillover effects.

If significant evaluation resources are going to be dedicated to estimating impacts, then these need to focus more on overall, portfolio-wide impacts and seek to incorporate as best they can all spillover effects as well as count non-energy net benefits.

Rather than dedicate significant evaluation resources to attribute intervention-specific net impacts, resources should be targeted to developmental evaluation and as real-time as possible formative research that can quickly provide feedback to enhance intervention targeting and operations.

WHAT ABOUT ENERGY EFFICIENCY RESEARCH AND EVALUATION FOR THE FUTURE?

Energy efficiency research and evaluation needs to redirect its focus to provide the information needed to enable energy efficiency to play a more substantial role at mitigating climate change (Nadel and Ungar 2019). This will require not only changing the metrics of what is measured, but also expanding the research agenda and modifying the institutional research and evaluation set-up, as briefly described below.

Using Research And Evaluation For Full Inclusion Of Climate Change Into Efficiency Efforts

The latest Intergovernmental Panel for Climate Change (IPCC) assessment highlighted that to keep global warming of the atmosphere to less than 1.5 degrees Celsius, we have to quickly curtail our use of fossil fuels. Energy efficiency can help and is widely seen among the best options available (IPCC 2018). But energy efficiency program spending is not seeing the levels of resources needed to fully and quickly tap the opportunities available. Policy makers need to provide a clearer signal and foster higher levels of resources targeted to energy efficiency. Research and evaluation can help by carrying out work that provides quick and actionable guidance where there are gaps in knowledge (e.g., identifying where efficiency leads to the largest GHG emissions reductions).

Research and evaluation should avoid becoming a policy or programmatic bottleneck, leading to paralysis by too much analysis; instead, research and evaluation should do "good-enough" work for the high-level decisions that

[12] "Free riders" refers to customers who availed themselves of the program offerings but did not need them to adopt the energy efficient product and/or service. "Free drivers" or "Spillover" refers to customers who adopted more energy efficient products and/or services as a result of the program offerings, but that the program did not get attribution for.

[13] "Industry standard practice" refers to the usual product or service that similar businesses adopt and are assumed to be what would have happened anyways (also known as the counterfactual) absent the energy efficiency intervention.

[14] "Net-to-Gross" factor corrects gross savings estimates by subtracting free riders and adding spillover energy savings, to get an estimate of the net savings attributable to the intervention.

need better information. This "big picture analysis" should be followed by ongoing, embedded evaluators to fine tune the design and implementation of energy efficiency interventions.

The Rapidly Changing Context and Climate Change Imperative Require Shifting Energy-Efficiency Interventions and Their Research and Evaluation

In the past, energy efficiency interventions sought to broadly impact society, given large opportunities for substantial and low-cost savings (e.g., compact fluorescent lamps) if spread widely (i.e., the product of small savings times large number of participants results in large savings). Today, we have a mature industry of energy efficiency products and services. But with a world of time-of-use and real-time rates, locational specific energy needs, climate change, and socio-demographic changes, there is a need to strategize and target energy efficiency to fit niche markets[15] rather than broad, one-size fits many, interventions.

To maximize the societal value of energy efficiency interventions, we need to enhance research to link where we think societies are going, what resources they will draw upon, and how much energy and of what types they can rely on. Research then can link the energy needs with identifying where efficiency can offer most value, and monitor progress as the myriad energy system options develop. Some of the major social changes that are expected include:

- We expect three-quarters of the world's population to live in cities in a few decades. This transition will increase the demand on resources to build and operate these cities. This includes an increase in concentrated energy (e.g., electricity) to fuel these urban lifestyles. Energy efficiency interventions will need to align to address the energy needs and opportunities of this urbanization. For example, avoiding a large increase in the air conditioning load can be done via energy efficiency appliance standards, education campaigns and/or incentives for better building shells and air conditioning equipment.
- We expect more automation of work, more work from home, more people living alone, more shared goods and services—particularly for mobility. These can reduce energy used to produce goods and optimize how many are made via improved automation and market data, reduce transportation energy use, but can also increase energy use in the home. Shared goods and services can reduce the energy used in their manufacture but increase their total energy use due to more people using these for longer periods of time. Energy efficiency opportunities prioritization and interventions will need to take into account these changes.
- We hope for a move away from consumerism to a more sustainable, resource efficient socio-economic construct, where energy efficiency can play a larger role.
- In the provision of electricity, we expect to see more options for demand to follow supply in stark contrast to the past, where supply followed demand (Scottmadden 2019; Shenot et al. 2019; Sioshansi 2017).
- We expect to see markets and electric grids that can work with multi-directional flows of energy in real-time, with low transaction cost IoT sensors and financial tracking. [16]

Energy Efficiency cannot continue to be a stand-alone field and needs to better integrate and partner with other supply and demand-side options such as renewables, storage, and lower transaction costs enabling prosumers to enter energy markets. It is imperative that energy efficiency interventions planning be done within a broader assessment of their opportunities to resolve high, societal cost situations. Key among these are climate change mitigation/adaptation and enhanced environmental resiliency, improved social equity, and resolving crucial and costly temporal and locational system needs. Two examples are shown below.

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[15] "Niche markets" are specific portions of the broader market that have particular characteristics that determine the best energy efficiency opportunities and/or how to garner these.

[16] A recent report surveyed thousands of the world's largest companies: besides highlighting the risks that they face from climate change, the report indicated that with an investment of $311 billion, they could gain $2.1 trillion in climate-related business opportunities (CDP 2019; Sioshansi 2017). How much of those $2.1 trillion could be used directly for energy efficiency or enabled by energy efficiency interactions? This is an area of research that needs to be expanded as energy efficiency opportunities shift and evaluating their temporal and locational societal values is made more important and possible.

(1) Over one-half of humanity currently lives in cities and by 2050 about sixty-eight percent will live in larger urban centers.[17] At the same time, fewer people are having children or even getting married, preferring to live in their own homes alone. Ongoing changes in the workplace, where currently more and more people can work remotely from their home or anyplace in the world and not at an office building, could also significantly change energy use patterns – both in the residential as well as in the commercial sector. There are increasingly higher property values and fewer younger people choosing to drive their own cars, preferring instead to use vehicle sharing options that were unavailable just 5 years ago. Electrified transportation is on the rise with several countries, cities, and even manufacturers already announcing 100% electric vehicles (EVs) in the near future. EVs will significantly impact the current needs for power and energy and offer significant opportunities to use energy efficiency (and storage, transactional markets, etc.), to find lower cost solutions to adapt our current electric grid to the needs of the future. How will cities adapt and change with these social and demographic changes? How many of the urbanites will live "modern", energy intensive lives, and how many will live in peri-urban, low-income, low energy-use/capita squalor? How many cities will be able to take advantage of current and new IoT technologies and institutional arrangements to open up new, significant energy efficiency opportunities to find and implement lower cost solutions to keep their cities viable/sustainable and places where people want to live?

(2) In areas with good access to distributed energy resources (DERs) based on renewable energy resources (e.g., solar and wind) such as Australia, much of Southern Europe, Western USA, and most of the developing world, it will be imperative to use energy efficiency judiciously to enable a much deeper penetration (approaching 100%) of climate friendly energy sources. Electric tariffs that promote electric use mid-day, with other policies and market options that enable and foster storage, but that first and foremost, also enable much more energy efficiency and demand response, are crucial (Lazar 2017; Sioshansi 2017). Research and evaluation will need to be carried out not only based on technical solutions to expected grid problems, but also, to better understand customer's willingness to participate more as prosumers than just passive consumers. Social psychology, anthropology, ethnography, sociology and economics are just some of the social disciplines who will need to be invited with their methods and insights to contribute and help us better understand not just individual behavior and decision-making processes, but more importantly, how our social constructs (such as regulatory frameworks) and institutions need to change to open up new spaces for energy efficiency and get rid of those that constrain such actions.

These are just two examples of the many unknowns being faced in an ever faster paced changing world. Energy efficiency policies and programs must be nimbler and be able to adapt faster and even foster and promote social changes that go beyond increased adoption of a more energy efficient technology for a specific end-use.

Energy Efficiency Research and Evaluation Needs to Integrate With Other Resource Efficiency Efforts

Energy and resource efficiency need to be better integrated. Research has been linking the two through different analytical perspectives (e.g., cradle-to-cradle, life cycle[18], water-energy[19]), but many of these results have yet to be integrated into energy efficiency evaluation or policy formulation (McDonough and Braungart 2002). This short-changes the net benefits and reduces the cost-effectiveness and support to energy efficiency programs. It also makes it harder to sell energy efficiency to customers as many aspects they care about have little to do with energy savings, but often are also affected by energy efficiency efforts. For example, energy efficiency efforts often improve comfort, less down-time in production facilities, lowered risk of occupational hazards, increased productivity or sales, among many others. We need more analyses of both non-energy benefits and drivers, and to make them more particular to specific locations and/or technologies. We also need more integrative assessments of the

[17] Per the latest United Nations estimates in 2018. See: https://population.un.org/wup
[18] "Life cycle" or "Life cycle energy analysis" examine all the inputs to making and using a product. See: https://en.wikipedia.org/wiki/Life-cycle_assessment.
[19] "Water energy" typically examines the energy used in all aspects of water provision, use, and discharge. It also is used to examine the water used to produce energy.

synergies among various energy saving technologies (Lovins 2018). These are not just technical fix analyses, but also require significant work on behavioral, institutional, social and environmental aspects.

Public entities need to foster this broader research, so that urbanization and rural development can take advantage of the IoT, enhanced urban and agricultural land use planning, and behavioral knowledge to develop more sustainable and livable smart cities and rural areas.

Energy efficiency research and evaluation needs to branch out beyond the confines of current offerings to offer deeper perspectives and knowledge on what is possible—and where to position and deploy energy efficiency to maximize its mitigation of climate change.

Finally, the evaluation community needs to conduct more research, with less emphasis on energy savings impact work. This research will help identify where energy efficiency offers the most value, how to best garner the opportunities it affords, and how to get customer, market, and policy actions that are aligned and work synergistically.

Assessing More Accurately the Societal Value of Energy Efficiency

Research is needed to better understand the true value of energy efficiency to society beyond just the electric grid, where most of the effort to date has taken place (Dyson, Engel, and Farbes 2018). Even there, we still need to improve our knowledge of the locational and temporal values that efficiency investments offer to the grid. Moving from using average costs of the grid to nodal pricing,[20] including future costs of grid investments and operations, is a first improvement. Also, examining where the grid supply is at most risk of not meeting demand, as well as comparing energy efficiency with other demand-side options, storage and supply, to identify the cheapest option and its backstop (next cheapest option), will help establish a more realistic value for efficiency investments as well as identify where it offers the most value. Several jurisdictions are moving in this direction – as seen in New York City's distributed energy resource effort and Pacific Gas & Electric's Port of Oakland's Clean Energy effort. In these and other instances, utilities are partnering with cities with regulatory support to avoid major electric grid infrastructure enhancements and/or to enable the shutting down of old, expensive and polluting power plants, via investments to modify demand, including energy efficiency (NYISO 2019; PG&E 2017; Prince et al. 2018; Scottmadden 2019). This also requires developing and tapping new analytical capabilities to optimize deployment of DERs to optimize future grid infrastructure investments (PG&E 2019).

Further improving the valuation of efficiency beyond its immediate savings to the electric grid will require estimating and valuing the non-energy benefits that we've just begun to incorporate (Aas 2016; Lazar and Colburn 2013; Shenot et al. 2019). Environmental adders have begun to be employed to recognize that efficiency by reducing resource extraction, use and throwing away, is likely to have fewer impacts on a per kWh and kW aspect than any energy supply technology. More needs to be done to further quantify or at least qualify all the environmental benefits. For example, the research on global climate change impacts, especially in local areas, either by academics and/or insurance companies tracking of payouts from climate change related events, could help develop a more socially accurate value to the mitigating effects of energy efficiency.

More research is needed to quantify a variety of other aspects that energy efficiency offers through increasing customers disposable income, improved comfort, reduced health impacts, increased democratization of the energy system and the political pressures on our governance institutions, etc. This research will enable a better valuation of energy efficiency and provide ammunition for public policies that support its further development and adoption for increased social resiliency and sustainability.[21]

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[20] "Nodal pricing" is where the costs of electric delivery are determined at specific points of the grid. These can vary significantly and for example, be much higher in remote locations with limited load and/or where large capital investments are needed to cover large loads that occur for very limited time periods.

[21] There are various organizations who are starting to address this issue. Some more prominent ones are: the American Council for an Energy Efficient Economy (see various publications at aceee.org); the International Energy Agency's "Multiple Benefits of Energy Efficiency" work (see: https://www.iea.org/topics/energyefficiency/multiplebenefits/energy-savings.html), and The Regulatory Assistance Project (see various publications at: raponline.org).

Going Forward: Examples of Future Energy Efficiency Research And Evaluation

Some examples of the types of research and evaluation are described below that will best serve energy efficiency's repositioning in society to make it more relevant.

- Research to link the needed macro trends of enhanced resource efficiency, particularly in urbanization and agriculture, for maximum climate change mitigation/adaptation via research.
- Optimizing the continued evolution of urbanization with minimum resource impacts and GHG emissions.
- Optimizing the electric grid edge with minimum GHG emissions via strategic deployment of energy efficiency that is optimally pursued by location and time-of-use.
- Evaluation needs to expand beyond siloed energy efficiency (Vine 2008), to also embrace other important social changes that are happening together with efficiency such as renewable energy resources, DER, distributed generation (DG), smart cities, IoT, artificial intelligence, societal norms (e.g., consumerism, gig work, bigger is better, fewer couples living together or driving), that are not only significantly altering how and where energy is needed, but also, affording newer, cheaper and faster ways of potentially reviewing the success of individual site-specific, to program-specific, to broader synergisms across societal efforts to mitigate and adapt to climate change.

CONCLUSIONS

Energy efficiency and its research and evaluation have to move out of their siloed present that is mostly focused on disseminating more efficient technologies, to integrate better and offer a deeper and broader array of opportunities to save energy and enhance societal sustainability. For example, larger opportunities for efficiency exist in moving to "smarter" urban centers, enhanced life-cycle resource optimization, changed social norms and economic systems that are based on circular economic systems where resources are re-purposed for ongoing re-use. Current research does not address these larger opportunities.

Energy efficiency research and evaluation will be crucial to identify broader opportunities for resource efficiency and guide how to tap these, while monitoring progress to provide useful feedback loops to continuously improve policy, interventions, and the institutions that manage these activities.

Energy efficiency research and evaluation needs to start by ridding itself of inherent, overly conservative biases in the assessment of energy efficiency net benefits. Boundaries of analysis need to be broadened. More localized analyses that seek to determine and then use more accurate assessments to guide locational and temporal interventions of efficiency are a first step. These can be followed by deeper research that helps identify, design, develop, and implement broader societal changes that will increase resource use efficiency significantly, while building institutional set-ups that are agile and have strong feedback loops to enable continuous improvement to policies, interventions, and the institutional setups involved. Research and evaluation can also tap and direct the development of IoT to garner much richer data sources and products and services to enable societies to move to more sustainable urbanization and resource use.

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