Multiple Benefits of Business-Sector Energy Efficiency: A Survey of Existing and Potential Measures

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Executive Summary

Business decision makers are more likely to implement energy-themed improvements if they can see a wider range of benefits than were immediately apparent. This is why proponents of these improvements should be able to articulate results that go beyond mere energy savings. By improving energy performance, businesses can positively affect their operational procedures, technology mixes, maintenance requirements, and other business agendas. Managers who fail to recognize energy efficiency's multiple benefits forfeit business earnings and diminish shareholder value. Conversely, businesses can promote economic development and reduce environmental pollutants by recognizing these benefits.

Energy efficiency resource planning and program evaluation should also consider the multiple benefits of energy improvements instead of limiting their evaluations to volumes of energy saved. These include the benefits—both energy and non-energy—that accrue to regional economies. Analysts should aggregate facility-level benefit data in sufficient volume to reliably estimate these benefits. As this report will demonstrate, such an estimation will require more data than can be generated by any one utility's customer base.

This study describes the current understanding of non-energy benefits that accrue to businesses. We surveyed experts and conducted a literature search to shape the call to action at the conclusion of the report. We focus on industrial, institutional, and large commercial facilities. Since their investment and management decision making differs from that of the residential sector, the designers and evaluators of their energy efficiency programs must use methods that are distinct from those used in residential-sector programs.

Attempts to properly evaluate the full consequences of business investment in energy efficiency have been sporadic and far from definitive. Evaluators have yet to develop standard protocols for defining, measuring, recording, and evaluating energy's multiple benefits. Measurements are difficult or impractical to achieve, especially when strictly defined energy evaluations fail to engage the appropriate stakeholders.

Still, we present evidence in this report that the inclusion of non-energy benefits can cut the payback time of some energy efficiency investments by 50%. Researchers will be able to learn much more by applying currently available statistical, sampling, and economic analysis tools. Further research will refine these tools and their subsequent application.

We call for several outcomes to advance energy efficiency:

- Make the full range of energy efficiency benefits more transparent to business investment decision makers.
- Stimulate the market for energy efficiency solutions by improving business-sector understanding of—and thus demand for—energy efficiency and its benefits.
- Expand the body of knowledge that can be used to promote energy efficiency to business facilities.
- Refine the cost–benefit evaluation of economic and societal benefits resulting from energy efficiency programs.
- Improve the determination of energy efficiency rebates and incentives offered by

utilities and similar program authorities.

- Highlight evolving methodologies for defining, measuring, documenting, and reporting benefits over and above energy savings.

Introduction and Purpose

Just as food fosters growth, endurance, acuity, and immunity in the human body, the energy consumed by business facilities may contribute to operations, reliability, product quality, comfort, safety, environmental compliance, and more. Energy use may influence all these functions, and vice versa. For example, a facility's equipment and fuel choices may dictate industrial process design and workplace environment. Conversely, workplace needs such as productivity and space management may dictate equipment type and quality of energy use. The takeaway is that business agendas and needs can shape a business's relationship with energy in a variety of ways.

This report focuses on energy efficiency's consequences for business-sector activities, with emphasis on industrial activities. While no less important, residential-sector impacts are different, especially with regard to the perceptions and decision processes that lead to implementing energy efficiency. Nevertheless, industrial-sector energy efficiency choices overlap in many ways with commercial and institutional sector concerns, perhaps not in terms of the technologies used, but with respect to the business and financial factors that shape energy choices.

Multiple Benefits: An Emerging Term of Art

Current policy and program dialog and supporting literature (especially in the United States) often refer to *non-energy benefits*, or NEBs. This term distinguishes between (1) values directly derived from energy savings, regardless of the energy forms involved, and (2) those values distinct from, but indirectly caused by, energy savings. The term *NEBs* does not fit conceptually when program evaluations distinguish between forms of energy. For example, natural gas savings may be considered ancillary *non-electricity impacts* relative to an electric utility's energy efficiency program cost-benefit evaluation. Gas utility program evaluation poses a similar challenge.

The terms *ancillary savings* and *co-benefits* are similar to *NEBs* in meaning, but appear less frequently. The term *non-energy impacts* (NEI) is used by some programs to describe both positive and negative outcomes. Unfortunately, the NEI acronym is used by other jurisdictions to describe non-electricity impacts. A global or even national consensus on nomenclature has yet to emerge.

We used the term *non-energy benefits* when we began this research. Alternative terminology became evident as research progressed. The term *multiple benefits* is an all-encompassing description of energy efficiency impacts, as it refers collectively to both energy and non-energy impacts. This nomenclature is deliberately broad to preclude restrictions or exclusions that cause some benefits to be overlooked. *Multiple benefits* is a term proffered by the International Energy Agency (IEA 2014). It also has become our term of choice for this report. Shorter and more positive than *non-energy benefits*, *multiple benefits* may be more effective for engaging the business sector as well as policymakers. While we prefer this term, we sometimes have to use the alternate terms found in our reference material to avoid distorting the source's meaning and context.

The multiple benefits (or impacts) of business energy improvements are not to be confused with the generally global impacts of climate change, both positive and negative, which manifest across international borders, cultures, and generations. In the context of this report, multiple benefits are primarily those achieved by facilities that implement energy improvements. The concept also recognizes the economic and environmental impacts that accrue in the region where these facilities are located.

Some additional concepts are clarified for this discussion:

- *Micro*. Facility-level capital investment justification. A micro perspective describes the value of benefits that accrue directly to the energy consumer or energy efficiency program participant as a result of specific energy improvement projects. These benefits include cost savings, productivity improvements, and employee health. Quantification of these values will be useful to public- and private-sector efforts to convey the value of energy efficiency to end users.
- *Macro.* Regional energy efficiency program cost-benefit analysis. A macro perspective clarifies the benefits that accrue to the electric grid or, similarly, to natural gas distribution systems. These benefits may include improved reliability, deferred capacity investments, and congestion relief. Efficiency program parlance often refers to these as "universal benefits."

To suggest a major energy improvement initiative—especially to an industrial facility—is to suggest changes to the core business. Change often threatens established habits, procedures, and spheres of influence within the organization. When they are unaware of energy's broader consequences, business leaders are often dismissive of energy efficiency opportunities (Russell and Young 2012). Revealing a variety of multiple benefits helps to secure wider organizational support for energy improvement.

Justification of energy improvements can and should reflect the quantification not just of energy savings, but also the magnitude and rates of return from additional non-energy benefits. In some circumstances, the value of non-energy benefits can exceed the energy savings value provided by certain energy efficiency improvements (Worrell et al. 2003; Lung et al. 2005; Bement and Skumatz 2007). By recognizing multiple benefits, energy efficiency policy and program professionals can facilitate the large-facility energy improvements that offset regional energy resource cost pressures borne by all consumers.[1]

To be effective, regional energy efficiency programs must engage an industrial sector that represents one-third of total U.S. energy end-use consumption. Notably, 90% of industrial facilities are characterized as small to medium scale, yet they represent 50% of total industrial energy consumption (Trombley 2014). Resource constraints common to smaller industrial facilities dampen their appetite for energy improvements, especially when these are predicated on capital investment (Russell and Young 2012). While facilities of all sizes can take advantage of energy efficiency's multiple benefits, smaller facilities offer numerous opportunities for—and challenges to—achieving industrial energy efficiency. Benefits over and above energy use will often be pivotal in motivating energy efficiency investment in

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[1] Energy conservation and load management programs consider a mix of conventional energy supply capacity along with measures to reduce energy waste at the point of consumption. Regulatory oversight of energy efficiency programs demands periodic cost-benefit analyses to ensure that energy capacity investments are allocated optimally across some mix of new construction versus investment in efficient end uses that offset the need for new capacity.

this sector.

Increased attention to the multiple benefits of energy efficiency is timely. In 2013 a White House initiative mandated the U.S. Environmental Protection Agency through Section 111(d) of the Clean Air Act to regulate greenhouse gases from existing power plants (Hayes et al. 2014). This initiative explicitly advocates end-use energy efficiency as a means to offset power plant emissions. Since end-use efficiency is at the discretion of energy-consuming business facility owners and managers, utilities seeking compliance with Section 111(d) should make the case to businesses that they should increase their investment in energy efficiency. This is an enormous opportunity to leverage the value of multiple benefits.

Previous studies identify a variety of multiple benefits, some of which are presented in table 1.

Table 1. Examples of possible benefits coincident with energy improvements

Societal/environmental benefit	Description
Greater wealth and higher employment	Energy optimization improves industry or sector competitiveness, contributing to economic stability and growth. Economic benefits for business can foster subsequent regional benefits, including higher employment, increased disposable income, and incremental business growth.
Energy security	Energy efficiency is caused in part by the ongoing monitoring and reporting of energy use, consequently ensuring the integrity and reliability of facility assets that consume energy. This information also improves a business's ability to detect and manage the consequences of energy market and supply volatility. Stated differently, ongoing energy management offsets the risks imposed on businesses from a variety of internal and external causes.
Energy prices	Reduced energy waste reduces proportionately the need to invest in energy generation, transmission, and distribution capacity, thus easing the system cost of energy provision borne by all utility customers.
Reduction of air pollutants	Energy improvements mitigate pollutants caused by business activity, thereby enhancing public health and well-being.
Water resource protection	The resource optimization efforts driven by energy management will often involve other inputs, including water. Water management ensures that increasingly scarce water supplies are protected from waste and contamination.
Business benefit	**Description**
	Revenue enhancement
Increased productivity	Energy improvements that cause an increase in production capacity, rate of output, or cycle times.
Premium pricing ability	Improvements that command a superior price due to the product quality or cycle time improvements caused by energy efficiency improvements.
New sustainable and green product revenues	New revenue attributable to products marketed as sustainable or green alternatives by virtue of their less energy-intensive manufacture.

Increased market share	Derived from marketing alliances with like-minded firms that act collectively as supply-chain allies to market their products as sustainable or "green" alternatives. Failure to join such supply chains may result in lost market share.
New revenues	Derived from emission reduction credits and/or demand response program participation fees.
Expense reduction, income enhancement	
Reduction of energy input costs	Lower energy consumed per unit of production attributable to energy efficiency gains.
Increased profit	Each dollar of energy savings contributes one full dollar of operating profit; such accounting can make energy management results more transparent and defensible to skeptics.
Reduced energy capacity charges	Reduction of charges for demand capacity, power factor, and similar costs imposed by electricity or gas distribution utilities.
Reduced requirement of material inputs	Reduced material inputs per unit directly attributable to more efficient energy use. May sometimes include reduced water requirements and volumes of water subject to waste treatment.
Reduced maintenance costs	Lower maintenance costs achieved by use of longer-lasting energy-efficient technologies.
Reduction of errors or scrap rates	Reduced waste coincident with more efficient use of energy, or subsequent to the implementation of production monitoring controls that monitors defects as well as energy and other inputs. Waste disposal costs are concurrently reduced.
Reduction of insurance premiums	Potential reduction in the number or size of insurable assets, caused by the adoption of energy-efficient technologies.
Reduced costs of emissions compliance	Administrative costs and penalties related to emissions compliance may decrease proportionately reduced energy consumption requirements.
Capital performance enhancement	
Capital cost avoidance	The adoption of efficient technologies will make redundant (or reduce the bulk of) some production equipment, either immediately or through subsequent capital planning cycles. In some circumstances, equipment life may be extended.
Increased facility and asset values	An escalation in the income-derived valuation of a facility made possible by its enhanced energy efficiency.
Increased shareholder returns	Incremental share value attributable to enhanced earnings caused by energy savings.
Risk mitigation	
Enhanced workplace health and safety	Human health and safety hazards reduced as thermal and mechanical hazards may be ameliorated commensurately with reduced energy consumption. Additional positive implications for staff retention and attraction.
Energy supply and price risk amelioration	Reduced exposure to energy market volatility, thanks to reduced dependence on energy inputs.
Reduced volatility of business results	Risks to operational goals are reduced commensurately with reduction of energy waste.

Source: Bement and Skumatz 2007; Birr and Singer 2008; Lazar and Colburn 2013; Newberger et al. 2007; Pye and McKane 1999; Reinaud 2012.

Improved knowledge of energy efficiency's multiple benefits may support efficiency program planning in several ways. First, it may inform utility programs that provide energy efficiency support to large customer facilities. Successful efficiency programs help customers meet their business goals. Facility managers who understand the business value of multiple benefits will be able to make a more compelling case for investment in energy efficiency upgrades and boost participation rates in efficiency programs.

Knowledge of multiple benefits may also be to the advantage of utility ratepayers in all economic sectors within a region. It may lead managers to implement more energy efficiency projects as a cost-effective alternative to investing in power generation, transmission, and distribution infrastructure (Birr and Singer 2008).

In addition, knowledge of the total value created by energy efficiency can inform the process that determines future utility tariffs, rates, and related incentives for customer investment. It allows utility regulators to more closely align energy tariffs and investment rebates with the total value and benefits of energy consumption.

Finally, greater business-sector awareness of energy's multiple benefits may stimulate demand for energy improvements that are achieved independently of efficiency program incentives. Such knowledge may also inspire larger project investments, further leveraging limited incentive and rebate dollars.

Business community interest in energy efficiency's multiple benefits will inevitably seek some quantification of value. Ideal value data would describe a functional relationship between energy savings and non-energy impacts for any type of energy improvement.[2] This ideal remains elusive for want of sufficient data. A second-best approach is to inventory the less stringent data that are actually available. The balance of this report takes that approach. At the same time, we look forward to an enhanced quantification of multiple benefits. Facility-level data should eventually be aggregated for the benefit of regional efficiency program cost-benefit evaluation. The report concludes by suggesting some next steps toward this goal.

Methodology

This study sought available documentation of energy efficiency's multiple benefits through interviews of North American subject matter experts, plus a literature search. This culminated in 86 information sources (respondents plus literature pieces) in the United States (51) and Canada (35). These 86 sources include some experience beyond North America. The useable sources are cited in the references section of this report.

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[2] Current energy efficiency program evaluation guidance literature provides algorithms for modeling the causal relationship between energy and non-energy impacts. Note that instead of coefficients distilled from regression analysis of actual data, these algorithms utilize net-to-gross impact factors based on no more than common assumptions. See MA-EEAC 2012.

APPROACH

We chose interview respondents on the basis of their activities in energy program design and evaluation. We asked respondents for data on non-energy impacts coincident with energy use. We also asked them if they could generate such data if they were not immediately available, or if they could refer us to an alternate source or potential respondent. Literature included white papers, reports, journal articles, or technical guides that address the concept, methodology, or actual metrics for non-energy benefits. The literature more often provided macro-level discussions, while survey respondents commented on micro, macro, and sometimes both levels.

RESPONSE TYPES

Table 2 cross-tabulates the 86 responses with respondent types. Appendix A provides descriptions of response and respondent categories.

Table 2. Cross-tabulation of survey response numbers and respondent types

Response types	Academics	Consultants	Government agencies	Industrials	Literature	NGOs	Solution providers	Utilities	Total
Specifically ignores NEBs							1	3	4
No data, no referral	3	3	2	1		2		3	14
Referral to another authority	1		2	1		2		2	8
Theoretical discussion of concept, may be in TRC context		2	1	1	4	1	3		12
Methodology discussion, no actual results		1		1	4				6
Anecdotes: nominal, multisectoral NEBs		1							1
Anecdotes: nominal NEBs existence, commercial/business/industrial		3		4	2		5	5	19
Percentage adders by expert consensus, no actual results		3			2			1	6
Algorithms for indirect estimation of NEBs, no actual results					2				2
Monetization of NEBs value for many projects in aggregate					3				3
Possible source for future data	1	3	1					5	10
NEBs described for single projects, barely quantified					1				1
TOTAL NUMBER OF RESPONSES	5	16	6	8	18	5	9	19	86

Most survey respondents can be characterized as being interested in the concept of multiple benefits and any future findings, but are currently able to provide little data, if any.

Background

NON-ENERGY BENEFITS: CONCEPTS, APPLICATIONS, AND AUDIENCES

Energy efficiency's multiple benefits arise from facility-level energy improvements referred to in facility engineering vernacular as "projects." Projects are discrete episodes of capital investment that involve the replacement, upgrading, or incremental addition of facility equipment that will in some way contribute to business operations. Compared to the intergenerational consequences of climate change that manifest over decades or centuries, facility-level projects pose relatively short-term impacts, with localized consequences. In other words, the various impacts of any single project are largely confined in time and location and accrue overwhelmingly to the communities that host the facilities that pursue such projects. It is in this sense that multiple benefits of facility-level energy improvements can be aggregated for evaluating their impact on regional energy efficiency program results.

Large business organizations tend to lose awareness of energy use among their many other daily priorities. If staff have little or no accountability for energy performance, then potential energy-derived value is often squandered. Not every business enterprise employs a professional energy manager. Most energy managers may only influence and advise rather than compel the rest of their organization's energy choices. Top business managers vary widely in their perception of benefits as well as in their motivation to measure and attain them (Russell and Young 2012; Birr and Singer 2008). Business leaders who underestimate energy value may delegate responsibility to staff with little authority to encourage its capture. Low-level staff may also have a limited concept of energy efficiency, expecting nothing more than reduced utility bills. Limited management awareness further complicates researchers' efforts to document multiple benefits.

Business information and accounting systems can both help and hinder the revelation of energy-related value. Business leaders increasingly rely on software that presents a dashboard of up-to-the-minute business performance indicators. Similarly, management priorities may be shaped to coincide with line items in a chart of accounts. Herein lies the challenge: Management tools may unwittingly hide or dilute energy expenses as well as the value coincident with energy use (Birr and Singer 2008). While this suggests a need to remodel these information systems, managers are often reluctant to endure the expense and hassle that such modifications require. These information barriers must be surmounted if business leaders are to become aware of—and motivated to pursue—the multiple benefits of energy efficiency (Newberger et al. 2007). If properly designed, business information systems will demonstrate not only energy efficiency's cost savings, but also improvements in productivity and product quality, mitigation of operational risks, and human resource skill enhancement (IEA 2014). Energy efficiency program administrators, however, are not typically accustomed to advocating the overhaul of business information systems.

Energy savings may motivate improvements at some facilities, while others facilities justify an identical investment primarily for productivity, safety, or reliability reasons. Add to this the fact that energy program administrators tend to promote energy savings as an isolated benefit, purposely ignoring the larger business contexts in which investment choices are made. For business leaders, energy efficiency investment choices are usually discretionary rather than obligatory. The concept of multiple benefits, then, opens the scope of perceived opportunities. Certain business investments are more likely to happen, if not because of their energy savings, but because of the greater visibility of their multiple benefits in total (Bement and Skumatz 2007). Transparency of multiple benefits is the key to compelling business initiatives that, among other outcomes, provide energy efficiency.

CHALLENGES FOR POLICY INTERPRETATION

The concept of multiple benefits may pose a policy conundrum. Is it an efficient and equitable use of energy efficiency program funds to cause non-energy benefits? While a definitive answer remains elusive, the elements of this debate may be summarized as follows.

Arguments for recognizing multiple benefits. Doing so should stimulate a greater volume and pace of end-use applications that contribute to universal energy savings. Investment proposals demonstrating multiple benefits should engage a wider range of business decision makers within a business enterprise. Instead of relying on facility managers to advocate energy projects to their superiors, efficiency program administrators may promote business solutions with consequences greater than mere energy savings. The promise of greater value—both in volume and variety—is more likely to generate investment support across departmental lines as well as with higher-level managers within any facility.

Arguments against recognizing multiple benefits. Some businesses are prepared to make energy efficiency investments even without program incentives. In these instances, program evaluators may perceive incentive dollars as a windfall to such companies. By extension, incentives for investments with multiple benefits would only exacerbate the windfall. This position presumes that efficiency program costs and disbursements are imbalanced. Following this argument, in other words, ratepayers that fund such programs risk an outcome in which their payments generate benefits that accrue in greater abundance and variety to entities other than the ratepayers themselves, who receive a presumably lesser value in the form of *universal system benefits* (defined in next paragraph).

To encapsulate this debate, consider a hypothetical scenario in which an energy efficiency program is intended to yield strictly defined energy savings to the exclusion of all other value. Presumably, the program achieves its *prima facie* goal of generating universal system benefits—that is, to offset the costs of generation, transmission, and distribution that are borne by all ratepayers. But how likely are benefits to remain strictly derived from energy savings? Or for that matter, how can benefits accrue strictly to the business that implements end-use efficiencies? A facility that cuts energy waste is likely to enjoy concurrent maintenance, productivity, and other benefits anyway. In total, these results ensure business competitiveness and viability, with positive regional implications for employment and income, spin-off business growth, and environmental impacts. Traditional energy efficiency program cost–benefit evaluations either ignore or do not attempt to quantify these non-energy benefits. Local communities lose enhanced economic benefits as a result.

The alternative is to recognize and actively promote multiple benefits. As before, there are both universal system benefits as well as regional economic and environmental spin-off benefits. At issue are the consequences for recognizing benefits beyond energy savings: Do businesses receive windfalls from energy efficiency programs that offer larger and more frequent investment incentives? Perhaps. But at the same time, the volume of universal system benefits rises directly as more end-use energy savings are achieved—perhaps driven by investors' interest in coincident non-energy benefits.

Some energy efficiency program regulators may wish to avoid issuing incentives that become effective windfalls to businesses. But does this approach also preclude the spin-off economic and environmental benefits that energy efficiency provides? The real question here is not whether windfalls are present. Rather, the question is whether the incremental value of universal system benefits (made possible by program incentives), plus spin-off regional economic benefits, are greater than the sum of windfall value accruing to business-sector efficiency program participants. The answer to that question depends on a better quantification of multiple energy benefits.

A CONCEPTUALLY IDEAL METRIC

We would succeed in quantifying energy efficiency's multiple benefits once we could reliably project the value of those benefits that coincided with a unit change in energy consumption. So, for example, we could anticipate a dollar value of non-energy benefits that could be expected to coincide with a unit reduction of electricity, gas, or other energy source. Furthermore, we could differentiate this functional relationship by technology, industry, and region. Statistical inference—the ability to assign the cause and effect between two or more variables—requires many observations. If the analysis is to be nuanced for different scenarios, the volume of data required grows exponentially. Appendix B describes in detail the criteria for reliable statistical inference.

Facility-level data for actual projects are not only scarce, but also fraught with inconsistent definitions and contextual interpretations of both energy and non-energy improvements. Available project data are limited to a handful of isolated examples, quantities far below the threshold needed for reliable statistical inference. The potential for synthesizing existing project data for inferential purposes is almost nil. Still, the potential for collecting future data seems more promising, with the assumption that facility stakeholders are properly informed and motivated to generate consistently usable data. This reiterates the need for a standard approach to the assimilation of data. A forward-looking effort most likely would require collaboration among several utilities and supporting entities that could guide the development of project-level data to ensure consistently appropriate data handling.

Findings

Overall, the majority of existing documentation of multiple benefits was created to support the cost-benefit screening of U.S. energy efficiency programs. These analyses rely on aggregate data describing impacts on entire economic sectors. Residential-sector content is almost always more prevalent than business-sector findings in individual program evaluation reports. In general, two types of data are available: (1) direct measurement data, which quantify the magnitude of multiple benefits in various ways, and (2) indirect measures, which describe how often these benefits are detected, if not actually measured.

Information documenting the project-level coincidence of energy and non-energy value creation is derived mostly from case studies that are prepared independently of each other and without reference to a standard methodology. Case studies are inconsistent in project definition, while performance metrics are not normalized for differences in utilization rates, load factors, labor rates, and other situational variables. Even if the data were properly normalized, the case studies are too few in number to provide statistically reliable inference of non-energy benefits. Because of the insufficient depth of available data, U.S. energy efficiency program administrators rely on expert consensus to provide multipliers or rules of thumb that presuppose the magnitude of energy efficiency's coincident benefits.

MICRO-LEVEL EVIDENCE

The goal at the micro level is to develop multiple-benefits data that fortify investment decision making in individual energy efficiency projects.

Direct Measurement Data

Theoretically, it should be possible to measure both energy and non-energy savings resulting from individual energy improvement projects. This has been attempted in a few separate research efforts, but these are inconsistent in their approach and always with an insufficient volume of data for forecasting purposes. Still, subsequent efforts can build on the lessons learned from these pioneer efforts described below.

LUNG ET AL. This 2005 Lawrence Berkeley National Lab (LBNL) study demonstrates both energy and ancillary benefits resulting from a sample of 81 U.S. industrial energy improvement projects implemented between 1999 and 2004 (Lung et al. 2005).[3] The study categorized ancillary benefits by nature as improvements to operations and maintenance costs, productivity, workplace environment, and environmental impacts, among other things. Additionally, observations come from a variety of industries, including steel, metal casting, aluminum, forest products, petroleum, mining, glass, chemicals, food processing, textiles, utilities, and general manufacturing.

The LBNL study presents the cost of conserved energy (CCE), an algorithm that displays the value created by avoiding a unit of energy consumption. When considering multiple benefits, each CCE describes combined energy savings and ancillary benefits on an individual project basis. CCE metrics are then arranged in rank order to create a conservation supply curve (CSC). Note that a single project CCE represents one data point in the CSC curve. This approach also indicates the unit cost to obtain energy from the market—that is, the cost to continue buying energy that could otherwise be avoided.

Note that a CCE fully loaded with ancillary value for any project computes as follows:

$$\frac{((\mathrm{TC} - (\mathrm{AC} + \mathrm{R})) \times q) + \mathrm{M} - \mathrm{B}}{\text{Annualized energy savings}}$$

where:

TC = Total project capital costs
AC = Total avoided capital costs attributable to the energy improvement
R = Total rebates and incentives received

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[3] Ancillary benefits are generally synonymous with the concept of non-energy benefits.

q = Capital recovery factor
M = Annual net change in O&M costs (can be positive or negative)
B = Total annual production benefits

and:

q = Discount rate/((1-(1+discount rate))^life span of project in years

When plotted as a graph, the CSC curve compares for a continuum of energy efficiency projects the total value created versus cost to buy energy, both expressed on per-unit basis of energy saved, as shown in figure 1:

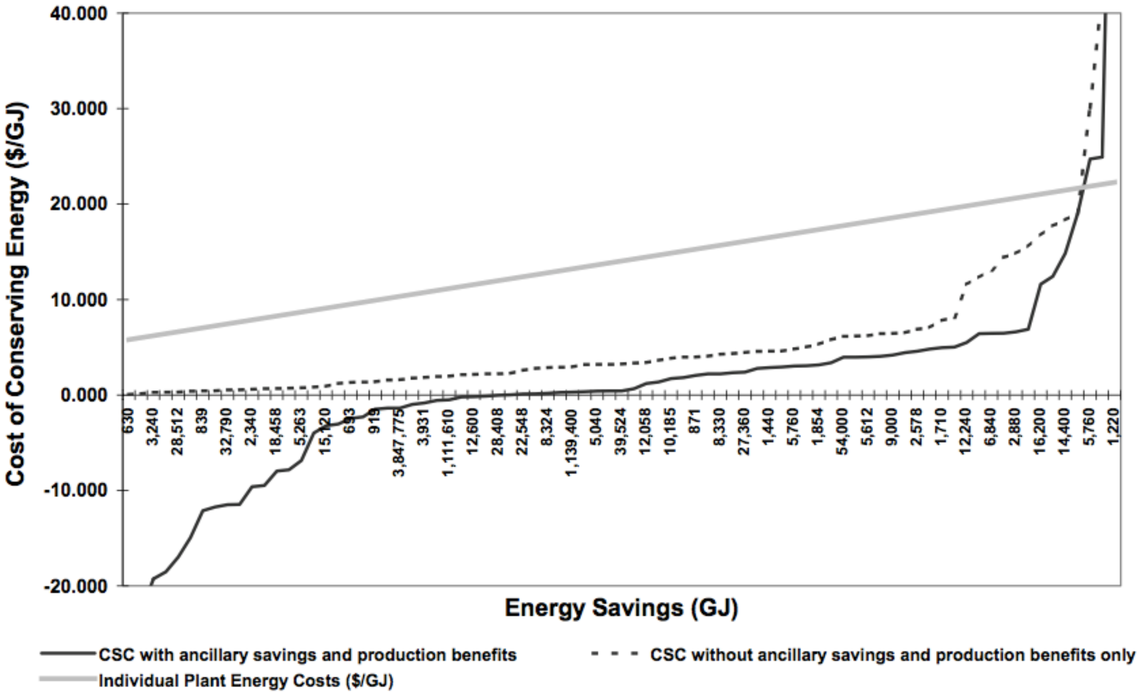

Figure 1. Conservation supply curve and corresponding cost of energy supply for 81 U.S. industrial energy projects. *Source:* Lung et al. 2005.

A negative CCE indicates a project that returned a value per unit of energy saved—in the form of ancillary benefits—that was greater than the cost to obtain that unit of energy savings. A summary of results for the 81 industrial project observations appears in table 3.

Table 3. Summary of ancillary benefits from 81 U.S. industrial energy improvement projects

Metric	Value
Total project costs	$68,219,115
Total annual energy savings	$47,662,220
Total annual ancillary value	$21,080,449
Total annual combined (energy + ancillary) benefit value	$68,742,669
Simple payback based on energy savings alone	1.43 years
Simple payback based on combined benefit value	0.99 year
Number of the 81 projects that demonstrate ancillary benefits	54 (67%)
Number of the 54 projects with ancillary benefits providing a negative CCE	31 (57%)

Source: Lung et al. 2005

Note the dramatic improvement in simple payback when the value of ancillary benefits is included.

This study has both a strength and a weakness. The strength is the analytical structure provided by the CCE algorithm and the resulting CSC curve. This framework can standardize the approach to recording and evaluating energy's multiple benefits. The weakness is in the data used to demonstrate the use of the algorithm. The 81 observations are insufficient in number to generate statistically reliable forecasts of ancillary value that result from a unit of energy savings. Also, ancillary benefits are not consistently defined across projects, nor are the results standardized to reflect different rates for energy, labor, or other inputs. It is impossible to use this study to confidently predict investment returns for any scenario with a specific technology and industry setting.

Similarly, the study used fixed financial assumptions for defining the capital recovery factor used to annualize project costs. The 7% discount rate, plus an economic life of 10 years, was arbitrary yet convenient choices for illustration purposes. In practice, however, investors use discount rates and time horizons specific to their situation. The LBNL study will at best encourage the individual investor's consideration of multiple benefit value, but the sample data by themselves are insufficient to forecast the returns from any singly defined energy improvement project.

The takeaway from the energy efficiency program administrator's (macro) perspective is that the CCE/CSC metrics provide a valuation methodology. The usefulness of this approach varies directly with the number of project observations available. At the micro level, the approach may work well for any one business that considers multiple investment options at any one time.

BC HYDRO BC Hydro has attempted to collect and evaluate industrial non-electricity impact (NEI) data from its own customer base. In an unpublished study, BC Hydro identified some 7,850 individual energy improvement measures installed by various customers (BC Hydro, internal data review, 2013). This total was reduced to observations from industries of interest and also to remove lighting applications.[4] This left 1,071 measures for consideration. Of these observations, 883 (82%) were described as having no coincident NEIs. Only 65 (7% of the 883) observations reported NEI values greater than zero.

The BC Hydro NEI data are at best anecdotal—it provides evidence that NEIs exist. While non-zero NEI values were ascribed to 65 distinct energy measures, there are too few to provide a meaningful inference of value that might be expected should similar projects be replicated elsewhere. Finally, BC Hydro's results to date reflect the fact it could work only with facilities within its own jurisdiction—a service territory too small to generate the volume of observations needed to achieve reliable statistical inference of NEI values.

Industrial Non-Electricity Benefits: A Sample Listing

A BC Hydro study (confidential internal data review, 2013) lists examples of benefits coincident with industrial facility energy efficiency improvements:

- Maintenance savings
- Gas savings
- Fuel savings
- Fiber and maintenance savings
- Operations savings
- Steam and maintenance savings
- Steam and chemical savings
- Product quality
- Miscellaneous (no specific description)

These examples are more engineering-focused than the general business benefits that appear below in this ACEEE report. Note that the scale of the BC Hydro study ensures that the listing is not exhaustive, nor does it allow us to ascribe a frequency or magnitude of occurrence for any specific type of improvement. In this study, there were, on average, only two observations for each type of measure. Note also that this list relied heavily on industrial respondents' abilities to define, detect, and record NEI benefits. It is highly doubtful that such self-reported data are defined and recorded consistently across facilities.

Despite their limitations, BC Hydro's NEI data stand up to anything else available from other North American utility companies. Research finds few comparable data sources, all of which suffer from very small numbers of observations.

CADDET CADDET documented 26 industrial electro-technology projects from the 1980s and 1990s (CADDET 1998). These are presented in narrative case studies written for both technical and policy audiences. Of these 26 case studies,

- 77% quantify kWh savings
- 4% quantify natural gas savings
- 42% describe gross savings (all forms) in dollars
- 58% describe electricity savings in dollars

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[4] Unlike industrial process activities that are central to business performance, lighting was not considered by BC Hydro to be a strategic application.

- dollar savings sometimes provided for various NEIs (up to 31%)
- 35% provide simple payback

The purpose of the CADDET studies was to promote energy savings. For the purposes of multiple benefits investigation, the CADDET case studies simply recognize specific kinds of benefits coincidental with energy improvements. The study provides cursory and inconsistent attention to multiple benefits. In only a handful of instances does the CADDET report indicate attempts to quantify non-energy benefits. Note that even among these 26 case studies, there are inconsistencies in the definition and measurement of non-energy benefits. In any case, there are far too few case studies to reliably infer their potential for other facilities.

IAC DATABASE The Industrial Assessment Center (IAC) database is one of the richest available depositories of industrial energy performance data. The strength of this database is its 122,000 individual project descriptions, distributed widely across industries and states. Its weaknesses are (1) all records provide only expert estimates of potential energy savings, as opposed to actual, (2) non-energy benefits are not consistently defined or sought, much less estimated, and (3) data are limited to U.S. observations. This database provides limited inferential power in that measures of central tendency (i.e., averages, medians, and modes) can be calculated for large numbers of cases, but these are based solely on expert estimates of energy savings.

We analyzed the IAC database's records added from 2000 through September of 2014.[5] The IAC database's Assessment Recommendation Code (ARC) classification system provided useful data only for lights, HVAC, and motor systems, but at least these technologies offer numerous project observations. Table 4 is an overview of useful IAC database information.

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[5] This time frame was intended to minimize the influence on performance averages imposed by obsolete facilities and mechanical systems, price changes for energy and other factors, and changes in operating conditions.

Table 4. Industrial assessment center database: highlights of relevant data, assessments since 2000

Measure	Freq.	Annual kWh saved	Natural gas MMBtu saved per MWh	Other fuel MMBtu saved per MWh	Non-energy cents saved per kWh	Ratio: $ non-elec savings per $ elec saved
Air compressors, hardware	496	105,663,196	0	0	1.43	0.24
Air compressors, operations	25	1,450,649	0	0	0.34	0.06
Motors, hardware	188	37,641,217	0.47	0	0.43	0.12
Motors, maintenance, repair	23	3,889,539	0	0	0.84	0.14
Motors, system drives	1,123	331,467,976	0.34	0.17	0.06	0.06
Other motor systems, hardware	511	82,807,274	1.54	0.11	12.25	2.21
Other motor systems, operations	12	1,255,260	0	0	16.07	2.68
TOTAL	2,378					

For illustration purposes, electricity is priced arbitrarily in this table at $0.06/kWh and natural gas at $6.00/MMBtu. Data shown here are not adjusted for region, annual utilization factors, overall system design, operating strategy, etc. "Non-energy cents saved per kWh" can include many kinds of non-energy benefits; individual project NEB values reflect the individual discretion of the auditor and are not uniform in determination. See the IAC database website for further explanation and definitions: http://iac.rutgers.edu/database/

Note that we would compromise statistical validity by further distilling the projects in table 4 to distinguish them by industry type and region. By narrowing the categories, we would end up with too few observations to reliably infer the value of implementing the same measure in other facilities.

Even given the limitations of the IAC database, it still offers modest inference potential for current purposes. Consider, for example, the column in table 4 presenting "Non-energy cents saved per kWh." See also the first two rows, which describe two different energy improvement types. The data imply that projects categorized as "Air compressors, hardware" (496 observations in total) provided 1.43 cents worth of NEBs per each kWh saved, while "Air compressors, operations" (25 total observations) created 0.34 cents of NEB value per kWh saved. For several reasons, be careful in interpreting these numbers:

- The ratios are derived from expert guesses and not actual observations.
- Note the disparity in the number of observations attained. The first category has 20 times more observations than the second. Statistical variance is inversely related to the number of observations used. Expect the metric for hardware measures, in this instance, to be more reliable than the metric for "operations," simply because of the difference in the total number of observations.
- Note the ratio of the two categories: 1.43/0.34. Ignoring for now the variance within each of the individual metrics, the ratio implies that the NEBs per kWh resulting from compressed air hardware improvements are four times greater than the NEBs/kWh value resulting from operations improvements. For this data set, the ratio (order of magnitude) comparison is a more reliable metric than the interval-scale measure of its individual components.

The takeaway here is that the IAC database can provide some useful information. Utilizing that information requires some compromise. The data are insufficient to provide reliable, interval-scale measures of NEBs value, especially if industry- or region-specific results are sought. Rather, NEBs values can be inferred more reliably when they describe orders of magnitude. For example, one could say that Measure A provides three times the NEBs/kWh value of Measure B, or four times the value of Measure C.

Indirect Measurement

Some studies describe multiple benefit values simply for their variety and frequency of occurrence. In statistical terms, such information is considered nominal data. That is, it simply indicates whether or not a condition exists. Nominal data are obviously far weaker than interval data (unit measurements) or ordinal data (ranked orders of magnitude). The volumes of data in each study are modest—once again, this precludes usable results when attempting to refine metrics down to the industry or regional level. These studies are described in this section.

WORRELL ET AL. (2003) This report synthesizes 52 industrial energy improvement case studies. However these are not broken down by technology, industry, or fuel type. Even so, the data set is too small to yield statistically reliable data. The data do describe energy savings and NEBs value in aggregate across all 52 observations. All projects in total provided these metrics:

- $12.9 million in annual energy savings
- $15.7 million in annual productivity savings
- Simple payback: 4.2 years when considering energy savings only; 1.9 years for energy and NEBs combined
- The ratio of non-energy benefits to energy-only benefits ranged from 0.03 to 70.0 across individual projects.
- Value of non-energy benefits exceeded energy savings in 63% of cases.

HALL AND ROTH (2004) While this report describes the results from only 15 observations, it is at least useful for indicating the variety of non-energy impacts. Note that these are for business facilities, which can be industrial, institutional, or commercial. See table 5.

Table 5. Percentage of respondents claiming non-energy benefits

Type of non-energy benefit	Percentage of 15 respondents claiming to experience this benefit
Decreased non-energy operating costs	47%
Decreased maintenance	40%
Increased production or productivity	33%
Increased employee morale and satisfaction	27%
Decreased waste generation	20%
Decreased defect/error rates	20%
Decreased personnel needs	13%
Increased sales	13%
Increased equipment life	7%

Source: Hall and Roth 2004

The value of these data is that they can be put to use immediately in communications material without need for modification.

WOODRUFF ET AL. (2012) A study of 63 business observations uses a similar indirect approach. As before, the small sample size limits statistical value. See table 6.

Table 6. Percentage of respondents claiming non-energy benefits

Non-energy benefit	Percentage of 63 respondents claiming to experience this benefit
Reduced maintenance material cost	92%
Reduced maintenance labor	71%
Avoided procurement cost	63%
Enhanced public relations image	44%
Permanent capital expenditure avoidance	33%
Avoided purchases of carbon offsets	10%

Source: Woodruff et al. 2012

Rather than providing direct valuation of NEIs/NEBs, most data merely describe benefits by type and frequency of occurrence. Even these data have insufficient depth to allow inferential estimates by industry, region, or technology-specific application. Such data are good for communications that promote energy efficiency improvements, giving some insight as to the frequency and type of benefits, but with nothing to infer dollar values.

Technology-Specific Studies

A number of studies are available that are technology-specific, such as those pertaining to lighting or motor applications. In general, these studies are generated by equipment manufacturers or manufacturer trade groups to fortify their marketing efforts. Reports focus on the qualitative results of energy efficiency—pointing out the existence of non-energy benefits. These studies tend to provide hypothetical results as opposed to actual, and with no attempt to differentiate results by industry or region. For example:

- Pump system efficiency studies describe hypothetical maintenance costs savings derived from the optimization of pump flow settings. To back up the hypothetical claims, one report provided an actual case study of pumps used in refinery distillation towers, where the installation of variable speed drive pump motors resulted in 63 MWh per year power consumption and a concurrent annual maintenance cost reduction of $5,400. The report provides no additional data that would allow comparison of these results to other facility scenarios (Martins and Lima 2008).
- Several lighting studies describe qualitative non-electricity benefits resulting primarily from conversion of metal halide to LED high-bay fixtures. Quantitative evidence of value is rare, and these are usually hypothetical calculations based on knowledge of related factor costs such as labor rates and hours. Lighting studies often point to the potential for non-energy benefits to exceed the value of energy savings (D. Gray, engineer, Hydro Quebec, pers. comm., November 19, 2013; L. Gregg, principal, LCG Energy Management Group, pers. comm., November 18, 2013).

In sum, the technology-specific studies can support industrial energy program marketing. They also provide a framework for estimating multiple benefits that may accrue from individual projects. The values derived in this manner are hypothetical and subject to refinement with rates and factor costs specific to individual situations.

Aside from individual technology studies is an approach that examines the minimum life-cycle costs of discrete energy end uses. The Industrial Sector Technology Use Model (ISTUM) compares end-use equipment alternatives for their total lifetime energy input requirements (Worrell et al. 2003). Comparisons for the same end-use are repeated for different applications by industry. While the ISTUM methodology was devised primarily to measure market penetration potential for competing technologies, the analytical approach employs data that can be adopted for measuring productivity changes in defined manufacturing processes. In this manner, the ISTUM approach may provide a reasonable proxy measure for energy efficiency's multiple benefits.

MACRO-LEVEL MEASUREMENT

The benefits of energy improvements implemented at individual facilities ultimately accrue to neighboring consumers of the same utility services. By achieving a desired level of production or service with reduced energy input, a facility's reduced energy demand relieves stress on the local utility's distribution assets. The conservation and load management programs that enable these reductions are effective when the cost per unit of avoided energy consumption is less than the unit cost of installing additional utility supply assets.

Energy Program Cost-Effectiveness Test Measures

To oversee the cost-benefit analysis of conservation and load management programs, regulatory authorities employ a variety of methodologies, each providing a performance metric that allows cost-benefit ratios to be trended over time. Evaluators have traditionally employed five distinct metrics for this purpose, each defining costs and benefits in different ways. Variance in approaches reflects the need to address different stakeholder interests. The approaches of the five current test metrics, plus an emerging sixth alternative, appear below with comments about their potential to incorporate non-energy benefits.

Participant test. This measures the quantifiable benefits and costs accruing to a customer that participates in a program. By considering only quantifiable costs and benefits, evaluators using this metric will ignore impacts that are intangible or are immeasurable because of a lack of data. This leads to the exclusion of most multiple energy benefits since these pose measurement challenges.

Ratepayer impact measure (RIM) test. This metric is intended as an indicator of the impact on bills or rates for all customers, regardless of their program participation, due to program impacts on overall utility revenues and operating costs. It is technically not a test of the cost effectiveness of an energy program, but rather, the effect on the distribution of who pays for already-sunk system costs. This test does not consider costs and benefits that accrue to the customer. While non-energy benefits may incent the magnitude and pace of energy improvements that contribute to the utility's own operating cost reductions, the RIM metric does not explicitly recognize non-energy benefits as a variable.

Total resource cost (TRC) test. This approach totals all costs associated with the energy efficiency measure—those accruing to the utility as well as to the participant customer. This combined utility and participant cost compares only to the benefits of the utility system costs avoided. While it is theoretically possible to consider non-energy benefits under a TRC test, non-energy benefits are almost never considered in practice.

Program administrator cost test/utility cost test. This test considers program administration costs plus incentives, but excludes any costs borne by program participants. The test is explicitly intended to focus on the costs and benefits to the utility system. It does not consider any costs or benefits external to the utility system, including non-energy benefits.

Societal test begins with cost-benefit inputs similar to the TRC but expands the number of variables to include externalities accruing to the general population, such as environmental impacts and energy security. While each externality poses unique measurement challenges, at least the framework accommodates any variable that evaluators choose to include.

Resource value framework is an emerging alternative metric for cost-benefit evaluation.[6] It is intended to address the weaknesses of the preceding frameworks, including their dismissal of non-energy benefits. This framework is a work-in-progress subject to input and coordination from a coalition of energy program evaluation experts.

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[6] This is a concept still under development, jointly promulgated by the Home Performance Coalition with foundation funding. See http://www.nhpci.org/projects/costbenefittesting.html.

Among the first five (traditional) options, the societal test may be the most conceptually practical for considering energy's multiple benefits in the evaluation of conservation and load management programs. This approach allows evaluators to compile all benefits from the bottom up, beginning with the monetized impacts of multiple benefits caused by individual, discrete improvement measures. In turn, individual impacts can be aggregated into a system-wide total. That being said, this approach remains dependent on the availability of usable data.

Prescribed NEB Values

Many energy efficiency program administrators, per regulatory direction, use prescribed values to express non-energy benefits value per unit of energy saved (CPUC 2012). Such values are the product of expert consensus. This means, for example, that the program will prescribe NEBs value to be, say, 10% of the total energy saving values tabulated for the energy improvements achieved in total by a certain economic sector. Prescribed, fixed-dollar NEB values per kWh saved are similar to percentage adders. Program evaluators use both approaches for energy efficiency program cost-benefit analysis. Table 7 shows examples of prescribed value-adders.

Table 7. Sample of prescribed non-energy benefit values developed and approved by various regulators

Source	Prescribed metric	Comments
California Public Utility Commission, eSource	CO: 10% IA: 10% for electric IA: 7.5% for gas OR: 10% WA: 10% BC Hydro: 15%	These same percentage adders are cited in at least two different sources.
Manitoba Hydro	NEI = 30% of pre-conservation measure electricity expense	2013
eSource	NH: 15% Pacificorp: 10% VT: 15%	Percentage adders. Pacificorp applies the same in CA, OR, WA, ID, UT, WY

Source: CPUC 2012; R. Marshall, industrial systems officer, Manitoba Hydro, pers. comm., December 2, 2013; T. Stout, senior fellow, eSource, pers. comm., December 2, 2013.

For current purposes, prescribed values are of very little use in ascribing multiple benefits value to a business' individual energy projects. The fact that these are numbers calculated for and sanctioned by regulatory commissions may provide some gravitas to this data when the business community considers it.

MASSACHUSETTS TECHNICAL REFERENCE MANUAL The State of Massachusetts commissioned a number of studies to quantify the costs and benefits that result from energy efficiency resource acquisition programs. These findings became the basis for the Massachusetts Technical Reference Manual, issued by regulators to guide the resource evaluations conducted by that state's utilities and related energy program administrators for 2013–2015 (MA-EEAC 2012). The result is a comprehensive set of metrics that prescribe NEBs values, derived from expert consensus, for a number of applications. Table 8 lists metrics from the manual that may be pertinent to industrial-sector energy activity.

Table 8. Annual NEI value per kWh saved by commercial and industrial (C&I) large retrofit projects

Application	Description of savings impact	Annual NEI value per kWh saved
Various lighting and occupancy sensors	O&M savings derived from reduced frequency of lamp replacements over economic life of fixture	$0.41 to $33.65
CHP systems	Administrative costs, O&M	$0.015
Prescriptive lighting	Administrative costs, material handling, material movement, other labor costs, O&M sales revenue, waste disposal	$0.027
Prescriptive HVAC	Administrative costs, other costs, other labor costs, O&M, rent revenue	$0.097
Custom HVAC	Administrative costs, material handling, material movement, other costs, other labor costs, O&M product spoilage, rent revenue, sales revenue, waste disposal	$0.024
Custom lighting		$0.059
Refrigeration		$0.047
Other		$0.056

Source: MA-EEAC 2012

Direct-install programs are those in which the energy program administrator simply installs energy-efficient upgrades at no cost to the facility. Table 9 presents the annual NEI value per kWh saved by these programs,

Table 9. Annual NEI value per kWh saved by C&I direct-install programs.

Application	Description of savings/impact	Annual NEI value per kwh saved
HVAC	Administrative costs, material handling, material movement, other costs, other labor costs, O&M, product spoilage, rent revenue, sales revenue, waste disposal	$0.097
Lighting		$0.027
Refrigeration		$0.047
Other		$0.056

Table 10 presents values for non-energy benefits resulting from natural gas savings.

Table 10. Annual NEB value per therm saved by C&I large retrofit programs.

Application	Description of savings/impact	Annual NEB value per therm saved
Boiler reset controls	Administrative costs, material handling, material movement, other costs, other labor costs, O&M, product spoilage, rent revenue, sales revenue, waste disposal	$0.14
Steam traps		$0.14
Thermostats		$0.14
Custom		$0.03

The NEBs measures described here represent average values per expert consensus. Program administrators designed prescribed metrics like this for ease of use by energy program administrators. This is easier than calculating a precise measurement for each individual project. This approach implicitly recognizes that NEB calculations for individual projects may be inexact, but when applied to many project results in aggregate, it is reasonable to assume that the positive and negative measurement variances will cancel each other out, leaving an overall average value. Rules of thumb like these deserve periodic revision as more precise data become available.

Issues and Opportunities for Quantifying Multiple Benefits

Many organizations worldwide have difficulty quantifying energy's multiple benefits. To merely list the types of benefits is a daunting task, considering the potential impacts that are unique to individual facility configurations. This calls for a consistent analytical approach (IEA 2014). Beginning at the level of individual energy improvement projects, a proper analytical framework for clarifying multiple energy benefits will define energy-related business outcomes that:

- Directly support current and future business goals
- Are achievable within current business constraints
- Demonstrate a calculable magnitude and rate of return
- Are urgent by virtue of their alignment with current priorities

The analytical framework will identify business stakeholders who benefit from these outcomes. Stakeholder engagement within any business facility will be shaped by its organizational design. In other words, the structure and nature of staff accountabilities within the organization precipitate the motivation to pursue energy's multiple benefits. Individual energy improvement proposals may be tailored accordingly to appeal to particular stakeholders.

The framework will also shape the investigation multiple benefits' causality and magnitude by:

- Formulating the appropriate questions to reveal benefit potential
- Making use of available data while influencing the formulation of additional data sources as these become feasible
- Devising appropriate performance metrics based on available data, especially data describing costs coincident with energy use such as material consumption, waste disposal, operations and maintenance, and compliance obligations
- Establishing methodologies for baseline scenarios, i.e., the opportunity costs associated with doing nothing by refusing investments that enable multiple benefits
- Effectively translating and communicating findings so that this information becomes integral to business decision making
- Iteratively refining the framework for multiple benefits quantification based on lessons learned, and replicating successes across like facilities

Similarly, a proper macro-level framework will inform the design and conduct of energy efficiency policies and programs. After compiling the inventory of regional energy supply needs, constraints, and end-use improvement opportunities, energy efficiency program administrators should

- Conduct outreach to boost business sector awareness of multiple benefits and stimulate demand for their capture
- Count and prioritize discrete efficiency project opportunities, sorting these by technology type as well as industrial context
- Thoughtfully segment the market for energy improvements so that the technology and organizational characteristics of business facilities shape subsequent energy efficiency program outreach

Program administrators should also do the following:

- Create metrics that strike a balance between ease of collection and universal applicability across different facilities and operational contexts.
- Collect data for individual energy improvement projects that directly compare the unit cost of conventional energy supply with the value of energy's multiple benefits expressed as a cost per energy unit avoided. This then allows a rank order of benefit values by project type.
- Establish a baseline measure of the installation costs of various projects that offset traditional investment in energy supply capacity.
- Provide guidance to facilities that enables staff to recognize and monitor the multiple benefits that manifest in their business process.
- Establish protocols that ensure the confidentiality of business data that are utilized for energy program purposes.
- Communicate results in ways that encourage replication across industries and throughout regions.

Quantitative data pursuits will necessarily start with a general market focus, seeking the measures and applications most common to all industries. Successive iterations of outreach can narrow the focus by context, especially as receptive market niches emerge. Expect the analytical framework to become nuanced to reflect distinct process needs, organizational structures, and unique regional variables. All of this infers a strong need for coordination across facilities—or in essence, a protocol—that reduces duplication of effort while ensuring the comparability of performance measurement and documentation. Energy efficiency program administrators are well positioned to coordinate these efforts, assuming they are prepared and empowered to do so.

Future Developments and Resource Needs

The following are suggestions for advancing the concept and quantification of energy's multiple benefits.

CONCEPTUAL IDEAL: PROBABILISTIC ESTIMATION

One ideal would be to describe the kind and value of multiple benefits that can be expected from any specific industrial energy efficiency improvement. The best data would be already collected, stored in large volume, and processed in a consistent format that permits instant access and interpretation. Users could estimate, within bounds of statistical certainty, the value of multiple benefits that can be expected to result from future installations. Few sources other than utility companies and their regulators have the capacity to accumulate such data.

Statistical inference—using past data to estimate future outcomes—establishes a functional relationship between two or more variables. In the context of non-energy benefits, this approach would permit a quantitative estimate of non-energy impacts to be expected per unit of energy saved by any discrete type of energy efficiency improvement initiative. This approach would yield an inventory of multipliers that describe ratios of energy to non-energy benefits, nuanced to reflect differences across technologies, industries, regional locations, and other situational variables.[7]

Effective and reliable quantification of multiple benefits depends on facility-level knowledge of process and business operations. This knowledge includes the flow of production, the interaction of each piece of equipment with all others in the same process, current levels of employee health and safety, current maintenance costs and issues, management priorities, and probably more elements. This effort requires not only a large volume of data, but also careful definition, measurement, and documentation of observations. Attempts to collect such data depend highly on self-reporting from individual facilities. In turn, adequate self-reporting depends on knowledgeable facility staff, probably including individuals other than the energy manager. Will facility staff have the time and motivation to pursue such data collection? Can facility representatives from dozens or hundreds of facilities be motivated to act in concert with energy program timelines and expectations? Even willing business facilities are likely to require guidance for undertaking this effort.

GUIDELINES FOR FACILITY MANAGER REFERENCE

Any concerted effort to improve the evaluation of energy's multiple benefits will depend largely on the business sector's ability and willingness to accurately detect, measure, and report these values. Motivation aside, facilities vary greatly in their ability to contribute to this agenda. Investigation of this nature demands skills and resources not always available within the facility. Data collection relies on unprecedented cooperation among the departments of a business organization. All of this suggests that guidance to these organizations is needed, not just to augment and build the appropriate diagnostic skills, but also to standardize definitions and measurements across facilities.

Industry engagement could originate from one or more utilities collaborating in the study of multiple benefits for their program cost-benefit evaluations. Energy program administrators would coordinate the standards for definition, measurement, and reporting. Utility program outreach may focus on a limited number of technologies that are implemented across a variety of industries. Alternatively, an industry-based initiative may consider a comprehensive range of technologies that are characteristic of that industry. In either case, outreach should probably be paced over time, perhaps beginning with a pilot effort that would inform and inspire successive rounds of participation.

A truly useful guidance product will be assembled in cooperation with industry representatives. It may be necessary at first to emphasize variables and methodologies that

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[7] A more detailed discussion of statistical methods and constraints as these apply to multiple benefits estimation appears in Appendix B.

minimize situational nuances, ensuring relevance across industries and regions. The utility regulatory community has a concurrent need for such guidelines to the extent that data collection efforts will be replicated for multiple utilities within their respective jurisdictions. Energy solution providers—the equipment providers and consulting engineers recognized as trade allies by utilities—can also employ multiple benefits data to enhance their project feasibility and marketing efforts.

BUSINESS CENSUS DATA: A PROXY

A different approach for discerning energy's multiple benefits involves U.S. business census data. At the time of this report, ACEEE is ramping up the resources to pursue this study. It involves examining industrial facility-level trend data from 1985 to the present. The census variables describe overall business productivity as a function of various factors, including energy consumption. This study would seek trends in overall business productivity that respond to changes in the intensity of energy inputs. In addition, the data for individual facilities may reveal changes in productivity trends that may coincide with the advent of an energy audit. ACEEE's intention is to distill productivity data to report these for individual industries.

Conclusions

This report has reviewed information available to describe the multiple benefits of energy efficiency to North American businesses, discussing

- current approaches to the quantification of value
- policy implications for using multiple-benefits concepts in practice
- the volume and quality of data requirements

In terms of data requirements, information about the energy consumption of various equipment types is no more than a starting point. Additional data must describe the volume and costs of inputs that are consumed concurrently with energy, and these data must be normalized to ensure comparability across applications, industries, and regions. We must recognize, however, that data collection relies heavily on the capability and motivation of business enterprises to compile and provide it.

The volume of data required to generate statistically reliable information about multiple benefits is enormous. A single utility's customer portfolio is too small to generate a statistically adequate volume of data. To accumulate the volume needed for current purposes, a continent-wide or larger effort may be in order. Any utility that maintains industrial project feasibility studies to support the provision of rebates and incentives is a potential contributor. Collaboration can also enhance the defining and measuring of multiple benefits. A number of organizations whose representatives we interviewed for this report are interested in quantifying non-energy benefits. Collaboration would facilitate data collection, methodological consistency, and cost control.

The task of developing a protocol for quantifying facility-level multiple benefits is daunting. The data requirements for reliable estimation of multiple benefits are certainly too large to be satisfied by the industrial population of a single utility service territory. This reiterates the need for collaborative effort. Attempts to measure multiple benefits data for narrowly defined industrial configurations may be problematic, even working with data collected from multiple North American sources. Statistical reliability (the ability to project multiple benefits with a fixed degree of confidence) is more likely to be achieved by compromising some definitional criteria. This might mean, for example, relaxing demands for industry- or region-specific results. It could also mean defining improvement measures more broadly.

Meaningful data collection is highly dependent on the cooperation of industrial facility staff. They will be better motivated to help if the effort returns value to them, for example, by improving productivity and other core business values in addition to energy performance. They can achieve this by measuring value at all points in a facility where energy use can be measured concurrently with value-added. They can then prioritize those interfaces to determine where large energy consumption and large production value-added (or loss) may coincide. The practical task is to demonstrate how production values are optimized at these points as a result of energy efficiency improvements. In reality, such cooperation will be achieved one facility at a time, on its own timetable, not on the utility's.

Future pursuit of facility-level data may include (1) mining of data archived from recent feasibility studies compiled by utilities to support their rebate and incentive programs, and (2) compilation of the same, but applied to future data collection per some protocol yet to be developed. The latter approach raises some questions. What is the best way to generate the necessary data? What resources are needed? Will regulators for the various utilities be consistent in their support for this effort? Are previously collected data subject to confidentiality restrictions that preclude proper investigation of multiple benefits? Are there other obstacles? What is a reasonable time line?

The best answers are likely to come through collaborative effort. In one possible scenario, a collaborative process may require up to a year to organize, followed by perhaps another year to process past data, and at least two more years to compile sufficient data from future project studies. ACEEE is currently assembling the advisory capacity to advance this agenda.

The body of knowledge that describes energy's multiple benefits must be clarified and expanded. As this happens, the knowledge can be better applied for the benefit of all stakeholders in energy efficiency program design and conduct. While this is an enormous task, some intermediate steps are easier to attain. They include the following.

Collaborative crafting of protocols for defining, measuring, and reporting multiple benefits. To some extent, this has already begun (IEA 2014; Fagan, Bradley, and Lutz 2011; MA-EEAC 2012). Multijurisdictional efforts can improve on individual efforts by amassing more data in a more consistent format.

Outreach to business leaders to stimulate their interest in energy efficiency's multiple benefits. Boiler rooms provide only a fraction of the necessary data, and the typical facility manager is unaccustomed to navigating business agendas outside the boiler room. Liaison with managers outside the facilities department could be a precursor to multiple benefits research. The balance of data will emanate from the cooperation of cost accountants responsible for operations and other core business performance. Such liaison will be new and challenging to many energy efficiency program administrators and their facility management counterparts. A new, nontechnical dialog must engage business leaders who have been historically averse to facility management details. The energy efficiency program mantra of "utility bill savings" is insufficient. Program outreach must leverage the small number of available case studies to illustrate the potential value of multiple benefits, thus motivating business leaders to take action.

Provision of guidelines or a practicum for facility managers who will then be better able to coordinate the detection and accounting of multiple benefits in their facilities. The expertise exists, but collaborative precedents are few. A train-the-trainers effort may be in order.

Development of proxy metrics. Pending the ability to collect adequate project-level data describing multiple benefits, data proxies may have to suffice. A proposed ACEEE initiative involves the use of U.S. business census data that trend changes in factor productivity over time. While this approach fails to quantify individual energy project results, it does capture enterprise-level trends in total productivity as driven by energy and production factors.

These intermediate steps should be useful in securing interest and support for subsequent research.

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Appendix A: Description of Survey Respondents and Response Types

Respondents displayed in Table 2 include the following.

Academics. University professors or staff, usually from mechanical engineering or similar departments, with deep involvement in industrial energy efficiency auditing and analysis.

Consultants. Private, independent entities that provide energy-themed engineering analysis and support services. Many of these entities serve as trade allies to energy distribution utilities as an integral part of utility program conduct. Some consultants responded with literature citations.

Government agencies. Federal, state, provincial, or regional public administrative agencies chartered to implement energy policy via program design and implementation.

Industrials. Industry-specific trade groups, or in a few instances, individual industrial enterprises.

Literature. Reports, white papers, journal articles, and other publications.

NGOs. Nongovernmental organizations. These are non-profit organizations chartered to support and advance energy policy, usually in concert with state or provincial utility regulators and utilities.

Solution providers. Private entities that sell energy-saving equipment, products, or services to industrial facilities.

Utilities. Corporations usually chartered as regulated monopoly franchises to generate, transmit, and distribute electricity and gas commodities within a defined franchise territory. This may include power cooperatives as well as energy efficiency authorities tasked with the redistribution of ratepayer revenues in ways that optimize the overall cost of energy supply within a defined region.

Table 2 also generalizes response types as follows:

A. Specifically ignores NEBs. The respondent indicates that their work to date has purposely avoided NEBs calculation because of the many difficulties in pursuing such information.
B. No data, no referral. The respondent simply indicated that they had no NEBs data and could not offer a referral to an alternate source.
C. Referral to another authority. While the respondent had no NEBs information, they referred to other contacts thought to have data.
D. Theoretical discussion of concept. Material that describes the NEB concept, but fails to provide actual data. Very often, this material discusses NEBs not from project-specific impacts and measurements, but in aggregate terms in the context of regulator-mandated energy efficiency program total-resource cost-benefit analysis.
E. Methodology discussion. Material that evaluates or prescribes the logistics for defining and measuring NEBs. No actual data presented.
F. Anecdotal documentation of nominal existence, multisectoral scope. Material that

discusses NEB impacts detected in all economic sectors (residential/commercial/industrial). May provide single-project data, but not enough to support inferential calculation.

G. Anecdotal documentation of nominal existence, commercial/industrial/business sectors. As above.
H. Percentage adders by expert consensus. Rules of thumb collaboratively developed by expert opinion, not from actual data. "Adders" prescribe NEB values of any combination all as one percentage of energy savings. These are often prescribed for use within a utility service territory, and sometimes without differentiation for economic sectors.
I. Algorithms for indirect estimation of NEBs. Similar to adders, these are formulas developed from expert consensus. Algorithms are algebraic formulae in which the user inserts energy savings (an independent variable) to calculate NEBs value (dependent variable).
J. Monetization of projects in aggregate. Some reports describe NEBs from the result of aggregated project data, providing composite dollar totals or rations of energy savings to NEBs. These aggregates are not nuanced to reveal individual projects, technologies, industries, or other descriptive variables.
K. Possible sources for future data. Some respondents expressed interest in the NEBs concept as well as the potential capacity to generate more robust data in the future. In all cases, these respondents indicate that resources would be needed to produce data of the quality required by this research.
L. Single-project descriptions of impacts. In these case studies, NEBs are recognized and categorized, but only sometimes are attempts made to quantify them. Overall, these cases are too few in number to support the creation of reliable energy-to-NEBs metrics.

Appendix B: Statistical Methodology and Data Collection Issues

CRITICAL ASSUMPTIONS

When seeking a reliable, functional relationship between energy saved and a coincident volume of non-energy benefits, the research requires data meeting several criteria. First, the energy improvement measures must be defined. For each defined measure, both energy performance and NEIs must be consistently detected and quantified across many observations, ensuring apples-to-apples comparison. Note that one distinct measure can cause multiple non-energy benefits; these benefits must be aggregated into one common denominator (dollars). Similarly, the industries and regions must be defined consistently. Each permutation of measure, industry, and region is a unique configuration that requires data in sufficient volume to convey statistical significance. This means that each configuration requires at least 30 observations.[8]

For example, 30 or more observations are required for a configuration defined as (1) the installation of a variable-speed motor drive (VSD) applied to an air compressor where the causation of NEBs can be confidently isolated to the VSD alone, plus the data have been normalized to correct for variation in throughput, load factors, and other operational characteristics unique to each facility; (2) implementation of the VSD in food processing facilities; and (3) results are differentiated by the facilities' regional locations. Change any one of these criteria, and the result is a different permutation that requires another set of 30 or more observations. Sampling requirements for this study are summarized in table B1.

Table B1. Sampling criteria for achieving valid inference of NEIs/NEBs

Criterion	Description
Real	The data represent measurements taken from actual operating installations. Laboratory or demonstration sites do not count. Also, measurements are not estimated or theoretical values.
Technology-specific	Data are derived from the operation of a discrete application observed in isolation so that they are not (1) biased by the simultaneous performance of other system components in the same facility, and are (2) consistently adjusted to control for any performance interaction.
Industry-specific	Performance data for any application is specific to a particular industry. Data would therefore nominally differentiate application performance across facilities of different industry types.
Normalized	Energy performance measurements would be accurately and consistently adjusted to account for variances attributable to the unique conditions found in each facility. Energy performance may vary with production throughput, equipment load or utilization factors, hours of operation, weather, and other factors.
Regionalized	Results are nominally differentiated for facility location.

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[8] Probability theory demands that no less than 30 observations be collected per unique variable to satisfy the parameters of inferential analysis. Barring the ability to collect adequate data for the entire population of existing applications, the next best approach is to infer that population's characteristics based on a sample of findings. Only normally distributed data samples of 30 or more allow the reliable inference of the larger population's characteristics.

Criterion	Description
Replication	Data meeting all the criteria listed above would be available in sufficient quantity to be statistically significant for inferential purposes. The minimum threshold for statistically significant data sets is 30 observations.

An extremely large volume of data is needed to ensure that 30 observations are available to satisfy each configuration. To illustrate this magnitude, consider the following parameters for a hypothetical study of multiple benefits observed in Canadian industry:

- There are 33 distinct industrial electricity improvement measures to be considered for current purposes. Why 33? Measures must be defined consistently (i.e., apples-to-apples) across all observations. The potential number of different measures increases directly as measures are more narrowly defined. The best body of measure definitions found as a result of this research is the Assessment Recommendation Code (ARC) Index developed for the U.S. Department of Energy's Industrial Assessment Center (IAC) database.[9] Specifically, this index lists 33 distinct (non-lighting) electricity improvement measures. This source is deemed best because of its clear documentation and widespread use over the past 30 years.
- There are 21 manufacturing industries in which the measures could be implemented. Industry definitions are provided by the North American Industry Classification System (NAICS).[10] The NAICS system classifies industries in progressive levels of detail.[11] For this discussion, the three-digit level (21 industries) is suggested.
- The ten Canadian provinces serve as a proxy for regional variation.

Based on these parameters, the total number of observations required to achieve statistically valid inferences about industrial NEBs would be found the following way:

33 measures × 21 industries × 10 provinces × 30 observations per unique configuration

= 207,900 total observations

Several problems with this total should be immediately evident. First, Industry Canada reports that there are only 51,418 manufacturing facilities of all kinds and sizes in Canada as of 2012.[12] Each facility would have to provide adequate documentation to describe, on

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[9] http://iac.rutgers.edu/database/. The IACs are operated by U.S.-based universities, funded by the U.S. Department of Energy, offering energy assessments to U.S.-based industrial facilities. This database has documented over 123,000 instances of energy-saving opportunities, variously defined by dozens of distinct measures, as found in over 16,000 different facilities.

[10] https://www.census.gov/eos/www/naics/. This system was collaboratively developed by economic policy authorities in the United States, Canada, and Mexico to standardize business and trade performance metrics.

[11] For example, the three-digit NAICS code 322 refers to paper manufacturing; four-digit code 3221 represents pulp, paper, and paperboard mills; and the five-digit code drills down to pulp mills only. Overall, there are 21 manufacturing industry categories at the three-digit level, 86 four-digit, 180 five-digit, and 364 six-digit industries.

[12] https://www.ic.gc.ca/app/scr/sbms/sbb/cis/establishments.html?code=31-33. Note that only 7% of these 51,418 facilities employed more than 100 people.

average, the results from four discrete electrical energy improvements. Perhaps half of these facilities counted in the census are too small to host many of the technologies considered here, and the remaining balance have not always made improvements. Even when improvements are made, not all facilities are able and willing to publicize the results. Those that actually attempt to provide data may not do so consistently and accurately. In sum, the population of industrial facilities in Canada is too small to provide the number of observations needed to make statistically reliable projections of NEBs data. Observations from the United States (and perhaps other countries) will be needed to satisfy data sampling requirements.

If sufficient data were lacking, the sampling criteria would have to be compromised in one or more ways to accumulate statistically valid observations for energy improvement measures. For example, a test of NEBs resulting from VSD motors applied to air compressors may have to commingle observations across regions or industry classifications. By relaxing the sampling criteria, the variance in performance measurement is increased—which reduces the data's ability to reliably infer the relationship between energy savings and NEBs value for any single facility.

DATA QUALITY ISSUES

Even after relaxing the sampling criteria, this exercise still requires consistent definitions for types of improvements, amounts of energy saved, and associated NEBs. As with energy, the value of NEBs must be consistent. If, for example, labor savings are the consequence of a particular energy improvement, the number of hours and labor rates will require normalization, as these vary across facilities.

Consider also that facilities often install multiple types of energy improvement more or less at one time. It may be impossible to disaggregate the NEB value caused by multiple measures in one facility, much less across many observations.

Data quality will be a constant concern. Industrial energy and NEB data collection will depend to a great extent on self-reporting by facility staff. This is a tall order, as many industrial facility representatives cannot tell you their total annual energy spending, much less how energy consumption has changed as the result of an isolated energy improvement. The quantification of NEBs would be even more elusive. Should facility staff be expected to disaggregate the individual causes of NEBs when several energy improvements are installed at once?

A paucity of data sufficient in quantity and depth to satisfy sampling criteria compromises the quest for statistically reliable metrics that link energy saved to NEBs value. Both current and future data are subject to errors in definition and measurement. Data that fall short of the sampling criteria described here will at best be anecdotal. Still, current research finds some NEB data. The goal changes accordingly: What information can be gleaned from

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available data, and what resources are required to generate data that would satisfy the original goal?