BEFORE
THE PUBLIC UTILITIES COMMISSION OF OHIO

In the Matter of the Application of Ohio	)	
Edison Company, The Cleveland Electric	)	
Illuminating Company, and The Toledo	)	Case Nos.12-2190-EL-POR
Edison Company For Approval of Their	)	12-2191-EL-POR
Energy Efficiency and Peak Demand	)	12-2192-EL-POR
Reduction Program Portfolio Plans for 2013	)	
through 2015	)	

DIRECT TESTIMONY
OF
JOEL SWISHER
ON BEHALF OF THE
NATURAL RESOURCES DEFENSE COUNCIL

October 5, 2012

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I: Introduction

Q: What is your name, address, and position?

A: My name is Joel Swisher. My address is 4188 Amber Place, Boulder CO 80304. I am an independent consultant retained by the Natural Resources Defense Council ("NRDC") as an advisor on energy efficiency. During January through June, I am a Consulting Associate Professor of Civil and Environmental Engineering at Stanford University.

Q: Describe your educational background and professional experience.

A: I earned a Doctor of Philosophy degree in Civil and Environmental Engineering in 1991, a Master of Science in Mechanical Engineering in 1980, and a Bachelor of Science, with distinction, in Civil Engineering in 1978, all from Stanford University. I am a registered Professional Engineer in Colorado. I have over 30 years of experience in research and consulting on energy efficiency, greenhouse gas mitigation, and electric utility resource planning. Recently, I was Director of Technical Services and CTO for Camco International, a developer of carbon offset projects, and before that I was Managing Director of Rocky Mountain Institute (RMI), where I led RMI's consulting work with electric utilities and major corporations in mining, oil and gas, and manufacturing of products ranging from semiconductor chips to potato chips. My resume is attached as Attachment 1.

Q: What do you teach at Stanford?

A: CEE 221A Planning Tools and Methods in the Power Sector in the winter quarter and CEE 272S Greenhouse Gas Mitigation in the spring quarter.

Q: Have you published documents relevant to this field?

A: Yes. I am lead author of over 100 professional publications including several commercial building efficiency guidebooks for the Electric Power Research Institute, and *Tools and Methods for Integrated Resource Planning*, a bilingual (English and Portuguese) textbook on energy efficiency program analysis and integrated resource planning, which I co-authored with a Brazilian colleague.

Q: Have you consulted with electric utilities and related organizations?

A: Yes. I have consulted with Pacific Gas & Electric, Southern California Edison, Kansas City Power and Light, Progress Energy, Duke Energy Carolinas, Dominion Energy, Nevada Power Corp., NStar Boston, Hawaiian Electric, Central Power and Light, Silicon Valley Power, Northern California Power Association, Nebraska Public Power District, Sacramento Municipal Utility District, Salt River Project, Kansas Energy Council, City of Palo Alto Utilities, California Public Utilities Commission, San Francisco Public Utilities Commission, North American Power Group, BC Hydro, Iberdrola, Spain, Eskom South Africa, Uganda Electricity Regulatory Authority, and Companhia Paulista de Forca e Luz.

Q: Have you previously testified before the Public Utilities Commission of Ohio?

A: No.

Q: What is the purpose of your testimony?

A: The purpose of my testimony is to recommend improvements to the evaluation of energy efficiency potential and the design of specific efficiency programs in the Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015 (the "Plan") of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company ("FirstEnergy" or "Companies"). Specifically, I will:

- Recommend the Companies apply a more realistic approach to estimating achievable energy efficiency potential,
- Recommend an efficiency program directed specifically at data centers or small server rooms and server systems in the commercial sector,
- Recommend a dedicated retro-commissioning program in the commercial sector,
- Recommend expanding the new construction incentive for small C&I into a comprehensive efficient new construction program that offers design assistance and financial incentives to cover system design and engineering, as well as more efficient technology, in both small and large C&I sectors, and

- Recommend the Companies apply a more realistic approach to estimating avoided costs, which will also improve the estimates of economic and achievable efficiency potential.

II: Market Potential Study

Q: Do the achievable energy efficiency potential results, from the Black & Veatch 2012 Market Potential Study and adopted by the Companies in their efficiency plans, appear to be realistic?

A: No. They appear to underestimate the true achievable energy efficiency potential.

Q: What is the significance of underestimating achievable efficiency potential?

A: The achievable energy efficiency potential is often considered as the maximum amount of savings that can realistically be expected from efficiency programs. It suggests that additional savings cannot be achieved and thus should not be in a utility's resource plan. In FirstEnergy's case, assuming reasonably successful implementation of the 2013-15 plan, the remaining efficiency resource would soon be constrained by the apparent limit of the achievable potential. Such a limit would make it difficult to achieve rates of incremental energy efficiency savings after 2015 that are mandated by SB 221 and that are already in the implementation plans of other Ohio utilities.

Q: What is energy efficiency potential?

A: Energy efficiency analysts routinely refer to three levels of efficiency potential:

- Technical efficiency potential describes the maximum amount of savings that could be achieved, not considering economic and market barriers, by installing energy efficiency measures. In practice, technical potential is not very useful, as the estimated maximum efficiency is typically limited by available data, not by technology. Because there is little interest in implementing measures that are not cost-effective, relatively little engineering work is expended to identify and analyze such measures in detail.
- Economic efficiency potential describes the amount of technical efficiency potential that is cost-effective. Assuming that the total resource cost (TRC) is the main cost-

effectiveness criterion, efficiency measure's levelized cost of saved energy must be less than the utility's avoided supply cost, to be included in the economic potential. Economic potential does not consider economic or market barriers to customers installing efficiency measures.

- Achievable efficiency potential estimates the amount of economic efficiency potential that could be captured by realistic efficiency programs that include cost-effective efficiency measures over the forecast period. Estimating achievable potential requires some judgment regarding how much and how fast a utility can implement programs to install the identified efficiency measures. Achievable potential therefore varies with the amount and type of marketing, the magnitude of rebates or incentives offered to customers to install efficiency measures, and other factors. Analysts use quantitative algorithms and computer models based on prior experience to translate economic potential into achievable potential.

Q: How is achievable potential defined in Ohio?

A: According to the Ohio Administrative Code:

> "Achievable potential" means the reduction in energy usage or peak demand that would likely result from the expected adoption by homes and businesses of the most efficient, cost-effective measures, given effective program design, taking into account remaining barriers to customer adoption of those measures. Barriers may include market, financial, political, regulatory, or attitudinal barriers, or the lack of commercially available product. "Achievable potential" is a subset of "economic potential."[1]

In other words, the achievable potential is what could be achieved by aggressive implementation of efficiency programs designed to remove barriers and according to industry best practices.

Q: Did the Companies use appropriate methods to estimate achievable energy efficiency program potential?

[1] O.A.C. 4901:1-39-01(A)

A: No. The method the Companies used to estimate achievable efficiency potential departs from the types of methods commonly used, which are generally based on observed results from energy efficiency programs in operation. The logic of the Market Potential Study is questionable, and its results appear unrealistic, which makes the method more questionable still.

Q: Why do you question the methodology used to estimate achievable potential in the Market Potential Study?

A: The approach used to estimate achievable potential in the Market Potential Study is flawed for several reasons:

- Data source: the Market Potential Study relies on surveys and interviews of customers and potential program participants to determine achievable program potential, rather than observed data from efficiency programs in the field.
- Type of data: the Market Potential Study relies on customers' opinions and speculation about future participation in programs, before the programs, incentives and marketing efforts are deployed, rather than ex-post performance of real customers in response to such programs and incentives.
- Documentation: while the Market Potential Study varies from the standard approaches to estimating achievable efficiency potential, it does not document evidence that its methods are superior, or even correlated with real behavior.
- Results: the Market Potential Study reports maximum achievable energy savings rates that are lower than actual rates being achieved in existing efficiency programs.

Q: How does the Market Potential Study use customer survey data in estimating achievable efficiency potential?

A: The Market Potential Study relied on "customer attitudes and preferences obtained through mail and telephone surveys and interviews"[2] to estimate achievable energy savings, program participation rates,

[2] Toledo Edison EE & PDR Program Plan at 6.

and determine the make-up of end-use equipment on customers' premises. Surveys were conducted of random samples of residential customers (500 customer returned the mailed survey), commercial customers (100 responded to a phone survey), and 13 large account-managed industrial customers.[3] To determine the amount of "Base Case" achievable energy efficiency, the energy savings produced by customers who responded "I plan to change" to an efficient option within an end-use category or expressed very high interest in a program were extrapolated across an end use in a service territory. To determine the amount of "High Case" achievable energy efficiency, the additional energy savings produced by customers who were "considering changing" or expressed high interest in a program were extrapolated across an end use in a service territory.[4]

Q: Why are customer surveys and interviews an inappropriate data source to estimate achievable potential in the Market Potential Study?

A: Today, FirstEnergy customers have little experience with efficiency programs. Lacking such experience, they cannot be expected to have an accurate view of their interest and ability to benefit from future efficiency programs. In the future, additional learning, improvement in program design, and customer education and familiarity with efficiency program benefits can be expected to expand the potential participation beyond the segment of the customer population that reports strong interest, sight unseen, today. It is reasonable to expect this potential to approach the levels now being achieved in states with mature efficiency programs and policies.

Q: Why are ex ante customer opinions and speculation about future participation in programs an inappropriate data source to estimate achievable potential in the Market Potential Study?

A: While such survey data might be useful for the purposes of program design and targeting of marketing campaigns, it is difficult to see how such data would be indicative of the true future potential for efficiency programs that might be offered to customers over the next decade. Customers are not energy experts, they have multiple demands on their time and attention, and they can hardly be expected to

[3] Black & Veatch, Market Potential Study: Energy Savings and Demand Reduction for Ohio Edison, Toledo Edison, and The Illuminating Company, June 22, 2012 at 35.
[4] *Ibid*. at 96.

answer accurately when asked what they will want at some future time. As such, the survey-based methodology applied in the Market Potential Study can be expected to measure what would be achieved following business-as-usual activity, based on existing information and investment patterns, not the result of well-designed programs.

Q: Were the achievable potential projections in the Market Potential Study correlated with observed real behavior in the field?

A: When asked if FirstEnergy or Black&Veatch had conducted analysis to correlate their survey-based results with past performance of energy efficiency programs or actual electricity use profiles at a customer's premises, they answered that "specific correlation analyses were not performed" (see Attachment 2).[5]

Q: Do the Companies' estimates of achievable energy efficiency potential appear realistic?

A: No. The incremental achievable efficiency is about 0.5% per year from 2015 onward, lower than the incremental energy efficiency savings that are mandated by SB 221 and already in the implementation plans of other Ohio utilities. This scenario of 0.5% incremental savings is directly contradicted by experience with utility programs in states that, even after decades of efficiency program activity, are still able to achieve incremental savings of more than 1% per year. These cases include utilities in the Northwest, where energy prices are low, and are crowned by the examples of Vermont and Massachusetts, which achieve about 2% incremental savings annually after many years of activity. According to the American Council for an Energy Efficient Economy, an independent non-profit that tracks progress in energy efficiency policy, more than ten states achieved incremental savings of 1% or more during 2010, or double the maximum achievable rate according to the Companies' Market Potential Study. [6]

[5] NRDC Set 3 INT-30

[6] American Council for an Energy Efficient Economy, State Energy Efficiency Resource Standard (EERS) Activity, October 2011, available at: http://www.aceee.org/files/pdf/policy-brief/State%20EERS%20Summary%20October%202011.pdf

Q: What makes the estimates of achievable potential in the Market Potential Study logically inconsistent?

A: Other utilities are already capturing energy savings 2-4 times higher than the Market Potential Study's reported achievable efficiency potential. This difference clearly indicates that more efficiency can realistically be achieved.

Q: How could the method for estimating achievable efficiency potential be improved?

A: One should examine the performance of the best programs in the country in reducing energy use among each end-use technology analyzed.[7] This approach would produce a more realistic achievable potential, as expressed in the Ohio Administrative Code: quantifying the real-world potential energy use reductions "given effective program design." Effective programs change existing information and investment patterns by increasing information availability, modifying investment patterns using program incentives and marketing, reducing transaction costs.

Q: Should the achievable efficiency potential estimates from the Market Potential Study be used in the design of the efficiency program portfolio?

A: No. The Commission should not rely on the results of the Market Potential Study to limit energy efficiency program investment. In the future, market potential study methodologies should be reviewed by the Collaborative and Commission Staff, and the Companies should base "expected adoption" of efficient technologies on observation of the best performing programs in Ohio and other jurisdictions (taking into account service territory-related differences). To determine appliance saturations and technology shares, the Companies should used onsite visits, perhaps partnering with other utilities in Ohio or other FirstEnergy operating companies. AEP-Ohio, for example, based its assessment of achievable

[7] See, generally, the Xcel Energy programs at https://business.responsiblebynature.com/?wssl=1, Efficiency Vermont programs at http://www.efficiencyvermont.com/Index.aspx, PG&E programs at http://www.pge.com/mybusiness/energysavingsrebates/ and Bonneville Power Administration programs at http://www.bpA:gov/energy/n/commercial.cfm

potential partially on a baseline survey[8] that included 68 residential and 136 commercial and industrial site visits (see Attachment 3).[9]

Q: Do you have any other recommendations?

A: I recommend the commission amend the plan to include my recommendations above.

III. Data center and server room energy efficiency

Q: Is the Companies' approach to energy efficiency in data centers and computer servers adequate?

A: No. The Companies' C&I energy efficiency portfolio does not include any program activity directed specifically at data centers or small server rooms and server systems. The portfolio only provides for servers to be "eligible as custom equipment under the C&I Energy Efficient Equipment Programs, Small and Large," according to the companies' responses to previous interrogatories (see Attachment 4).[10]

Q: Why is the C&I custom equipment program insufficient to capture this opportunity?

A: The custom program requires an individual application and can be time-consuming for the customer. Waiting for customers to apply to this program would not help to overcome existing barriers to customers identifying and implementing energy efficiency opportunities.

Q: Why are data centers and servers an important energy efficiency resource?

A: Data centers are servers are mostly very inefficient in terms of energy use, compared to best practices. Due to their rapid market growth and spread into all aspects of business, data centers and servers represent a major energy saving opportunity and potential resource.

Q: Don't high technology facilities such as data centers have advanced technology that is highly efficient?

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[8] AEP Ohio, 2012-2014 EE/PDR Plan-Appendices, Case No. 11-5568-EL-POR, et al., November 29, 2011, Page A-16.

[9] Navigant Consulting, AEP-Ohio Residential DSM Potential 2012-2014 Preliminary Results, presented to Stakeholder Group, May 4, 2011.

[10] NRDC Set 2-INT-12.

A: No, unfortunately energy efficiency has been generally an afterthought in the design of such facilities, at least until very recently. Although data centers, servers and IT equipment generally are considered "high tech," these types of facilities and equipment are highly inefficient in their energy use.

Q: How much of the electric energy used in a data center performs useful computing?

A: In fact, most of a data center's energy is wasted, and it is typical for only about 3% of the electricity consumption to perform useful computing. The typical energy chain is as follows (see Attachment 5):[11]

- Of each kW that enters the facility, about one-third is used for cooling, removing the heat generated by the servers and other equipment, leaving 670 watts
- Of this amount, about 4% is used for lighting, leaving 640 watts
- Of this amount, about 15% is consumed as losses in the uninterruptible power supply system, leaving about 540 watts
- Of this amount, about 10% is used by the internal server fans, leaving 490 watts
- Of this amount about 35% is dissipated as heat in the server power supply (which is why they need fans and a cooling system), which leaves 320 watts
- Finally, the remaining power reaches the servers, which are operated at only about 8% average utilization (the rest of their capacity is idle), meaning that only about 25 watts actually perform useful computing, and more than 97% is wasted.

Q: What type of efficiency program activity should the Companies undertake beyond the planned custom equipment efficiency programs?

A: Rather than limiting data center and server efficiency to custom equipment programs to which customers might or might not apply, I recommend the Commission should modify the plan and order the FirstEnergy to deploy a program that directly targets these applications with marketing, incentives and program delivery.

Q: How should such an expanded program link with the existing efficiency portfolio?

[11] Rocky Mountain Institute, 2009. A Framework for Data Center Efficiency Strategy, p. 4, www.rmi.org

A: A dedicated data center and server room energy efficiency program could be bundled together with other C&I programs such as lighting and HVAC, and it could apply the existing incentive payment structure (which appears to offer $0.10 per annual kWh saved).[12]

Q: How should such a program be structured to meet the different needs of large data centers, smaller server rooms and other customer facilities with significant energy use in servers and related IT equipment?

A: The program could be fully deployed in the Large C&I Energy Efficient Equipment Program, for data centers are larger server room facilities, and a subset of the full program could be applied in the Small C&I Energy Efficient Equipment Program, where it would focus on a more limited set of measures aimed at smaller data rooms.

Q: Do utilities have a successful history with data center and server room energy efficiency programs?

A: Yes. Data center and server efficiency programs were pioneered by Pacific Gas & Electric Company,[13] starting in 2005, and these types of programs are now offered by utilities around the country (see Attachment 6).[14]

Q: Is there any experience with data center and server room energy efficiency program implementation in Ohio?

A: Yes. AEP-Ohio is introducing a data center efficiency program (recently approved by the Commission) that provides incentives for participating businesses to support: [15]

- a facility assessment to identify energy efficiency opportunities
- technical assistance from an approved program implementation contractor

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[12] This is the ratio of modeled rebate levels to annual kWh savings for custom C&I programs, Toledo Edison EE & PDR Program Plan, Appendix C-1.

[13] The PG&E program is accessed at: http://www.pge.com/mybusiness/energysavingsrebates/incentivesbyindustry/hightech/

[14] Consortium for Energy Efficiency, 2010. Data Centers & Business Computing Program Summary, www.cee1.org/files/DataCentersSummary.xls

[15] AEP Ohio, 2012 TO 2014 Energy Efficiency/Peak Demand Reduction (EE/PDR) Action Plan, section 4.2.10.

- program incentives paid directly to the contractor
- installation of approved energy-savings equipment by approved, trained contractor, and
- pre- and post-installation inspections to ensure quality and verify energy savings.

Q: Does this type of efficiency program entail specific requirements or qualifications for the implementation contractors, or are they similar to other building energy efficiency programs?

A: The implementation contractors for this type of program are not the same as those employed for familiar HVAC and lighting. They must be specifically trained for the more specialized IT work.

Q: What types of energy efficiency measures should be covered by a data center and server efficiency program?

A: I recommend the efficiency measures covered by programs that address both large data centers and smaller server rooms should include:

- Identification and decommissioning of unused "ghost" servers
- Server virtualization to reduce the number of physical servers by using virtual servers on a few host machine, increasing server utilization up to ten-fold and enhancing reliability
- Use of centralized or "cloud" services that migrate IT workloads from equipment in server rooms to "the cloud" or a central data center, where operations are highly efficient
- Refreshing older equipment with Energy Star Servers with maximum power supply efficiencies and minimum power factors at various loads, saving 10-15%
- Efficient cooling through improved airflow, efficient Computer Room Air Conditioning (CRAC) or Computer Room Air Handler (CRAH) units, variable-speed drives, etc.

Q: Are there additional efficiency measures that are specifically applicable in specialized central data centers?

A: Yes. I recommend the efficiency measures covered by programs that address large data centers should include:

- High efficiency Uninterruptible Power System (UPS), with savings of up to 10% of overall data center consumption
- Efficient floor layout with hot-aisle/cold-aisle arrangements, which is easier to achieve if coupled with server virtualization, to reduce cooling energy up to 10%
- Optimized temperature and humidity set points, which are typically set lower than needed for equipment operation, resulting in reduced reliability and increased energy use
- Air-side economizers to reduce cooling energy by using direct outside air whenever ambient temperature and humidity are low enough to cool the space and equipment without mechanical refrigeration. This strategy is enhanced by optimizing set points. Other strategies include air-to-air heat exchangers (exhaust air heat recovery) or water-side economizers (direct use of cooling towers to bypass mechanical chiller operation).

IV. Retro-commissioning:

Q: Is the Companies' approach to operational energy efficiency in existing C&I facilities adequate?

A: No. The Companies C&I energy efficiency portfolio includes an insignificant (0.2% of total investment and savings) level of activity to deploy retro-commissioning in large C&I customer facilities. The portfolio plan calls for only 20 customer participants per year across all three Companies.[16]

Q: Are retro-commissioning measures properly positioned in the C&I buildings efficiency program portfolio?

A: No. The portfolio only provides for retro-commissioning as a minor part of the custom buildings component of the C&I Energy Efficient Equipment Programs, Large. The broader program is aimed at building shell measures, which is completely different from retro-commissioning, which targets operational efficiency and energy savings in building equipment and controls. This confusing positioning

[16] Toledo Edison EE & PDR Program Plan, Appendix C-2., Ohio Edison EE & PDR Program Plan, Appendix C-2., Cleveland Electric Illuminating EE & PDR Program Plan, Appendix C-2.

within the portfolio could be a barrier to participation, and it could result in the assignment of implementation contractors that are not properly trained to perform retro-commissioning work. Moreover, the portfolio does not include any program activity directed specifically at retro-commissioning in smaller C&I customer facilities.

Q: Why is the C&I custom buildings program insufficient to capture this opportunity?

A: The custom program requires an individual application and can be time-consuming for the customer. Waiting for customers to apply to this program would not help to overcome existing barriers to customers identifying and implementing operational energy efficiency opportunities in the C&I sector, which are complementary and additional to conventional retrofit efficiency measures and programs. Moreover, a dedicated retro-commissioning program would provide credibility and confidence for customers to work with pre-approved, trained and qualified retro-commissioning experts and implementation contractors.

Q: Is the proposed program budget consistent with the type of actions needed to capture this efficiency opportunity?

A: No. The proposed budget for this measure is more than 80% operations and less than 20% incentives.[17] This budget structure makes little sense based on the program description, in which efficiency measures are "intended to encourage customers to gain and utilize certified building system operation training and energy management systems to reduce energy consumption and demand by improved building energy performance."[18] This description makes the program sound like a relatively passive incentive program that connects pro-active customers with approved contractors that deliver the commissioning service, but the budget is less than 20% incentives. It would make more sense to devote considerable operations budget to building capacity to scale up such a program, but the projected participation is flat at 20 participants per year.

Q: What is retro-commissioning?

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[17] Toledo Edison EE & PDR Program Plan, Appendix B-4.
[18] Toledo Edison EE & PDR Program Plan at 50, Section 3.4.9.

A: Retro-commissioning is the diagnosis and correction of operational problems in a building's energy systems and equipment, such as lighting and space conditioning, to ensure that they operate according to their intended design, which is rarely the case in practice. A recent study completed by Lawrence Berkeley National Laboratory, supported by the U.S. Department of Energy, surveyed over 560 existing buildings (>90 million ft^2), commissioned by 37 different commissioning providers, and found (see Attachment 7):[19]

- Median costs of measures implemented from retro-commissioning were $0.30/ft2
- Whole-building energy savings averaged 15%
- Simple payback period was 1.1 years on average
- Most reported improved occupant comfort and/or productivity.

Q: How is retro-commissioning distinct from C&I building retrofits?

A: With retro-commissioning, energy savings result from restoring a building's operational performance and do not overlap with savings achieved by efficient technology upgrades. Rather, retro-commissioning can be complementary and mostly additional to efficiency retrofits. Essentially, technology retrofits upgrade the capability of building equipment to provide comfort and functionality while using less energy, and retro-commissioning helps ensure that the equipment performs according to its true capability.

Q: What type of efficiency program activity should the Companies undertake beyond the planned custom building efficiency programs?

A: Rather than limiting retro-commissioning to the custom large building program to which customers might not even apply for an equipment-related activity such as commissioning, I recommend the Commission should modify the plan and order FirstEnergy to deploy a dedicated retro-commissioning program that offers financial incentives to cover the cost of the commissioning assessment and capital improvements recommended by retro-commissioning.

[19] Mills et al., Building Commissioning: A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions, 2009, available at: http://cx.lbl.gov/2009-assessment.html

Q: How should such an expanded program link with the existing efficiency portfolio?

A: Conventional efficiency retrofit measures installed during the commissioning process should still be eligible for retrofit incentives. The retro-commissioning program can thus be integrated together with other C&I equipment programs such as lighting and HVAC, using the existing marketing, incentives and program delivery structure.

Q: How should such a program be structured to meet the different needs of large C&I customer and small enterprise customers?

A: I recommend a comprehensive retro-commissioning program should be fully deployed in the Large C&I Energy Efficient Buildings Program, or the Large C&I Energy Efficient Equipment Program, and a subset of the full program similar to the AEP Ohio "RCx Lite" should be applied in the Small C&I Energy Efficient Buildings Program or the Small C&I Energy Efficient Equipment Program, focusing on a more limited set of measures aimed at smaller buildings.

Q: Do utilities have a successful history with retro-commissioning in their energy efficiency program portfolios?

A: Yes. Retro-commissioning programs have been in operation for about ten years and are now offered by utilities around the country. In Illinois, Commonwealth Edison's Smart Ideas program includes retro-commissioning for large commercial buildings (>50,000 ft^2), offering incentives that cover the commissioning assessment and M&V cost, with a customer implementation requirement, in addition to the standard utility incentives that apply to implemented retrofit measures. ComEd is now piloting an instrumented "monitoring-based" (continuous) commissioning program to achieve deeper, more persistent savings, and also looking at new approaches for smaller buildings (see Attachment 9).[20]

Q: Is there any experience with retro-commissioning program implementation in Ohio?

A: Yes. AEP-Ohio is introducing a retro-commissioning program (recently approved by the Commission) that provides financial incentives to help customers overcome the first-cost barriers to

[20] Matthews, D., 2011. A Utility's Perspective on Retro-commissioning, 19th National Conference on Building Commissioning, http://www.peci.org/ncbc/2011/documents/presentations/09_ncbc-2011-utility_perspective_rcx-matthews.pdf

conducting a commissioning study and implementing the study's recommendations. The incentives are intended to support: [21]

- An initial retro-commissioning study for the customer, in exchange for the customer's commitment to complete those recommendations with short (1.5 year) payback times
- Recruitment, oversight and training, as needed, of retro-commissioning service providers (RSP), who provide commissioning services, and installation contractors, who review the studies and install recommended measures
- Where applicable, the commissioning study may include an assessment of energy savings opportunities eligible for retrofit incentives through other utility C&I programs
- Program incentives paid directly to the contractors
- Pre- and post-installation inspections to ensure quality and verify energy savings
- A customer education component, linked to existing industry activity such as Building Operator Certification, to promote the value of retro-commissioning services, targeting senior management, as well as facility operations and maintenance staff.

Q: Is AEP's retro-commissioning program a good model to emulate?

A: Yes. I recommend the Commission modify the plan to include a retro-commissioning program similar to the AEP-Ohio program. AEP's program is a useful model from which to start, and the members of the Ohio Collaborative are familiar with the AEP program and can provide useful feedback.

Q: How is the AEP Ohio retro-commissioning program targeted?

A: The AEP Ohio comprehensive retro-commissioning program is aimed at large (>500kW or about 100,000 ft^2) C&I customers. The program also includes a "RCx Lite" component for smaller buildings, using a limited set of likely energy-saving opportunities in HVAC, lighting and motor controls.[22]

Q: What types of measures are included in the AEP Ohio program?

[21] AEP Ohio, 2012 TO 2014 Energy Efficiency/Peak Demand Reduction (EE/PDR) Action Plan, section 4.2.7.
[22] *Ibid.*

A: In the comprehensive program for large C&I, eligible measures include:

- HVAC systems and controls: Economizers, demand control ventilation, heat recovery ventilators, fan and pump control, head-pressure control, setback and night vent control
- Lighting controls: Occupancy/vacancy controls, photo-sensors, timer controls
- Motor controls: Variable frequency drives, timer controls
- Process controls: Where applicable.

Q: Does this type of efficiency program entail specific requirements or qualifications for the implementation contractors, or are they similar to other building energy efficiency programs?

A: The RSPs and implementation contractors for this type of program are not the same as those employed for familiar HVAC and lighting. They must be specifically trained for the more comprehensive retro-commissioning assessment work.

V. C&I new construction:

Q: Is the Companies' approach to energy efficiency in new C&I facilities adequate?

A: No. The Companies C&I energy efficiency portfolio includes an insignificant (0.6% of total investment and savings, about one tenth as much devoted to small C&I efficiency "kits") level of activity to advance energy efficiency in the design and construction of new, small C&I customer facilities. Moreover, the portfolio does not include any program activity directed specifically at new construction of large C&I customer facilities.

Q: Why is the C&I new buildings program insufficient to capture this opportunity?

A: The portfolio only provides for new construction efficiency incentives as a minor part of the C&I Energy Efficient Buildings Programs, Small. The portfolio plan calls for 72 small C&I customer participants per year by 2015 across all three Companies, and no large C&I customer participants.

Q: Is the proposed program budget consistent with the type of actions needed to capture this efficiency opportunity?

A: No. The proposed budget for this measure is more than 85% operations and less than 15% incentives.[23] This budget structure makes little sense based on the program description, in which the program "provides financial support through incentives for the design and construction of buildings that exceed standard building codes and practices by 15% of the electrical consumption and meet ENERGY STAR. The incentives will cover a portion of the incremental cost for design services over the consumption and demand by improved building energy performance."[24] This description makes the program sound like a relatively passive incentive program, but the budget is less than 15% incentives. It would make more sense to devote considerable operations budget to direct design assistance to building designers and marketing outreach to build capacity to scale up such a program, but the program design does not address these functions.

Q: Isn't the small share of new buildings built each year insignificant in the overall market?

A: No, for two reasons. First, the small projected scale of the new construction program may be due partly to the slow rate of new construction in Midwest economy recently, but new construction potential increases as the local economy strengthens, with manufacturing recovering and statewide unemployment below the national average. Second, new buildings are 100% of the new buildings market, and the potential cost and performance synergies of high-efficiency design, not just measure-by-measure equipment improvements, can only be captured in the design phase, before these potential gains become "lost opportunities."

Q: What do you mean by "lost opportunities" in new building energy efficiency?

A: Retrofitting today's new buildings at a later time to improve energy efficiency is sure to cost more and achieve less than maximizing efficiency in new construction. Realizing the cost and performance synergies possible in new construction requires high-efficiency system design, not just measure-by-measure improvements (although measure efficiency is complementary and indeed part of efficient system design).

[23] Toledo Edison EE & PDR Program Plan, Appendix B-4

[24] Toledo Edison EE & PDR Program Plan at 41, Section 3.3.7.

Q: What are the potential synergies in energy-efficient new building design?

A: The potential cost and performance synergies in efficient system design include:

- The opportunity to down-size heating and cooling equipment based on reduced loads, thus reducing the capacity, size and cost of, for example, HVAC equipment
- Reduced cost by upgrading equipment when it is new and incremental costs are lowest, compared to replacing equipment still in service at higher incremental cost
- Focus on efficient system design in new construction provides for intensive upgrades, which avoids "cream-skimming" of only the fastest-payback measures.

Q: What type of new C&I building efficiency program activity should the Companies undertake?

A: Rather than limiting new construction incentives to a fixed target (based on ENERGY STAR) under the C&I small building program, the Commission should order FirstEnergy to modify the plan and expand the new construction incentive for small C&I into a comprehensive efficient new construction program that offers direct design assistance and financial incentives to cover the cost of additional high-efficiency system design and engineering, as well as more efficient technology.

Q: What about large C&I new construction?

A: In addition, a similar type of new construction program should be initiated in the Large C&I Energy Efficient Buildings Program.

Q: How should such an expanded program link with the existing efficiency portfolio?

A: Conventional component-level efficiency measures should still be eligible for equipment incentives. These program incentives, including design assistance, should also be available and actively marketed to the large C&I customer segment.

Q: Do utilities have a successful history with new C&I buildings in their energy efficiency program portfolios?

A: Yes. C&I new construction programs have been conducted by some utilities since the 1980s and are now offered by utilities around the country. For example, Xcel Energy has run a new construction program for C&I customers in Minnesota and Colorado since 1993, initially called Energy Assets and now called Energy Design Assistance. The Xcel program funds independent design assistance, including building energy simulation analysis, and offers incentives for each peak kW saved compared to a code-compliant baseline. The investment per unit of energy saved has been similar to that proposed by FirstEnergy (which appears to offer $0.10/kWh), [25] but larger investment levels ($120,000) and load reductions (about 200 kW and 1000 MWh/y) are achieved per participant (see Attachment F).[26] The program also includes relatively large buildings among the participants.

Q: How do such programs address system design synergies for efficient new buildings?

A: The key is usually design assistance. Xcel's approach enables whole-system design that employs diverse design strategies and captures system design performance synergies. Other utilities offer similar new construction programs with names like Savings by Design, which emphasize support for design assistance to improve building performance in the design phase.[27]

Q: Is there any experience with new construction program implementation in Ohio?

A: Yes. AEP Ohio has an on-going C&I new construction program that provides design assistance to architects and engineers in the form of building simulation modeling of efficient designs. The program takes a whole-building approach and offers incentives for the design team as well as the owner. In addition to supporting design assistance, the program provides incentives for the installation of high-efficiency lighting, HVAC, building envelope, refrigeration and other equipment and controls. [28]

Q: How is the AEP Ohio new construction program targeted?

A: The AEP Ohio C&I new construction program is aimed at all C&I new construction projects. The program includes a marketing mechanism for architects and engineers to promote energy-efficient building design to building owners and managers.

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[25] This is the ratio of modeled rebate levels to annual kWh savings for custom C&I programs, Toledo Edison EE & PDR Program Plan, Appendix C-1.

[26] The program history is from York, D., et al., "Compendium of Champions: Chronicling Exemplary Energy Efficiency Programs from Across the U.S." American Council for an Energy Efficient Economy, 2008, available at: http://www.aceee.org/research-report/u081. The current Xcel Energy program is accessed at https://business.responsiblebynature.com/rebate-programs/energy-design-assistance?wssl=1

[27] For example, see http://www.savingsbydesign.com/

[28] AEP Ohio, 2012 TO 2014 Energy Efficiency/Peak Demand Reduction (EE/PDR) Action Plan, section 4.2.3.

Q: Is the AEP Ohio C&I new construction program fully scaled up?

A: Not as yet. The program design projects moderate levels of investment ($20,000) and energy savings (25 peak kW and 200 MWh/y) per building project. The program is projected to be highly cost-effective (TRC benefit/cost > 12), suggesting that more generous incentives could be applied to capture deeper efficiency gains without risking the program's cost-effectiveness.

VI. Avoided costs:

Q: Have you reviewed the avoided cost values used by the Companies, in their energy efficiency plans and in the Market Potential Study that the plans reference?

A: Yes. They appear to underestimate the true avoided costs of electricity supply.

Q: What are avoided costs?

A: Avoided costs are the economic value of the electricity supply that would be needed in the absence of planed energy efficiency measures and program, and that is therefore "avoided" if the efficiency measures and programs are in place. Avoided costs are quantified according to the full forward-looking, long-run marginal costs of electricity supply.

Q: Why does it matter if avoided costs are underestimated?

A: Underestimating avoided costs will tend to discourage energy efficiency investments. Some potential efficiency measures will not pass utility cost-effectiveness tests using the depressed avoided costs, although the same measures would appear cost-effective using the full avoided costs. By using full avoided costs to test the cost-effectiveness of efficiency programs, FirstEnergy can ensure that it captures as much of the cost-effective potential as possible.

Q: How do the estimates of avoided costs influence the cost-effectiveness of efficiency measures and programs?

A: In most of the cost-effectiveness tests, including total resource cost, utility cost, and rate impact, the "benefit" of energy efficiency is the avoided cost. The value of this "benefit" becomes the maximum efficiency program cost that can be considered cost-effective. Therefore, if the "benefit" of efficiency is underestimated, then the maximum allowable cost for efficiency measures and programs must be lower than if a higher, more realistic avoided cost estimate served as the "benefit." The Market Potential Study states that "the avoided costs provide the only economic throttle on cost effectiveness."[29]

Q: Besides excluding higher cost efficiency measures from consideration, how does the underestimation of avoided costs affect the measures that do get implemented?

A: Emphasizing only the lowest-cost measures, because more expensive measures are found to be not cost-effective, leads to "cream skimming," where each customer receives only a few inexpensive measures. Later, if more comprehensive efficiency upgrades are considered, the package of remaining measures appear more expensive, because the low-cost measures are already in place. A better strategy would be to enable comprehensive upgrades from the start.

Q: Did the Companies use appropriate methods to estimate avoided costs?

A: The results appear unrealistic and are therefore likely to result from methodological errors. The main components of FirstEnergy's avoided costs appear to be lower than one would expect using common-practice avoided cost analysis methods and assumptions, and some components appear to be missing entirely, and presumably assumed to be zero.

Q: Where does one find these "common-practice avoided cost analysis methods and assumptions" that you reference?

A: For example, the National Action Plan for Energy Efficiency, a resource developed by a Leadership Group of more than 50 leading electric and gas utilities, state utility commissioners, state air and energy agencies, energy service providers, energy consumers, and energy efficiency and consumer advocates, facilitated by the U.S. Department of Energy and U.S. Environmental Protection Agency, presents a

[29] Black & Veatch, Market Potential Study: Energy Savings and Demand Reduction for Ohio Edison, Toledo Edison, and The Illuminating Company, June 22, 2012 at 35.

useful summary in the 2007 National Action Plan for Energy Efficiency, Guide to Resource Planning with Energy Efficiency (see Attachment 10).[30]

Q: Do the Companies' estimates of avoided energy costs appear realistic in the cost-effectiveness calculations?

A: No, generally, but the available data are confusing. Regarding the reported[31] avoided energy cost values (see Attachment 11), the avoided energy costs per MWh are estimated at about $40 peak / $30 average / $25 off-peak in 2012, rising to about $50 peak / $40 average / $33 off-peak in 2015, and escalating at about 1% annually thereafter. Levelized at 8.5%, the average energy cost is about $42.5/MWh. However, when levelized in the cost-effectiveness calculations, the avoided energy cost appears even lower, averaging only about $25/MWh,[32] which is lower than the reported average avoided energy cost. It is unclear why or by what methodology these values don't seem close to agreeing with the reported cost values.

Q: Is it realistic that the avoided cost estimates escalate at only 1% annually after 2015?

A: No. As the EPA's Mercury and Air Toxics Standards (MATS) regulations take effect, coal plants that comprise some of the lowest variable cost generation resources will need to be retrofitted or replaced, which would tend to increase costs for both energy and capacity. Therefore, I would expect faster escalation of avoided energy costs.

Q: Do the Companies' estimates of avoided generation capacity costs appear realistic?

A: No. According to the spreadsheet provided by FirstEnergy,[33] avoided generation capacity costs per kW-year are estimated at only $9 in 2013, jumping to about $107 in 2016, dropping to $52 in 2018, and escalating at about 2% annually thereafter. The 2016 value of $107/kW-year may be realistic, but the other values appear low.

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[30] National Action Plan for Energy Efficiency, Guide to Resource Planning with Energy Efficiency, Prepared by Energy and Environmental Economics, Inc., 2007, available at: www.epA:gov/eeactionplan.
[31] FirstEnergy provided an avoided cost spreadsheet in response to NRDC Interrogatories Set-2-RPD-10
[32] This ratio is obtained by dividing the energy benefits by the MWh saved in Tables PUCO 7A-7G in Toledo Edison EE & PDR Program Plan, Appendix C-3.
[33] *Ibid.*

Q: Doesn't this reflect a realistic expectation of the need for generation capacity specifically in the year 2016?

A: The peak value in 2016 is consistent with such a scenario, but the other values are not. The 2016 value appears to correspond to the annualized capital cost of a new combustion turbine[34] or a coal-plant retrofit[35] for environmental compliance, which are generally considered to be around $100/kW-year (see Attachment 12 and Attachment 13). However, the 20-year present value (at 8.5% discount rate) of the future avoided generation capacity costs is only about $510/kW, or about half the annualized capital cost of a new combustion turbine. The assumption that future avoided generation capacity cost values never reach the marginal cost of new generation is unrealistic and suggests a methodological error.

Q: Isn't it methodologically correct to use market prices to indicate avoided costs?

A: Market prices can be used if the internal logic is consistent. The Companies' future cost estimates are based on present forward capacity market values, escalated into the future in proportion to price projections from the Energy Information Administration's 2012 Annual Energy Outlook for the region.[36] However, adopting price forecasts and escalation forecasts from different sources is suspect.

Q: Why do you suspect that the different forecasts are not logically consistent?

A: If the future capacity market price trajectory never reaches the cost of new capacity, then by definition it describes a scenario in which new capacity will not need to be built. Since the plan makes clear that new capacity will indeed be needed, the method and assumptions used are not realistic.

Q: How are these avoided cost assumptions reflected in the cost analysis of the energy efficiency program portfolio?

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[34] See, for example, U.S. Energy Information Administration (EIA), 2016 Levelized Cost of New Generation Resources, http://www.eia.gov/oiaf/aeo/pdf/2016levelized_costs_aeo2010.pdf. The levelized cost of $38.5/MWh for an advanced combustion turbine, multiplied by the assumed 30% capacity factor and 8760 hours/year, is $101/kW-year. The corresponding value for a combined cycle plant is about $170/kW-year.

[35] For coal plant retrofit costs, see U.S. EIA, 2010, Annual Energy Outlook, Electricity Market Module, http://www.eia.gov/forecasts/aeo/assumptions/pdf/electricity.pdf. The full retrofit cost for a 300-MW coal plant is estimated at $684/kW, which corresponds to about $82/kW-year (assuming a fixed charge rate of 0.12), for the capital cost of keeping out-of-compliance existing plants in operation.

[36] Black & Veatch, Market Potential Study: Energy Savings and Demand Reduction for Ohio Edison, Toledo Edison, and The Illuminating Company, June 22, 2012 at 105.

A: According to the Companies' TRC benefit/cost tables in the cost-effectiveness calculations,[37] the total avoided capacity costs per kW-year appear to be about $50/kW-year.[38] Netting out the assumed $20/kW-year T&D capacity costs makes the estimated generation capacity cost about $30/kW-year.

Q: Are these values realistic?

A: No, although again the data are confusing. Levelized at 8.5%, the reported avoided capacity cost is about $54/kW. A generation capacity cost estimate of $30/kW-year is lower still. Using either value, the assumed capacity cost levels would not cover the capital costs of combustion turbines or environmental retrofits, let alone more expensive new baseload capacity. Therefore, the avoided capacity costs appear to be unrealistically low, especially for systems that have any load growth at all, or where investments are needed to build new capacity in response to load growth or the need to retire out-of-compliance steam plants as FirstEnergy has announced its plans to do.

Q: Are there other components of the avoided costs of electricity supply that were omitted and that should be addressed?

A: Yes. Omitted cost components include T&D losses, environmental costs, and price elasticity feedbacks.

Q: How should T&D losses be included?

A: Avoided T&D losses are typically a component of both the avoided energy and capacity cost calculations, since energy efficiency measures lower the electric current levels in the T&D grid, reducing losses.

Q: Aren't environmental costs already reflected in the avoided supply costs?

A: Since there are no costs associated with emissions of SO_2, NO_x and Hg, these residual (allowed) emissions must be assumed to impose zero cost, and costs of emissions above allowed levels must be captured in the supply costs to achieve the assumed emission levels. These assumptions are consistent if the costs of environmental compliance, including the pending MATS rule, are indeed included in the

[37] Toledo Edison EE & PDR Program Plan, Appendix C-3

[38] This ratio is obtained by dividing the capacity benefits by the kW load reduction in Tables PUCO 7A-7G in Toledo Edison EE & PDR Program Plan, Appendix C-3.

avoided supply costs. As noted above, it is unclear if these costs are fully accounted in the avoided cost methodology.

Q: And isn't the cost of CO2 emissions zero?

A: Since there appear to be no explicit measures planned to reduce CO_2 emissions, and no cost of residual emissions, the implied cost of CO_2 emissions is zero. While that is true today, assuming zero cost over the entire planning horizon indicates zero chance of any CO_2 cost being imposed by regulators at any time during the planning time horizon over 15 years. This doesn't seem like a prudent assumption. Nine northeastern states and, starting in 2013, California have explicit market prices for CO2 emissions in the power sector.[39] Also, some state's (including Colorado, Idaho and Oregon) regulators require utilities to account for future CO2 costs in their cost analysis for planning and procurement purposes (see Attachment 14).[40]

Q: What are price elasticity feedbacks?

A: There is a price feedback effect of demand reduction, since energy efficiency measures reduce electricity demand and shift the power and fuel markets' demand downward, causing a decrease in the market-clearing price for electricity and for fuel (which also helps lower electricity prices), which benefits all electricity consumers. Because demand reduction reduces energy market prices, it avoids an additional amount of supply cost resulting from the *price decrease*, apart from the supply costs saved by demanding a lower *quantity of energy*. These cost savings in the energy markets are attributed to the demand reductions that cause them in proportion to the price elasticity of energy.

VII: Conclusion

Q: Does this conclude your testimony:

A: Yes it does, but I reserve the right to amend or modify my testimony based on new information received or discovered.

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[39] see www.rggi.org for the Regional Greenhouse Gas Initiative in the Northeast, and http://www.arb.ca.gov/cc/capandtrade/capandtrade.htm for California's AB-32 carbon market.

[40] Bokenkamp, K., et al, Hedging Carbon Risk, *The Electricity Journal*, July 2005.

CERTIFICATE OF SERVICE

I hereby certify that a true and accurate copy of the foregoing *Direct Testimony of Joel Swisher* has been served upon the following parties via electronic mail on October 5, 2012.

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Dr. Joel Swisher is an independent consultant with over 30 years experience in research and consulting on many aspects of clean energy technology. He is an expert in energy efficiency technology and policy, carbon offsets and climate change mitigation, and electric utility resource planning and economics. Dr. Swisher has analyzed and evaluated electric power markets for Brazilian utilities, energy efficiency programs for North American utilities, and carbon trading programs for European governments.

Dr. Swisher is a thought leader in several areas of clean energy technology and business strategy. He teaches a graduate-level course (spring quarter 2012) at Stanford University on Greenhouse Gas (GHG) Mitigation that addresses both technical and business strategies to manage GHG emission costs and risks. He has consulted with numerous utilities and technology companies on resource planning and clean energy deployment strategies. He has also helped consumer-oriented firms design strategies to expand simple cost-saving energy investment programs into brand-building corporate sustainability campaigns.

As Director of Technical Services and CTO for Camco International, Dr. Swisher helped develop carbon offset projects in reforestation, agriculture, renewable energy and building energy efficiency, and he has authored emission inventories, baseline studies and monitoring and verification plans for multilateral banks and private offset buyers. Starting in 1989, Dr. Swisher performed seminal research on carbon offset baselines and technical and economic analysis of carbon offsets in the energy and land-use sectors.

Dr. Swisher was managing director of research and consulting at Rocky Mountain Institute (RMI), where he created the concept of "The Smart Garage," which explores the efficiency gains and environmental advantages of energy system-level integration via connection of the power grid to the vehicle fleet, enabled by advanced plug-in hybrid vehicle designs emerging from collaborations with the automotive industry. He also led the consulting work of RMI's Energy & Resources Team for high-profile clients, including the cities of San Francisco and Palo Alto, many electric utilities, and major corporations in mining, oil and gas, and manufacturing of products ranging from semiconductor chips to potato chips.

Dr. Swisher is a registered Professional Engineer and holds a Ph.D. in Energy and Environmental Engineering from Stanford University. Dr. Swisher speaks five languages and has worked in 20 countries. He is author of over 100 professional publications including *The New Business Climate: A Guide to Lower Carbon Emissions and Better Business Performance* and a bilingual (English and Portuguese) textbook on energy efficiency program design and evaluation and integrated energy resource planning.

Current Position(s):

Consulting Associate Professor, Dept. of Civil and Environmental Engineering, *Stanford University*. Teaches graduate-level courses in greenhouse gas mitigation and electric utility planning methods.

Senior Fellow, Rocky Mountain Institute, Snowmass CO. Collaboration on clean energy technology.

Senior Associate, Camco International, Broomfield, CO. Collaboration on carbon offset development.

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Education:

- Stanford University. Ph.D., Resources Planning Program, Civil Engineering Department, May 1991. Dissertation Topic: *Prospects for International Trade in Environmental Services: An Analysis of International Carbon Emission Offsets*. Field Work in Costa Rica and Guatemala, evaluating energy efficiency, conservation and reforestation programs.

- Stanford University, M.S., Thermosciences Program, Mechanical Engineering Department, January 1980. Completion of Heat Transfer and Energy Systems specializations.

- Stanford University, B.S., Environmental Engineering Program, Civil Engineering Department, June 1978.

Previous Experience:

Director of Technical Services and CTO, Camco International, Broomfield CO, 2008-2011. Responsible for North American technical services in carbon emission inventories, emission reduction assessment, carbon offset qualification, and consulting to utilities, manufacturers and other major GHG sources.

Managing Director, Research and Consulting, *Rocky Mountain Institute*, Snowmass CO, 2001-2008. Entrepreneurial non-profit organization dedicated to breakthrough innovation in resource efficiency and system design. Responsible for developing research grants and consulting business, project execution and delivery, team coordination and integration, and thought leadership in practice areas of Energy and Resources, Built Environment, Advanced Transportation, and Breakthrough Industrial Design.

Co-founder and President, *E4, Inc*., Boulder CO, 1995-2001. Consulting on electric utility emissions analysis and evaluation, energy-efficiency policy analysis and training, analysis and development of carbon offset projects, and technical and economic analysis for utility asset valuation, rate structure design and geographic targeting of distributed power generation projects and load management programs.

Selected Consulting Clients and Projects Completed – 2004-2011:

- American Clean Skies Foundation, 2011. The Business Case for Integrating Clean Energy Sources to Replace Coal. Analysis of the cost, performance, availability, and system compatibility of flexible gas-fired power generation and variable renewable sources to replace coal-fired generation and lower the compliance costs of Federal clean air regulations and state-level renewable portfolio standards.

- Newmont Mining Corp, 2011. Carbon Trading Playbook for Newmont Mining. Design of a portfolio of in-house emission reduction measures and externally purchased renewable energy credits and/or carbon offsets to minimize the cost (or make a profit) in achieving Newmont's GHG reduction targets. Analysis and risk management to resolve the "make vs. buy" question with regard to GHG emission reduction opportunities for Newmont.

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- Ice Energy, 2010. System Benefits of Distributed Thermal Energy Storage. Evaluated the physical and environmental impacts on the power supply system resulting from mass deployment of thermal energy storage in the form of Ice Energy's distributed ice storage technology. Analysis of peak-coincident capacity savings in generation and delivery, annual savings in energy, fuel and emissions, and impacts on costs and reliability across 12 US utility systems.

- North American Power Group, 2009. Generating Carbon-Related Value from Carbon Capture and Storage (CCS). Regulatory analysis and development of documentation to achieve regulatory compliance and harness economic benefit from the addition of CCS to generation stations planned in the Western U.S. Analysis of proposed greenhouse gas regulations and carbon markets at the Federal and regional levels, as well as California's utility and environmental policies. Assistance with grant proposals for finding of CCS site characterization studies in Western states.

- Anglo Gold Ashanti, 2009. Business Case for a Corporate Response to Climate Change. Analytic contributions to the corporate greenhouse gas (GHG) emissions footprint, assessment of physical, financial and regulatory risk factors, identification of GHG reduction opportunities, evaluation of GHG regulation and carbon market scenarios, and business cases for recommended measures.

- Progress Energy, 2008. Developing a Utility Carbon Strategy. Review of greenhouse gas (GHG) inventory data, assessment of staff training needs, and identification of early GHG reduction options. Evaluation of supply and demand-side technical measures to improve efficiency and reduce emissions. Development of strategies to capture the value of early GHG reductions under a range of regulatory scenarios and carbon market structures.

- The Smart Garage, 2008. Development of the Smart Garage concept, which is the inter-connection of the vehicle fleet, building stock and power grid to create energy system synergies in efficiency, cost and emissions. Collaborated with utilities, electric car designers, and control and communications vendors to define the requirements for interconnection and interoperability of building-to-grid (B2G), one-way vehicle-to-grid (V1G), and two-way vehicle-to-grid (V2G) configurations, and conducted an interdisciplinary design workshop to initiate collaborative design projects on these topics.

- Frito-Lay Inc., 2008. Framework for a Corporate Climate Strategy. Development of a strategy to manage climate-related business risks and opportunities related to greenhouse gas (GHG) emissions from Frito-Lay operations. Elements of the climate strategy include identifying and prioritizing internal reduction opportunities, harnessing the carbon markets to monetize the value of reductions, and building a comprehensive strategy to mitigate GHG liabilities, while developing and monetizing energy- and climate-related assets.

- E-Fleet Design Consortium and Workshop, 2008. Assembled and convened an industrial consortium (including Alcoa, Johnson Controls, Google, RMI and others) to develop a new, light-weight, plug-in hybrid electric vehicle platform for Class 2 truck fleet applications. Collaborated with the design firm IDEO to conduct a week-long, intensive, interdisciplinary design charrette and workshop to initiate the design concept and provide a working design to attract funding and move toward production, which is now proceeding under the spin-off for-profit company, Bright Automotive in Indiana.

- Duke Energy, 2007. Innovative Regulatory Treatment of Utility Energy Efficiency Investments. Supported Duke Energy to design a regulatory mechanism for to reward utilities for implementing cost-effective energy efficiency and distributed resources. Testimony at the North Carolina Public Service Commission on the need for such incentives and merits of different approaches, including system benefits charges, utility vs. third-party administration, and various cost recovery mechanisms.

- Northern California Power Authority (NCPA), 2007. Developed a tool for estimating technical and economic energy efficiency potential for 34 California publicly owned utilities to assist in complying with California legislation. Conducted training workshops to guide participants in using the tool to prioritize energy efficient technologies and program design strategies to achieve efficiency goals.

- Rio Tinto Mining, Technology and Innovation Unit, 2007. Innovation Workshops for the Design of Iron Ore and Copper Mines. Analysis of energy and greenhouse gas (GHG) footprints of baseline mine designs, site evaluations of existing and proposed mine sites, and the design, preparation and facilitation of intensive design workshops for three planned mine developments. Workshops were designed and executed to enable whole-systems thinking around efficient mine design, identify and develop promising new technologies and design alternatives, prioritize opportunities for new projects and investments, and estimate technical and economic performance of recommended options.

- State of Hawaii Department of Business, Economic Development and Tourism, 2007. State Energy Strategy. Analysis of energy supply and demand scenarios, evaluation of energy supply and demand-side options, and design of technology and policy strategy to reduce oil imports, energy cost and related emissions while accelerated use of solar, wind and biofuel resources.

- Silicon Valley Power (SVP), 2007. Development of energy efficiency targets. Analysis of SVP's residential, commercial, and industrial customers, development of models to estimate technical, cost-effective, and feasible energy efficiency potential. These models can be used by SVP over time to continually revise and update these efficiency estimates.

- Nebraska Public Power District (NPPD), 2006. Supply risk analysis and development of an Energy and Resource Investment Strategy and greenhouse gas management strategy, based on both supply- and demand-side resources, including load management, end-use efficiency, and combined heat and power, that will allow NPPD to better manage its load while maintaining low cost and high reliability.

- Wal-Mart, 2006. Development of energy efficiency and greenhouse gas (GHG) reduction strategies and targets. During the initiation of Wal-Mart's sustainability drive, identification and quantification of efficiency opportunities in Wal-Mart buildings and truck fleets, analysis of short- and long-term potential, development of implementation strategies, and support to Wal-Mart management in setting sustainability targets and communicating them to staff and the public.

- City of Palo Alto Utilities, 2005. Implementation of Energy Resource Portfolio Planning. Review of the current electric resource plan, design of economic criteria for efficiency programs, prioritizing efficiency program strategies, and evaluating the potential for local energy resource options. Options included energy efficiency, renewable sources, distributed co-generation, and conventional generation. Integrated supply and demand-side options into risk-managed, least-cost portfolios.

- Public Utilities Commission, City of San Francisco, 2004: An Energy Resource Investment Strategy for the City of San Francisco. Scenario analysis and integrated resource plan to identify and prioritize opportunities to implement alternatives to central fossil fuel electricity generation. Options include energy efficiency, renewable energy, distributed generation, transmission and distribution solutions.

Earlier Professional Experience:

UNEP (United Nations Environment Programme) Collaborating Centre on Energy and Environment, at University of Roskilde and Risø National Laboratory, Denmark, 1993-1995. Development of programs to assist developing countries with environmentally-sustainable energy planning, and research on national-level options, costs and benefits of reducing environmental emissions. Collaborations with energy ministries and utilities in Brazil, Venezuela and Sri Lanka.

Lund University, Lund Sweden, 1991-1993. Visiting Research Scholar and Lecturer (see below). Working for NUTEK (Swedish National Board for Technology and Industrial Development), responsible for a national study of the timing of end-use efficiency improvements and issues of time-dynamics in integrated electricity planning. Evaluation of existing energy-efficiency policies and programs, and research on the role of energy-efficiency in a competitive electricity market.

Electric Power Research Institute, Palo Alto, CA, 1989-1991. Engineering Consultant to Commercial Energy Utilization and Demand-Side Management Departments. Technical and economic analysis of lighting and HVAC efficiency options, and resulting utility load, production cost and emission impacts.

Architectural Energy Corporation, Boulder, CO, 1986-1988. Senior Engineer. Responsible for engineering analysis, computer software development, and field data acquisition for passive and active solar and energy-efficient residential and commercial buildings. This work led to the development of state-of-the-art building energy diagnostic and evaluation methods.

Pacific Energy Design, Auckland, New Zealand, 1984-1986. Consulting Engineer. As a consultant to the Ministry of Energy, responsible for residential energy design guidelines, building energy performance monitoring and evaluation, and low-energy residential and regional planning and policy development.

Solar Energy Research Institute (now NREL), Golden, CO, 1980-1983. Research Engineer. Research on solar-heated and low-energy buildings using computer simulations and monitoring of existing buildings.

Other Information:
--Languages: native English, fluent Swedish, functional Portuguese and Spanish, basic German.
--Registered Professional Engineer - Colorado.

jnswisher@aol.com +1-720-883-3624

NRDC Set 3
Witness: Miller

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3– INT-22 Referring to Miller Direct Page 18, Lines 11-22 and Page 19, Lines 1-7, and Miller's response to NRDC Set-2, INT-1 and INT-2, why does the "total portfolio annual budget" and incremental annual projected MWh savings 2014 and then decline in 2015 for Ohio Edison and Toledo Edison, when the required energy efficiency savings continue to increase? We would expect savings and budget to increase commensurate with an increase in required savings.

Response: Please see the responses to NRDC Set 2, INT-1 and INT-2.

Note that each year's savings values reflect incremental annual savings on a partial year basis which depends on the number and timing of individual participants in each year. In each instance, the incremental annual savings, when combined with prior year savings, is projected to exceed the statutory benchmarks.

NRDC Set 3
Witness: Miller

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-23 Referring to Miller's response to NRDC Set 2, INT-3, and to Appendix B-4 of Attachments A, B, and C, how much of the operations costs for each Measure, Segment, and Program encompass General Awareness Marketing?

Response: The plan budgets for General Awareness Marketing were not based on estimates for each measure, segment or program, but were instead based on the Companies' estimated total general awareness marketing costs to support the Ohio EE&C Portfolios. These General Awareness Marketing costs are estimated as approximately 5% to 7% of total Portfolio Operations costs for individual operating companies.

NRDC Set 3
Witness: Miller

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-24 Referring to Miller's responses to NRDC Set 2, INT-5, and Appendix C-1 of Attachments A, B, and C, did FirstEnergy make efforts to update incremental costs from Technical Reference Manuals that have not been updated within the last year?

Response: No.

NRDC Set 3
Witness: Miller

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-25 Referring to Miller's response to NRDC Set 2, INT-7, how will does FirstEnergy plan to respond if one of its programs or measures exceed the program-level budget?

Response: Objection. The request is vague and ambiguous and calls for speculation.

Without waiving the objection, the Companies will work within the budget guidelines as contained in Ohio Administrative Code 4901:1-39-05 (C)(2)(c). Situations under which the Companies may shift funds between programs or measures are described in the Companies' Plans in Sections 5.1.2 and 5.1.2.1.

NRDC Set 3
Witness: Miller

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-26

Referring to Miller's response to NRDC Set 2, INT-8, how will FirstEnergy encourage efficient new construction in the Large Enterprise Sector?

Response: The Companies' proposed Portfolios include a Custom Building sub-program for the Large Enterprise Sector. The Companies intend to hire program implementation vendors who will be responsible for developing and executing marketing plans to promote participation in this sub-program. As described in the response to NRDC Set 2, INT-8, the Companies will target builders for efficient new construction, with Large Commercial and Industrial Customers incented under the Custom Building sub-program.

In addition, the Companies also will provide program awareness and energy efficiency education, including new construction program opportunities, to its Large Enterprise customers through the Companies' key account managers and other Company resources.

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-27 Referring to Miller's response to NRDC Set 2, INT-9, what is FirstEnergy's strategy for integrating technologies that are known, tested, accepted in other utility territories, but not yet in First Energy's, into its energy efficiency portfolio?

Response: Objection. This question is vague and ambiguous, and calls for speculation. Without waving this objection, as stated in the response to NRDC Set 2, INT-9, the Companies will discuss potential for such technologies with the Collaborative Group as appropriate.

Technologies that have been adopted in other jurisdictions may or may not compliment the Companies' Portfolio Plans for a number of reasons, including but not limited to, differences in jurisdictional energy efficiency guidelines or policies, approved portfolio budgets or program costs, varying target markets and customer demographics, fundamental makeup of market support, costs, or professional capabilities, and duplication or competition with current program offerings.

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-28 Referring to Miller's response to NRDC Set 2, INT-12, how does the plan encourage energy efficiency in the use of computer servers by smaller commercial customers that are unlikely to participate in the custom program?

Response: As stated in the response to NRDC Set 2 INT-12, computer servers are eligible as custom equipment under the C&I Energy Efficient Equipment Programs, Small. The Companies intend to hire program implementation vendors who will be responsible for developing and executing marketing plans to promote participation for eligible custom measures, including data servers, to smaller commercial customers.

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-29

Referring to Fitzpatrick's response to NRDC Set 2, INT-14, did the analyst consider methods of determining achievable potential that relied on observed ex-post performance in efficiency programs, rather than ex-ante speculation in customer surveys, or that calibrated or verified ex-ante projections using observed ex-post performance data?

Response: Yes.

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-30 Referring to Fitzpatrick's response to NRDC Set-2, INT-15, describe the correlation the analyst found between the interests and intentions expressed in the Existing Plan's Market Potential Study and actual realized participation in the Companies' programs.

Response: Specific correlation analyses were not performed.

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 3–INT-31 Referring to Appendices C-4 of Attachments A, B, and C, do the Companies anticipate providing incentives for Linear Fluorescent Retrofits that change T12 lighting to Standard T8 and T5 lighting?

Response: Yes, consistent with EM&V protocols as adopted by the Commission, the Companies would incent and claim savings based on as-found conditions for equipment that is replaced as early retirement. This may include T12 lighting to Standard T8 or T5 lighting retrofits.

Case No. 12-2190-EL-POR, Case No. 12-2191-EL-POR, Case No. 2192-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 3 – RPD-11 Referring to Section 3.4 of Attachments A, B, and C, within the Kits element of the Home Performance Program, please provide a list of contents (including CFLs by number and wattage) that the Companies plan to include in the Standard, All-Electric, and School Kit.

Response: The measures listed below were included for purposes of modeling in each of the Company's Home Performance Program energy efficiency kits. Actual kit contents may vary based on evaluation results, implementation experience, and market feedback.

Standard Kit
(3) 26 Watt CFLs, (2) 19 Watt CFLs, (4) 13 Watt CFLs, (2) LED Nightlights, (1) Furnace Whistle, (1) Smart Strip

All-Electric Kit
(3) 26 Watt CFLs, (2) 19 Watt CFLs, (4) 13 Watt CFLs, (2) LED Nightlights, (1) Furnace Whistle, (1) Smart Strip, (1) Shower Head, (4) Aerators

School Kit
(2) 19 Watt CFLs, (2) 13 Watt CFLs, (2) Aerators

AEP Ohio
Residential DSM Potential
2012-2014
Preliminary Results

May 4, 2011

Navigant Consulting

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Introductions

- Jon Williams, Manager EE/PDR, AEP Ohio
- Randy Gunn, Managing Director, Navigant, Chicago
- Stu Slote, Associate Director, Navigant, Vermont

Meeting Objectives

- Present draft results of 2012-14 residential DSM potential
- Discuss how results inform 2012-14 residential DSM plan
- Answer questions and address concerns
- Discuss next steps

Approach to Estimate DSM Market Potential

- Develop market-based performance benchmarks from 2009 benchmarking results to calibrate model impact levels
- Summarize baseline profiles from baseline study to establish end-use saturations and potential model starting points
- Characterize measures: run eQuest building simulation model to estimate kW/kWh unit impacts (in-situ EE implicit) using baseline study results; characterize measure cost
- Assess cost-effectiveness per TRC screen => economic potential
- Measures grouped by program
- Combine profiles, characterizations, benchmarks & cost-effectiveness: Technical / Economic / Market Potentials by end use and program
- Program potentials incorporated in program plans

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DSM Benchmarking Data Collection

- 2009 DSM program spending and savings results were collected from ten utilities' annual report to regulatory agency
- 2009 baseline sales and revenue were collected from FERC Form 861 from www.eia.doe.gov
- 2009 DSM savings and spending were normalized to 2009 baseline sales and revenue

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Navigant Benchmarked Ten IOUs in the Midwest or Neighboring Ohio, each with Relatively New DSM Requirements and Portfolios.

State	Organization
OH	AEP
	Dayton P&L
	First Energy
IL	Ameren
	ComEd
MI	Consumers Energy
	Detroit Edison
PA	Allegheny
	First Energy
	PECO

DSM Reporting Practices Vary, for example, by Savings Attributes:

State	Organization	Savings Verified	DSM GWh At meter or generator	Net or Gross
OH	AEP	Yes	Meter	Gross
	Dayton P&L	Yes	Generator	Gross
	First Energy	No	Meter	Net
IL	Ameren	Yes	NS	NS
	ComEd	Yes	Meter	kWh Gross, kW Net
MI	Consumers Energy	Yes	Generator	Gross
	Detroit Edison	Yes	Generator	NS
PA	Allegheny	2 of 7*	NS	Gross
	First Energy	NS	NS	Gross
	PECO	Yes	Meter	Gross

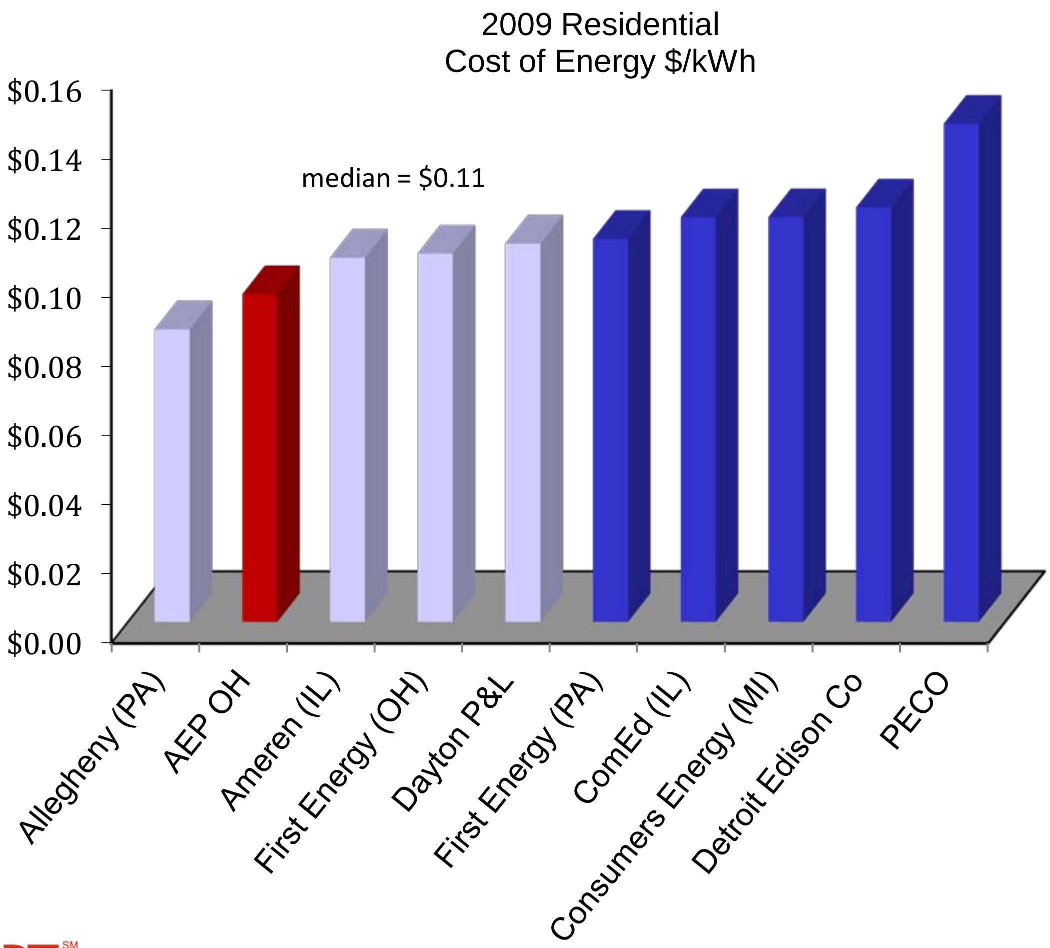
NS = not specified

* = savings for 2 of 7 programs were verified.

Benchmarking is not a Horse Race.

- Given variation in program offerings and reporting practices across DSM portfolios, no benchmarking can achieve strict apples-to-apples comparison
- Benchmarking is, however, useful to identify which organizations and programs to analyze more closely
- This close analysis affords better understanding to inform cost-effective program design
- **Most importantly, analysis identifies performance benchmarks, based on actual program results, to calibrate potential model**

2009 Retail Cost of Residential Energy $/kWh



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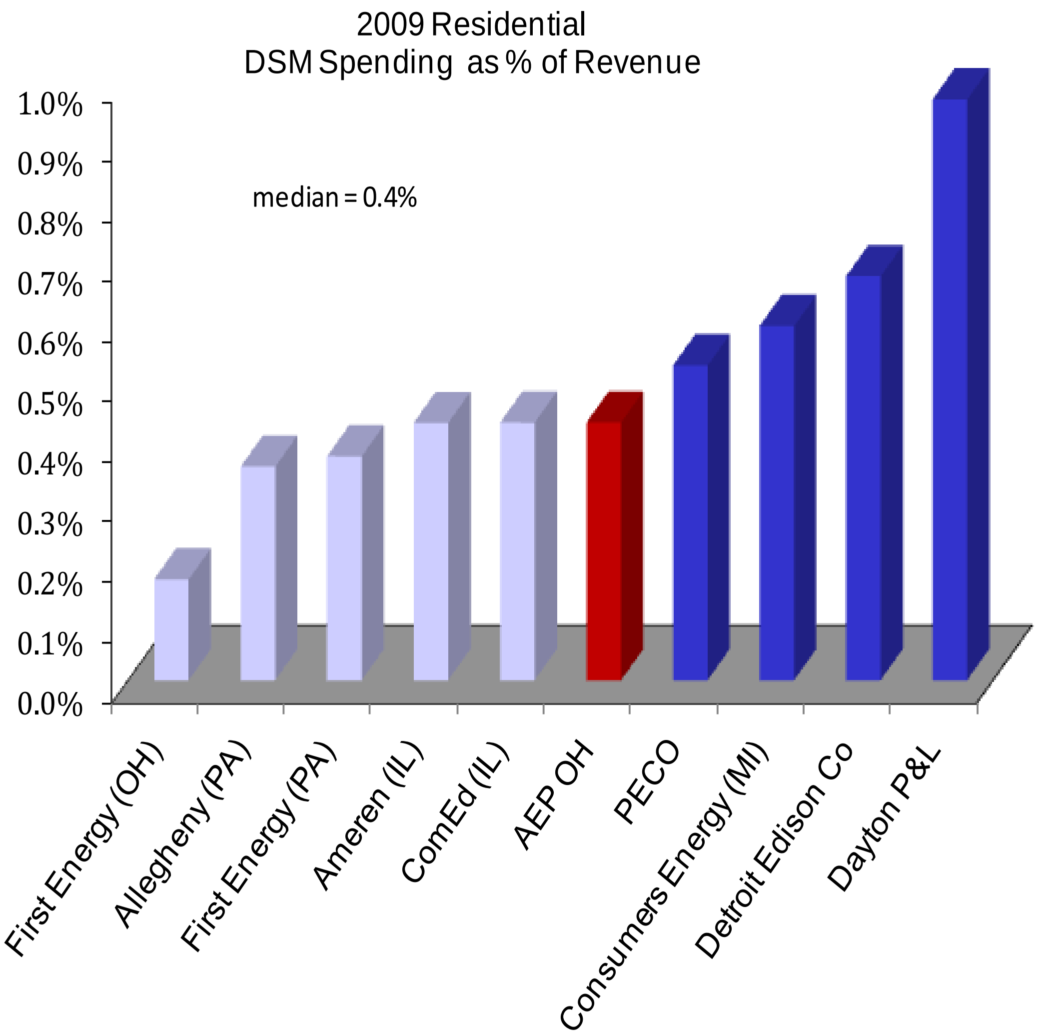
In the charts in this power point, the median is indicated as the value between the light blue bars and the dark blue bars, AEP OH is indicated as the red bar.

2009 Residential DSM Spending as % of Residential Revenue



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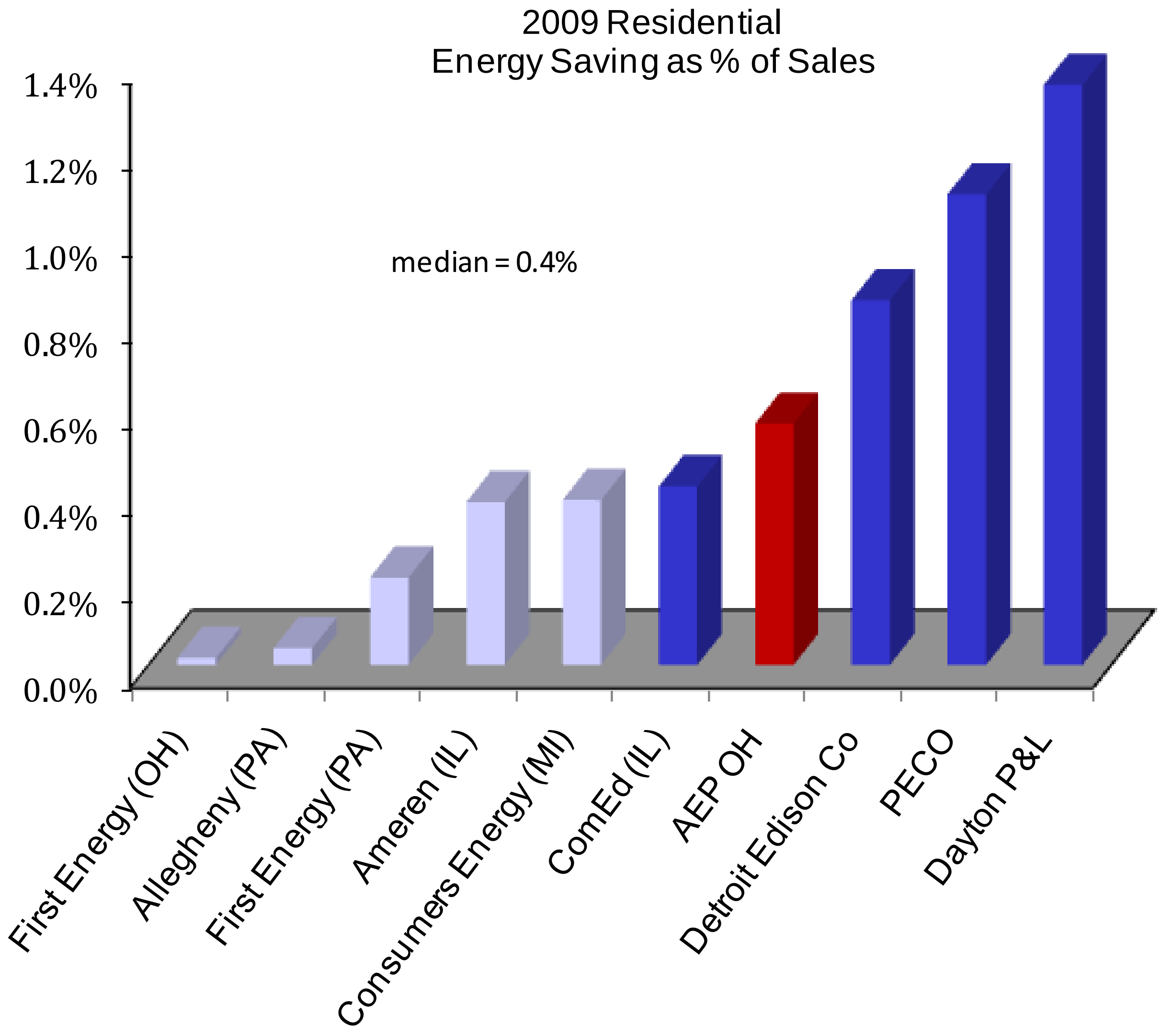
2009 Residential Energy Savings as % of Residential Sales



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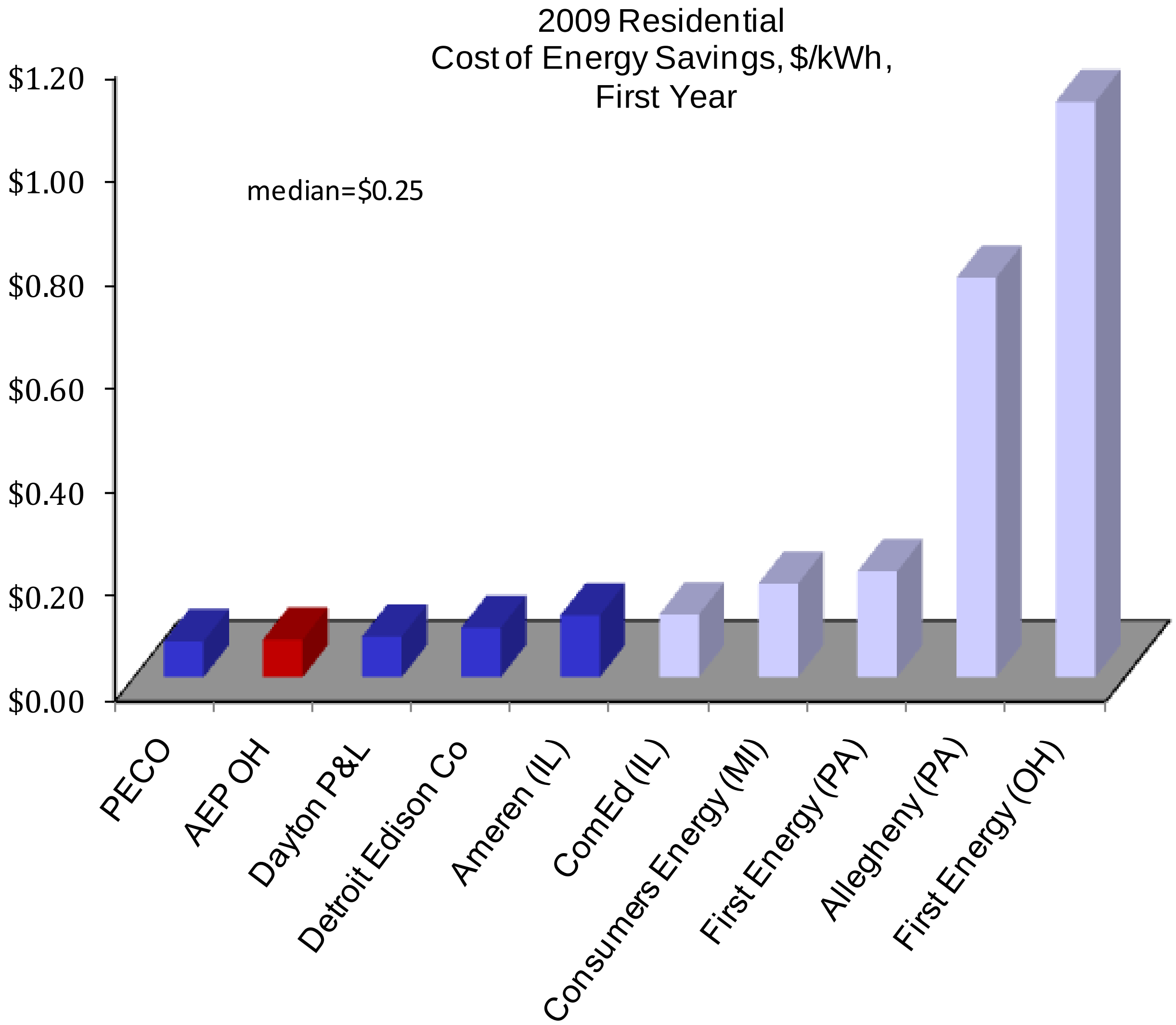
2009 Residential Cost of Energy Savings, $/kWh, First Year



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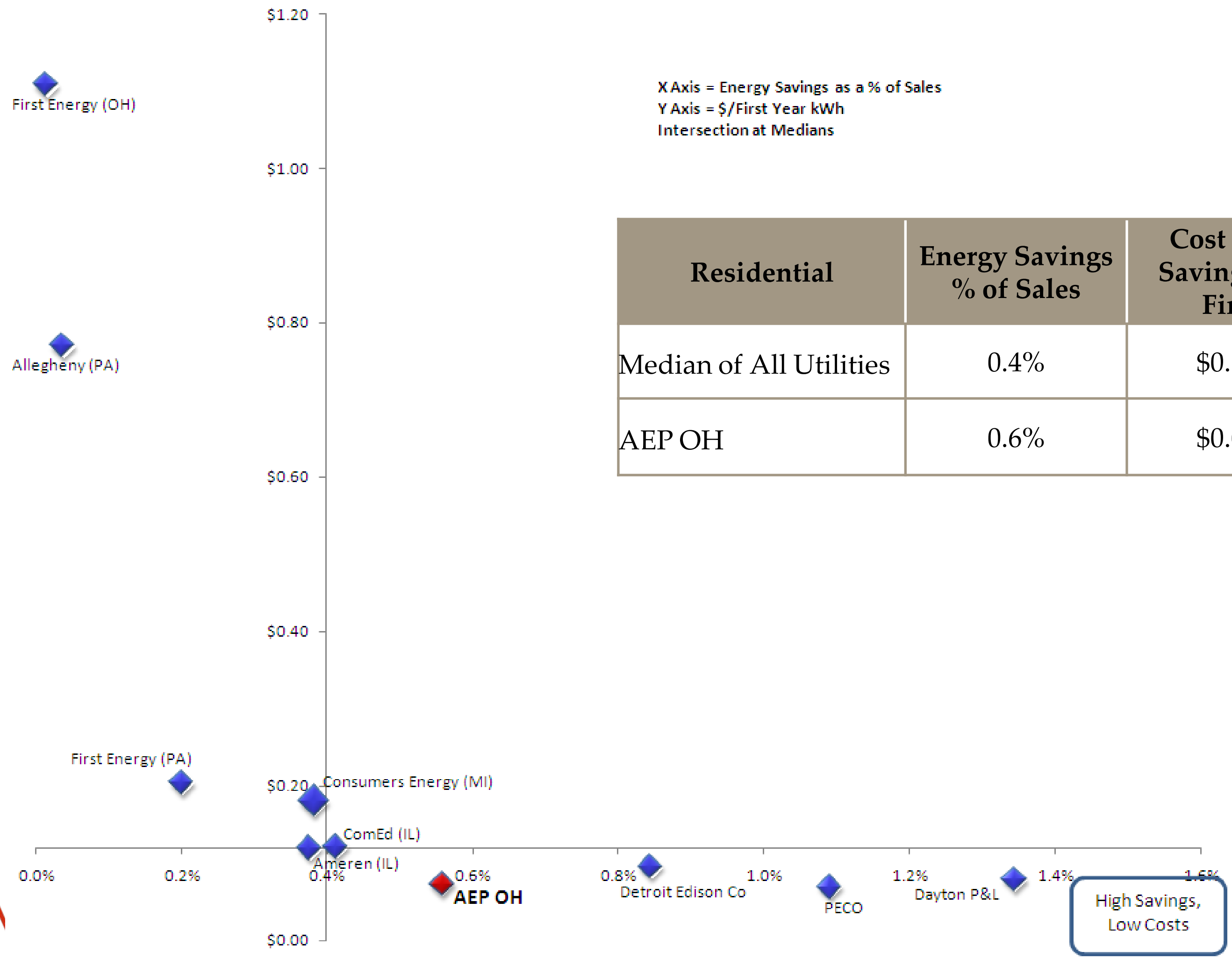
2009 Residential Energy Savings as % of Sales and Cost of Energy Savings, $/kWh, First Year



Residential	Energy Savings % of Sales	Cost of Energy Savings ($/kWh) First Year
Median of All Utilities	0.4%	$0.12/kWh
AEP OH	0.6%	$0.07/kWh

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2009 Distribution of Residential DSM Energy Savings by Program

Residential					
	AEP OH	ComEd (IL)	Dayton P&L	Detroit Edison Co	PECO
Program/Measures					
Lighting	90%	80%	92%		95%
Cooling/Heating/Roofing			4%	1%	
Prescriptive				75%	2%
Refrigerator/Freezer Removal	6%	14%	4%	11%	3%
Retrofit				2%	
Multifamily		2%		6%	
Low Income	3%	4%		3%	
Education				2%	
Total Residential Savings (GWh)	81.9	110.2	68.8	123.6	140.7
Annual Residential Sales (GWh)	14,642	26,620	5,120	14,625	12,893
Residential Savings as % of Residential	0.56%	0.41%	1.34%	0.85%	1.09%

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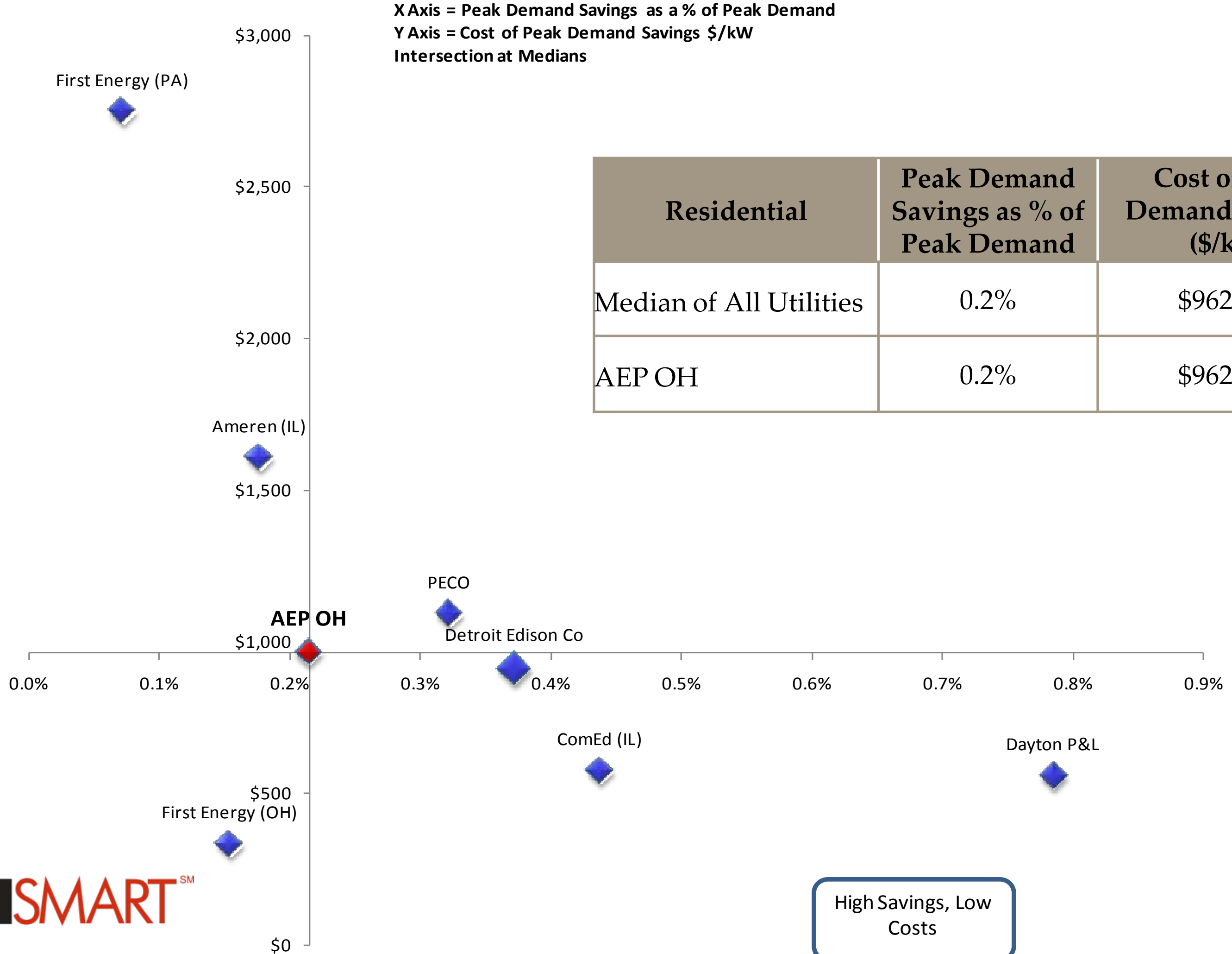
2009 Residential DSM Cost of Energy Savings by Program

Residential					
	AEP OH	ComEd (IL)	Dayton P&L	Detroit Edison Co	PECO
Program/Measures					
Lighting	**$0.05**	**$0.07**	**$0.05**		**$0.04**
Cooling/Heating/Roofing			$0.43	$1.03	
Prescriptive				**$0.05**	$1.22
Refrigerator/Freezer Removal	$0.16	**$0.14**	$0.11	**$0.12**	$0.14
Retrofit				$0.18	
Multifamily		$0.32		$0.18	
Low Income	$0.20	$0.37		$0.63	
Education				$0.23	
Total Residential Savings (GWh)	81.9	110.2	68.8	123.6	140.7
Total Costs ($M)	$5.9	$13.3	$5.4	$11.8	$9.7
Costs of Residential Savings ($/kWh)	$0.07	$0.12	$0.08	$0.10	$0.07

2009 Residential Peak Demand Savings as % of Peak Demand and Cost of Peak Demand Savings, $/kW



Residential	Peak Demand Savings as % of Peak Demand	Cost of Peak Demand Savings ($/kW)
Median of All Utilities	0.2%	$962/kW
AEP OH	0.2%	$962/kW

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Allegheny (PA) is not included in bar chart as to not skew the scale (0.01%, $10,639/kW)

Summary of Best Practices for Electric Residential DSM Portfolios

Summary of BP Utilities' Electric Residential DSM Portfolios	
DSM Spending	Generally 0.4-1.0% of Residential revenues
DSM Savings	Energy savings at 0.4-1.3% of Residential sales
DSM Costs	Energy savings generally cost less than 12 ¢/kWh (first year costs)
Top Programs	Prescriptive Rebates, especially Lighting
	Appliance Recycling

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Baseline Study Objectives

- Develop comprehensive **information to support AEP Ohio's DSM program planning, program design, and continuous improvement functions**
- **Develop information to support AEP Ohio-estimates for saturations of key DSM measures** in OPCo and CSP service area, at relatively early stage of the Company's DSM programs
- **Estimate customers' initial awareness** of AEP Ohio's DSM programs and major DSM measures
- **End-use saturations and baseline profiles used as potential model starting points**

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Baseline Study Methodology

- Conducted telephone surveys with random sample of AEP Ohio's customers:
  - 384 residential
  - 768 commercial and industrial
- Telephone surveys primarily assess customer awareness of AEP Ohio EE programs, EE purchasing criteria, and recent retrofit activity
- Conducted on-site surveys with sub-samples of telephone respondents:
  - 68 residential
  - 136 commercial and industrial
- On-site surveys determine saturation of major EE measures, building characteristics, and customer awareness of significant EE measures

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Residential Customer Awareness and Interest Level of AEP Ohio Residential Programs

AEP Ohio Programs	Awareness	Interest Level
Appliance Recycling Program	67%	80%
Smart Grid Pilot Program	42%	72%
Energy Star Lighting Discount Program	25%	87%
Programs for Kids: e3Smart	16%	48%
Self Generation Solar Program	0%	0%

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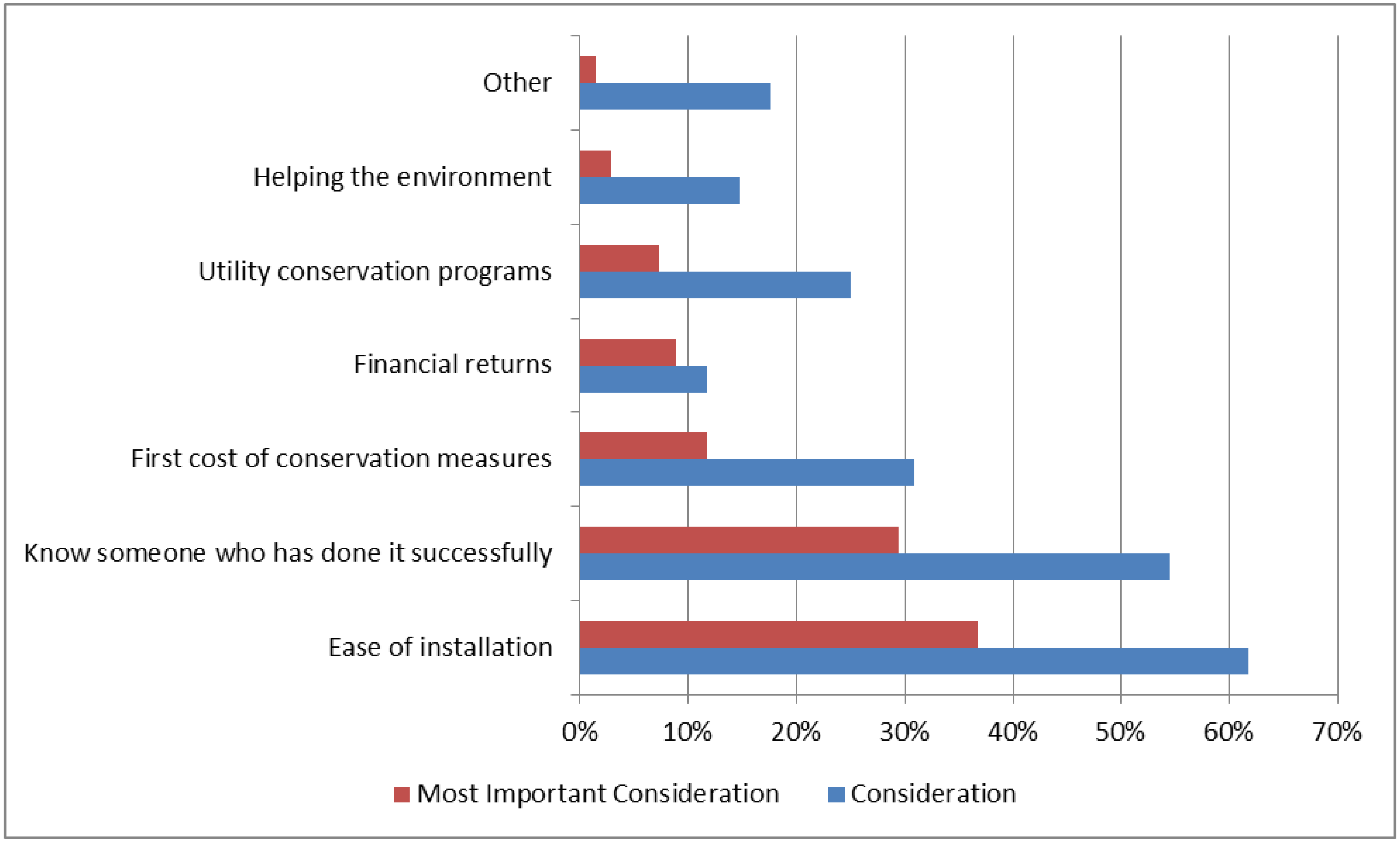
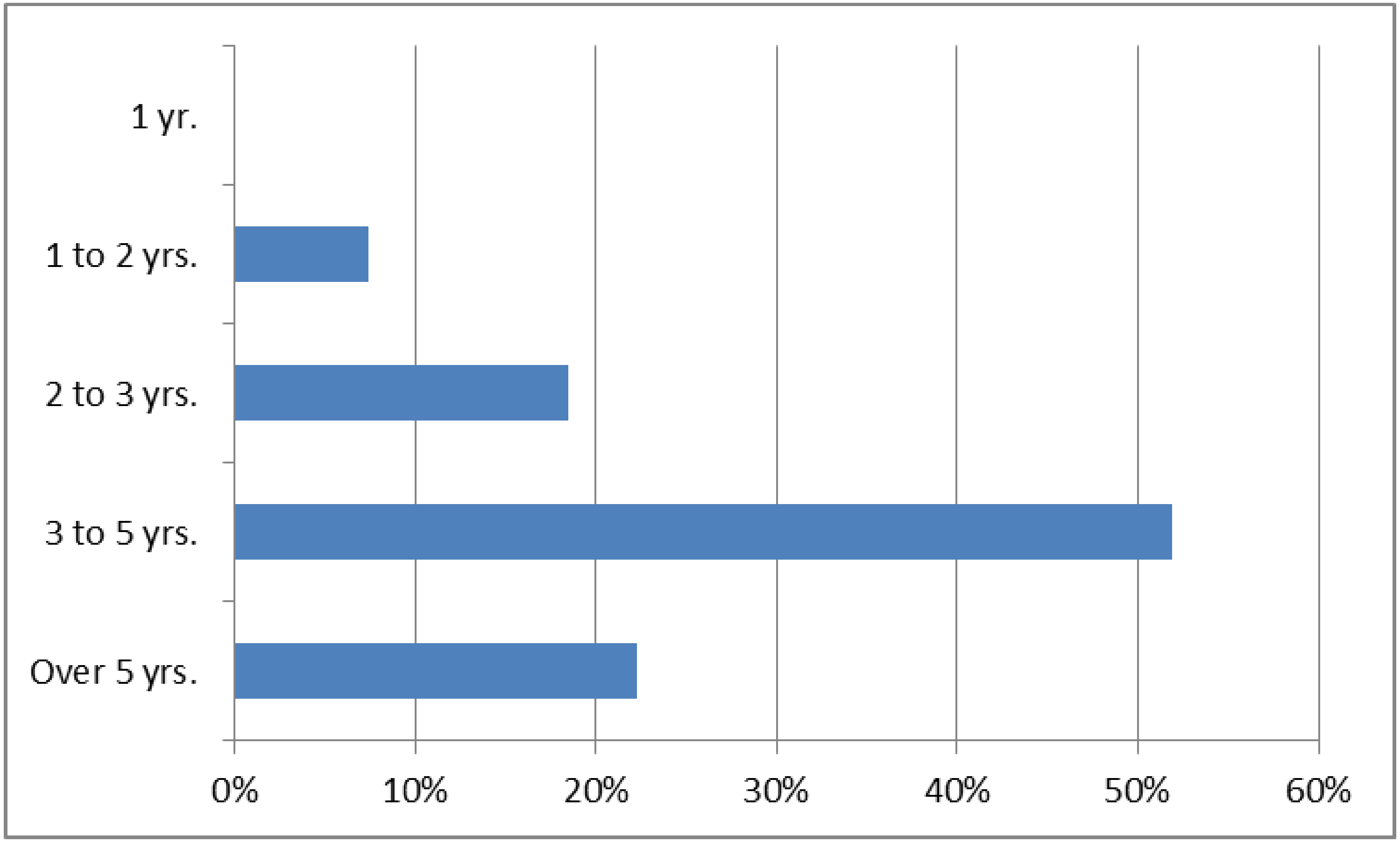
Residential Considerations: "Ease of Installation" and "Know of Someone who has Implemented Successfully" are the most important and most common considerations, more so than financial considerations.



Residential Decision Making: Payback periods of 3 to 5 years are required by more than 50% of customers.



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Residential Lighting: 81% of homes have at least one CFL, but CFL saturation is only 32% of all lamps and fixtures that can take a CFL.

Residential Lighting	
Average Bulbs per Home	57.7
Homes with at least 1 CFL	81%
Bulbs that are CFL	32%

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Residential Heating: Electricity is the space heating fuel type in 31% of existing homes, 20% of new construction.

Space Heat Fuel Type	Percent of Homes by Building Type	
	SF - Exist	SF - New
Electricity	31%	20%
Natural Gas	61%	80%
Other	7%	0%

System Type	Percent of All Homes	
	% Primary	% Secondary
Central Furnaces	67%	19%
Boiler/Steam/Hot Water	6%	2%
Heat Pumps	19%	7%

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Note: Residential New Construction is defined as homes built since 2005.

Residential Cooling: 63% of all homes use Central Air Conditioners as their primary source of cooling.

Cooling System Type	Percent of All Homes	
	% Primary	% Secondary
Central Air Conditioners	63%	60%
Room A/C	12%	40%
Central Heat Pumps	25%	0%

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Residential Cooling: About one third of cooling systems have been serviced within the last year.

Last Service or Repair	% of All Homes
Less than 6 months	15%
6 - 12 months	23%
1 to 2 years	14%
More than 2 years	17%
Never	25%
Not Sure	6%

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Residential Cooling: Awareness of Most Cooling Measures Is High, 70-96%.

Energy Efficient Measure	% Aware
High Efficiency Central Air Conditioner	84%
High Efficiency Room Air Conditioner	70%
Heat Pump - Air Source	74%
Heat Pump - Ground Source	65%
Whole House Fan	68%
Attic/Roof Insulation	96%
High Performance Dual Pane Windows	90%
White Roof	61%

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Residential Cooling: The Major EE Installation Barrier for Cooling and Shell measures is that the Existing Equipment Still Works.

Energy Efficient Measure	Already Implemented Measure	Top Barriers Identified			
		Existing Equip Still Works	Not Aware of Measure	Don't Know Why Not	Cost Effect. Concerns
High Efficiency Central Air Conditioner	23%	45%	16%	3%	6%
High Efficiency Room Air Conditioner	3%	13%	30%	14%	0%
Heat Pump - Air Source	23%	20%	26%	9%	7%
Heat Pump - Ground Source	0%	19%	35%	9%	17%
Whole House Fan	14%	1%	32%	12%	3%
Attic/Roof Insulation	72%	6%	4%	6%	6%
High Performance Dual Pane Windows	64%	14%	10%	1%	4%
White Roof	9%	23%	39%	6%	0%

Residential Water Heat: Electricity is the water heating fuel type in 44% of existing homes, 38% of new construction.

Water Heat Fuel Type	Percent of Homes by Building Type	
	SF - Exist	SF - New
Electricity	44%	38%
Natural Gas	50%	63%
Other	6%	0%

Water Heating Equipment	Percent of Homes by Building Type	
	SF - Exist	SF - New
Electric Storage	44%	38%
Gas Storage	50%	63%
Electric Tankless	0%	0%
Gas Tankless	0%	0%
Solar	0%	0%
Heat Pump	2%	0%
Other	4%	0%

Residential Water Heat: "Existing Equipment Still Works" and "Not Aware of Measure" are the two major barriers to implementing more efficient water heaters.

Energy Efficient Measure	Already Implemented Measure	Major Barriers Identified			
		Existing Equip Still Works	Not Aware of Measure	Don't Know Why Not	Cost Effect. Concerns
Water Heaters					
High Efficiency Water Heat	19%	38%	16%	3%	13%
Heat Pump Water Heater	0%	23%	58%	4%	3%

Note: "High Efficient Water Heaters" assume a .95 Energy Factor for Electric Water Heaters.

Residential Plug Load Devices

Plug Load Devises	By Building Type	
	SF - Exist	SF - New
Televisions per Home	2.5	3.5
% of TVs that are CRT	61%	40%
% of TVs that are LCD	33%	55%
% of TVs that are Plasma	2%	4%
% of TVs that are DLP	3%	0%
DVR/Tivo Boxes per Home	1.37	1.73
Computers/Laptops per Home	0.8	1.3
% of Monitors that are CRT	89%	78%
% of Monitors that are LCD	11%	22%
Computers Peripherals per Home	0.8	0.7

Residential Plug Load Devices: Efficient Saturation

Efficient Plug Load Devises	% of Technology by Building Type	
	SF - Exist	SF - New
ENERGY STAR Televisions	26%	29%
ENERGY STAR Computer Monitors	0%	0%
ENERGY STAR Cable Boxes (DVRs)	0%	0%
Plug Load Management Systems*	28%	20%

*Plug Load Management Systems are as a percentage of homes surveyed.

Residential Refrigerators and Freezers

Refrigerators / Freezers	% of Homes by Building Type	
	SF - Exist	SF - New
Number of Refrigerators per Home	1.35	1.60
ENERGY STAR Refrigerators	7%	25%
Number of Freezers per Home	0.67	0.47
ENERGY STAR Freezers	6%	29%

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EE Measure Characterization Methodology

- Estimated five key parameters for each measure: energy and demand savings, lifetimes, incremental and total costs
- Used building simulation models to estimate savings for weather dependent measures – insulation, efficient HVAC systems and interactive effects from indoor lighting
- Used published sources and engineering calculations to estimate characteristics of non-weather dependent measures – efficient refrigerators
- California Database of Energy Efficiency Resources (DEER) and/or other Deemed Savings sources were starting point for lifetime and cost estimates
- Costs adjusted for AEP Ohio with RS Means location factors

Residential Characteristics: Lighting

Efficient Measure Description	Baseline Measure	Effective Useful Life (yrs)	Energy Savings (kWh)	Demand Savings (W)	Incremental Costs
Lighting					
LED Lighting	Incandescent	20	41	6.6	$20.00
CFL: Screw-In (<25W) Indoor	Incandescent	6	35	5.6	$3.40
CFL: Screw-In (>=25W) Indoor	Incandescent	6	94	12.0	$5.50
PIN Based CFL Indoor Fixture (retrofit)	Edison Based Fixture	9	35	5.6	$18.00
CFL: Pin-Based (<25W) Indoor	Incandescent	9	35	5.6	$3.40
CFL: Pin-Based (>=25W) Indoor	Incandescent	9	94	12.0	$5.50
CFL: Screw-In (<25W) Outdoor	Incandescent	6	35	0.0	$3.40
CFL: Screw-In (>=25W) Outdoor	Incandescent	6	94	0.0	$3.40
PIN Based CFL-Outdoor Fixture (retrofit)	Edison Based Fixture	9	35	0.0	$18.00
CFL: Pin-Based (<25W) Outdoor	Incandescent	9	35	0.0	$3.40
CFL: Pin-Based (>=25W) Outdoor	Incandescent	9	94	0.0	$3.40
LED night light	7W Incandescent Light	16	15	0.0	$3.00
LED Holiday Lights (300 bulb string)	300 x 0.48 W Incandescent Lights	15	58	0.0	$10.00

Residential Characteristics: Appliances

Efficient Measure Description	Baseline Measure	Effective Useful Life (yrs)	Energy Savings (kWh)	Demand Savings (W)	Incremental Costs
Appliances					
Clothes Washer - Tier 3 >= 2.2 MEF-w/elec dry	Fed Standard 1.26 MEF	11	175	535.6	$561.00
Clothes Washer - Tier 3 >= 2.2 MEF-w/gas or no	Fed Standard 1.26 MEF	11	135	413.5	$561.00
Efficient Dishwasher - .75 EF	Standard Dishwasher - .6 EF	10	217	1388.4	$321.00
Energy Star Refrigerator	Refrigerator meeting 2001 standar	19	256	23.4	$930.91
Refrigerator Recycling	Old Appliance	5	992	167.1	$15.00
Freezer Recycling	Old Appliance	4	753	126.9	$15.00
Convection Oven	Regular Oven	19	92	9.1	$100.00
ENERGY STAR® Dehumidifier	Non-Energy Star Dehumidifier	15	102	0.0	$1.00
ENERGY STAR® Ceiling Fan	Savings from lighting, thus the sm	15	174	61.7	$25.00
VSD Pool Pumps	One speed pump	10	911	965.6	$413.21
ENERGY STAR Freezer	Freezer meeting 2001 standard	14	209	19.1	$586.09
ENERGY STAR TV	Standard TV	5	72	30.1	$512.82
ENERGY STAR Monitor	standard monitor	5	178	24.9	$189.00
Smart Strip Power Bar	No sensor power strip	5	88	0.0	$20.00
ENERGY STAR Cable Boxes	Non-ENERGY STAR Cable Boxes	4	43	3.9	$300.00

Residential Characteristics: Hot Water

Efficient Measure Description	Baseline Measure	Effective Useful Life (yrs)	Energy Savings (kWh)	Demand Savings (W)	Incremental Costs
Hot Water					
Faucet Aerator	No Aerator	9	107	24.0	$13.24
Low Flow Shower	Standard Shower	9	143	31.1	$30.00
Pipe Wrap	No Wrap	10	143	31.1	$2.42
Heat Pump WH - 2.0 EF	Standard Water Heater - .904 EF	19	1737	68.6	$1,498.00
Instantaneous WH - .99 EF	Standard Water Heater - .904 EF	20	507	20.0	$1,449.99
High Eff. Elec. Water Heat - Tank - .95 EF	Standard Water Heater - .904 EF	20	377	14.9	$275.97
Passive Solar Water Heat	Standard Water Heater	15	3321	724.0	$4,744.00
Drain Water Heat Recovery (42% efficient or hig	No Heat Recovery	15	1661	216.5	$500.00
Shower Start/Stop	No Start/Stop on Shower	9	80	6.6	$24.95

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Residential Characteristics: HVAC and Shell

Efficient Measure Description	Baseline Measure	Effective Useful Life (yrs)	Energy Savings (kWh)	Demand Savings (W)	Incremental Costs
HVAC / Building Shell					
(Double replace) Single Pane Windows	Single Pane Windows	20	694	63.1	$1,392.00
Ceiling Insul R-45	R-25 Ceiling	20	383	29.2	$890.00
Celing Insu. R-30	R-25 Ceiling	20	259	22.0	$700.00
Reduced ACH 0.3	ACH 0.6	20	1919	216.6	$530.00
Reduced ACH 0.5	ACH 0.6	20	731	68.6	$260.00
CAC tune-up - charge & airflow	Standard Tune-up	3	2280	674.9	$45.00
Duct Sealing Insulation Unconditioned	Leaky un-insulated Ducts	10	105	70.5	$760.00
ECM Fan Motor	Std PSC motor	15	170	50.3	$175.00
Triple Pane Windows	Double Pane Windows	20	273	29.0	$210.00
Wall Insul. R-11	Un-Insulated Wall	20	1557	176.9	$141.00
Low-e Window Film	Single Pane Clear	10	392	38.9	$280.00
Energy Star Window AC	EER 9.8 window AC	7	966	89.9	$220.00
SEER 15 CAC	SEER 13.0 CAC	15	59	28.6	$198.00

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EE Measure Benefit-Cost Analysis Process

- Benefit-cost analysis used Navigant's DSM Energy Efficient Resource Assessment Model (EERAM)
- Electric avoided energy and capacity costs provided by AEP Ohio; used levelized costs per 20-year forecast
- Escalation rates per AEP Ohio
- EE baselines and market penetrations per baseline study
- Measure costs and unit impacts per measure characterization
- Used initial retail rates per AEP Ohio

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EE Benefit-Cost Analysis Tests

Total Resource Cost Test (TRC)

- Most widely used test
- Evaluates whether EE is cheaper than supply side options
- Benefits are avoided costs due to EE
- Costs are EE measure costs + program administrative costs

Utility Cost Test (UCT)

- Evaluates whether EE is cost effective to utility
- Benefits are avoided costs due to EE
- Costs are total EE program costs

Rate Impact Test (RIM)

- Evaluates whether EE will cause utility rates to increase or decrease
- Benefits are avoided costs due to EE
- Costs are total program costs plus “lost revenues” due to DSM

Participant Test

- Evaluates whether EE is cost effective to customers
- Benefits are energy bill savings due to EE
- Costs are net EE measure costs

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EE Benefits and Costs Included in Standard Tests

	Benefits				Costs			
Test	Externality	Energy	Demand	Non Energy	Net lost revenues	Program Admin	Program Rebates	Customer Costs
1. Total Resource (TRC)		X	X			X		X
2. Societal Cost Test (SCT)	X	X	X	X		X		X
3. Utility Cost Test (UCT)		X	X			X	X	
4. Rate Impact (RIM)		X	X		X	X	X	
5. Participant		X	X	X				X

Note: AEP Ohio avoided costs include emissions factors

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EE Residential Measure Benefit-Cost Analysis Results

- Analysis produced results for all four California standard tests
  - Focus on most widely used test: Total Resource Cost Test (TRC)
- Majority of residential EE measures analyzed passed TRC, Utility Test, and Participant Test
- No residential measures that passed TRC Test failed Participant Test
- Nearly all residential measures failed RIM Test

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EE Market Potential Estimation Approach

1. **Estimate Technical and Economic potential.**
   - Technical potential: maximum DSM technically feasible; with no economic or market barriers factored in
   - Economic potential: all measures that are "cost effective", i.e., measures that pass TRC test (> 1.0)

2. **Estimate preliminary Market potentials for each measure**

3. **Calibrate overall and end use Market potential estimates to EE benchmarking results.**
   - Primary benchmarks used are annual savings ~ 1% of baseline energy sales
   - Adjust initial years to reflect start-up

- Estimates should be realistic but stretching; unrealistic to target California levels in short to medium term

- Target Iowa and Minnesota performance medium term ~1% of energy

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Residential Economic Potential: 2012-2014 Cumulative Annual MWh

End Use	2012	2013	2014
Lighting	2,538,469	2,457,095	2,375,718
Water Heat	277,616	277,562	277,508
Appliances	914,132	914,099	850,588
HVAC/Shell	551,920	551,920	551,677
Behavior	107,113	107,113	107,113
Total	**4,389,250**	**4,307,789**	**4,162,604**
Percent of Sector Forecast	29.29%	29.04%	28.18%

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Residential Economic Potential: 2012-2014 Cumulative Annual kW

End Use	2012	2013	2014
Lighting	346,784	335,209	323,634
Water Heat	40,117	40,112	40,108
Appliances	479,192	479,189	473,388
HVAC/Shell	77,361	77,361	77,309
Behavior	14,446	14,446	14,446
Total	**957,899**	**946,317**	**928,884**
Percent of Sector Forecast	26.63%	26.51%	26.57%

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Net to Gross

- Assumed NTG = 1.0
- Free Riders and Spillover equal
- Recommend PUCO rules with NTG = 1.0
- Seems logical but impractical to forecast (hard enough to gauge historical levels)
- Approach used in current PUCO green rules
- Similar to approach used in some Midwestern states such as Iowa

Senate Bill 221 Targets

Energy Savings: percent of preceding 3 years annual, average, normalized kWh sales

- 0.8% in 2012
- 0.9% in 2013
- 1.0% in 2014

Peak Demand Savings: percent of preceding 3 years annual, average, normalized MW sales

- 0.75% in 2012, 2014 and 2014

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Residential Market Potential: 2012-2014 Incremental Annual MWh

End Use	2012	2013	2014	2012-2014 Total
Lighting	71,944	79,567	89,930	241,441
Water Heat	5,598	5,747	6,179	17,524
Appliances	27,099	27,784	24,392	79,274
HVAC/Shell	13,814	14,068	14,843	42,724
Behavior	13,430	13,594	12,216	39,241
Total	**131,884**	**140,760**	**147,560**	**420,204**
Percent of Sector Forecast	0.88%	0.95%	1.00%	-

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Residential Market Potential: 2012-2014 Incremental Annual Summer Peak kW

End Use	2012	2013	2014	2012-2014 Total
Lighting	9,564	10,570	11,905	32,039
Water Heat	917	929	981	2,827
Appliances	14,053	14,611	15,256	43,921
HVAC/Shell	1,865	1,907	2,021	5,793
Behavior	1,811	1,833	1,648	5,292
Total	**28,210**	**29,851**	**31,811**	**89,872**
Percent of Sector Forecast	0.78%	0.84%	0.91%	-

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Residential Market Potential: 2012-2014 Incremental Annual MWh

Program	2012	2013	2014	2012-2014 Total
Products	43,145	47,052	48,836	139,033
Retrofit	47,604	51,083	56,237	154,923
Appliance Recycling	10,488	10,475	10,863	31,826
Home Energy Reports	13,430	13,594	12,216	39,241
New Construction	2	4	6	13
Low Income	17,214	18,553	19,402	55,169
Total	**131,884**	**140,760**	**147,560**	**420,204**
Percent of Sector Forecast	0.88%	0.95%	1.00%	-

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Residential Market Potential: 2012-2014 Incremental Annual Summer Peak kW

Program	2012	2013	2014	2012-2014 Total
Products	16,393	17,417	18,757	52,567
Retrofit	6,072	6,499	7,104	19,675
Appliance Recycling	1,767	1,765	1,830	5,361
Home Energy Reports	1,811	1,833	1,648	10,932
New Construction	0	1	1	2
Low Income	2,167	2,336	2,471	6,974
Total	**28,210**	**29,851**	**31,811**	**95,512**
Percent of Sector Forecast	0.78%	0.84%	0.91%	-

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Residential EE Potential Conclusions

- Most EE measures analyzed cost effective from TRC, Utility, and Participant Test perspective; most fail RIM Test

- Benchmark: High-end residential electric EE program savings
  - ~ 0.5% to 1% of baseline sales annually
  - ~ 0.4% to 1% of residential revenues spent for EE programs

- EE potential estimates consistent with EE best practice programs and SB 221 targets

- Additional review and refinements needed

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NRDC Set 2
Witness: Edward Miller

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-1 Referring to Exhibit ECM-3, why does the "total portfolio annual budget" peak in 2014 and then decline in 2015 for Ohio Edison and Toledo Edison?

Response:

The Companies' budgets are based in part on projected participation rates at the measure level and are then aggregated to the program level. The budgets at Ohio Edison and Toledo Edison peak in 2014 due to different participation assumptions across the measures for each of the Companies specific to each year of the Portfolio Plan. Forecasted participation by measure is included in Appendix C-2 of the Companies' Plans.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2– INT-2

Referring to Exhibit ECM-2, why do incremental annual projected MWh savings peak in 2014 and then decline in 2015 for Ohio Edison and Toledo Edison?

Response:

The Companies' projected MWh savings are based on projected participation rates at the measure level and assumption for partial year contribution. The projected MWh savings at Ohio Edison and Toledo Edison peak in 2014 due to different participation assumptions across the measures and different partial year contribution for each of the Companies, specific to each year of the Portfolio Plan. Forecasted participation by measure is included in Appendix C-2 of the Companies' Plans.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2– INT-3 Referring to Appendix B-4 of Attachments A, B, and C, how were operations costs determined for each Measure, Segment, and Program?

Response: Operations costs include costs associated with CSP administration, measurement and verification (M&V), internal labor, general awareness marketing, tracking and reporting and other. These costs were determined as follows:

- CSP administration costs were informed by experience for similar programs operated by FirstEnergy in Ohio or in other jurisdictions. Costs were identified by two components, (1) fixed program/sub-program, and (2) variable measure unit cost. These components were allocated to programs/sub-programs/measures based on projected number of units.
- M&V costs were estimates as 4% of total portfolio costs allocated to the program/sub-program level based on input from the Companies' energy efficiency consultant, and allocated to measures based on projected number of units.
- Internal labor costs were based on Company estimated EE&C Portfolio administration costs, allocated to each program based on the CSP administration and M&V costs, and allocated to measures based on projected number of units.
- General Awareness Marketing costs were based on Company estimates of large-scale media campaigns relative to the Ohio market, allocated to each program based on the CSP administration and M&V costs, and allocated to measures based on projected number of units.
- Tracking and reporting costs were based on existing contracts, allocated to each program based on the M&V costs, and allocated to measures based on projected number of units.
- Other costs, including cost associated with Plan development, employee expenses, legal fees, the Market Potential Study and modeling software costs, were informed by existing contracts, or Company estimates, allocated to each program based on the CSP administration and M&V costs, and allocated to measures based on projected number of units.

Certain costs were escalated relative to the changes in the Consumer Price Index from the Energy Information Administration's 2012 Early Annual Energy Outlook in future years.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-4 Referring to Appendix B-4 of Attachments A, B, and C, how much of the operations costs for each Measure, Segment, and Program encompass FirstEnergy internal labor?

Response: The plan budgets for internal labor costs were not based on estimates for each segment or program, with the exception of the Low Income Program, but were instead based on the Companies' estimated total to support the Ohio EE&C Portfolio, allocated to each Operating Company based on Company accounting practices. These costs were then allocated to each program, with the exception of the Low Income Program, based on the CSP administration and M&V costs, as modeled. The Low Income Program internal labor costs were based on current operations. FirstEnergy internal labor costs are estimated as 7.8%, 7.0%, and 8.0% of total Portfolio Operations costs for CEI, OE, and TE, respectively.

NRDC Set 2
Witness: Edward Miller

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-5 Referring to Appendix C-1 of Attachments A, B, and C, how did FirstEnergy determine the incremental cost of measures?

Response: Incremental costs of measures were based on 1) incremental costs as listed in the current draft State of Ohio Energy Efficiency Technical Reference Manual (TRM), 2) incremental costs as listed in TRMs of other jurisdictions, and 3) Company assumptions based on historic data, or vendor pricing.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2– INT-6 Referring to Exhibit BDE-1, why is "Additional Energy Efficiency Beyond Mercantiles" subtracted from "Fully Adjusted Retail Sales" to determine the Baseline and Benchmarks?

Response: The "Additional Energy Efficiency Beyond Mercantiles" are the energy efficiency programs from other than self-directed mercantile customers. The "Additional Energy Efficiency Beyond Mercantiles" are being subtracted from forecast model results that predict sales based on historical data prior to efficiency programs. The sales models cannot reflect impacts of programs that were installed recently or future programs needed to meet efficiency requirements so the subtraction of additional energy efficiency from those model results is necessary to predict sales levels that will be realized after the programs are developed and in place. The reduced model results form the best estimation of future sales which would be used in the calculations of benchmarks for future years.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-7 Referring to Appendix B-4 of Attachments, A, B, and C, why is only around .6% of the total program budget directed to improving efficiency in new buildings (the New Construction – Small C&I measure)?

Response: The Company's program budgets are constructed using the methodology described in NRDC Set 2-INT- 3 which includes measure participation projections. The Company made participation projections based on past measure performance, comparison to the Market Potential Study results, and input from the Companies' Energy Efficiency Consultant.

While the Company provided a measure level budget for transparency, budgets are managed at the program level, allowing the Companies to shift resources among measures within the program as needed. As such, the measure level budgets as listed in Appendices B-4 of each plan do not limit participation in any given measure.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-8

What is FirstEnergy's strategy for avoiding the creation of "lost opportunities" generated by the greater cost to improve energy performance in an existing building compared to the cost to improve energy performance of a building during initial construction of the building?

Response:

The Companies' proposed Portfolios include New Construction sub-programs for the Residential and Commercial & Industrial segments, in addition to programs that target existing buildings. The Companies will target builders for participation in the New Construction sub-program, and building owners for participation in other programs. This approach not only targets multiple audiences, but also offers customer opportunities during the initial construction phase as well as for existing buildings, allowing participation in these programs throughout a building's life cycle.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-9 What is FirstEnergy's strategy for integrating "emerging technologies" into its energy efficiency portfolio?

Response: The Companies anticipate expanding program measures to include emerging technology that shows the potential to produce costs effective savings and may not have been well known, tested, accepted by the market, or produced in sufficient quantities at the time this Plan was designed. The Company will monitor emerging technologies that it identifies throughout the 2013-15 time frame, and will discuss potential for such technologies with the Collaborative Group as appropriate.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2– INT-10 Referring to Appendix B-4 of Attachments A, B, and C, why is only around .2%-.4% of the total program budget directed to Retrocommissioning?

Response: The Company's program budgets are constructed using the methodology described in NRDC Set 2-INT- 3 which includes measure participation projections. The Company made participation projections based on past measure performance, comparison to the Market Potential Study results, and input from the Companies' Energy Efficiency Consultant.

While the Company provided a measure level budget for transparency, budgets are managed at the program level, allowing the Companies to shift resources among measures within the program as needed. As such, the measure level budgets as listed in Appendices B-4 of each plan do not limit participation in any given measure.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-11 Referring to Appendix C-1 of Attachment C, why is the Measure Life of "Retrocommissioning – Large C&I" 1 year?

Response: Due to the nature of Retrocommissioning initiatives, that include optimized building operations that are subject to changes over time, the Companies assumed a 1 year measure life as a conservative estimate.

NRDC Set 2
Witness: Edward Miller

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-12 How does the plan encourage energy efficiency in the use of computer servers by commercial and industrial customers, both large and small?

Response: Computer servers are eligible as custom equipment under the C&I Energy Efficient Equipment Programs, Small and Large. Program descriptions, including target market, implementation strategy, and marketing strategy, are located in Plan Sections 3.3 and 3.4 for the Small and Large sectors, respectively.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2– INT-13 Will FirstEnergy update the market potential study as it designs its next energy efficiency plan (for years 2016 and beyond)?

Response: Objection. The information requested is irrelevant and is outside the scope of this proceeding.

NRDC Set 2
Witness: George Fitzpatrick

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-14 Referring to the Market Potential Study, did the analyst consider methods of determining achievable potential other than the customer survey-based approach utilized? If so, what other methods were considered and why were they rejected?

Response: In addition to the survey based approach, methods such as comparable participation and diffusion-curve/algorithm methods were used by other entities such as AEP to determine achievable potential, which given their proximity to FirstEnergy Service territories, were also factored into the methodology. Most other methods use secondary data sources to arrive at a participation number. The customer-survey based approach was selected due to its ability to use primary data which reflects customer characteristics of each individual FirstEnergy operating company. This method also provides measure-by-measure insights into customer mindset.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-15 Referring to the Market Potential Study methodology, did the analyst check participation actually realized in the Existing Plan programs with the interest and intentions expressed in surveys used in the Market Potential Study included in the Existing Plan?

Response: Yes.

NRDC Set 2
Witness: Edward Miller

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-16 Referring to Section 8.0 of Attachments A,B, and C, what assumptions or analysis did FirstEnergy use to determine the avoided Transmission and Distribution cost of $20 per kW-year and what assumptions and analysis undergird the $20 per-kW-year value in the Existing Plan?

Response: The $20 per kW-year value for avoided Transmission and Distribution ("T&D") costs is based off the values as approved in the Companies' Existing Plans in Case Nos. 09-1947-EL-POR et. al. These amounts were deemed reasonable based on the Companies' Energy Efficiency Consultant's expertise in the industry. FirstEnergy did not conduct a specific avoided T&D cost study for purposes of this Plan.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-17 Referring to Page 8 of Attachment C, how does the Company propose to make mid-stream adjustments to the plan?

Response: Please refer to Sections 5.1.2 and 5.1.2.1 of the Companies' Energy Efficiency & Peak Demand Reduction Program Portfolio Plans.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-18

How has FirstEnergy's Proposed Plan incorporated recommendations from the Evaluation, Measurement, and Verification of programs under its Existing Plan and provide specific examples of evaluator recommendations that were, if any, included in the Proposed Plan.

Response:

In developing the proposed Plan, the Companies engaged their EM&V contractor for input regarding items such as participation projections, measure selection and assumptions, and budgets. The Company reviewed the 2011 EM&V findings on the 2011 programs to identify additional design considerations for development of the Plan. Specific examples that were incorporated into the 2013-2015 Plan stemming from this additional feedback include, but are not limited to, adjusted realization rates applicable to the Appliance Turn-In Program in both the Residential and Small Enterprise sectors, and adjusted savings assumptions related to residential CFLs and the On-line energy audit.

NRDC Set 2
Witness: Edward Miller

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-19 How does FirstEnergy intend to evaluate the energy savings impact of the Online Audit Program?

Response: The evaluation of the Online Audit Program will be conducted similar to the evaluation methodology used by FirstEnergy's EM&V Contractor in the current Online Audit Program which was developed in consultation with the Ohio Independent Evaluator. The energy savings impact of the Online Audit Program is evaluated from a retrospective perspective using a quasi-experimental approach. Because the program is designed to be opt-in, an evaluation approach that uses a randomized control trial, which must be applied prospectively, cannot be used. Moreover, this approach is consistent with approaches used by other evaluators to evaluate on-line energy audit programs.

The evaluation approach that FirstEnergy's EM&V Contractor uses for analyzing the energy savings impacts is the well-known "difference-in-differences" approach. With this approach, the starting point for determining the impact of an audit is to analyze changes over time in the energy use of audit participants, effectively comparing their energy use after receiving an audit to energy use before receiving the audit. However, changes in other factors besides the audit could have caused changes in energy use for the participants. To take these natural dynamics into account, the change in energy use over time is observed among customers not receiving an audit. Subtracting the change observed over time among non-participants from that observed among beneficiaries provides an estimate of the savings impact of receiving an audit.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2–INT-20 How does the Company plan to utilize its Account Representatives to market C&I Energy Efficient Equipment Program – Large and Energy Efficient Buildings Program – Large?

Response: The Company will utilize Account representatives in an advisory role—educating customers of available program offerings, incentives, and assisting customers in making informed energy decisions. In order to accomplish this, the Company will continue to train Account representatives on program offerings, participation options, and energy efficiency opportunities. The Companies communicate regularly with their Account Representatives, informing this group of relevant program updates.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

RESPONSES TO REQUEST

NRDC Set 2– INT-21 Is any portion of, and in what way is, FirstEnergy Account Representative compensation tied to customer participation in energy efficiency programs?

Response: FirstEnergy Account Representative compensation is not tied to customer participation in energy efficiency programs.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 2 – RPD-3 Referring to Application Attachment C, Page 78, Figure 2: Organization Chart, please provide the resume of each person listed as a Director or Manager.

Response: Objection. The requested information is is irrelevant and is not designed to lead to any admissible evidence in this proceeding.

Without waiving the objection, resumes of Company witnesses, including that of Edward Miller, Manager, Compliance & Development, were filed as part of each witnesses' testimony.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 2 – RPD-4 Referring to Application Attachment C, Page 78, Figure 2: Organization Chart, please provide a list of the energy efficiency conferences employees listed as Vice President, Directors, and Managers attended from January 1, 2011 to August 10, 2012 by employee.

Response: Objection. The requested information is irrelevant and is not expected to lead to any admissible evidence in this proceeding.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 2 – RPD-5 Referring to Appendix B-4 of Attachments A, B, and C, please provide all inputs, assumptions, and logic used to determine "2013 to 2015 Operations" costs, by measure or program.

Response: Objection. The request is vague, overly broad and unduly burdensome.

Without waiving said objection, the Companies have provided major input assumptions and logic as listed in NRDC Set 2-INT-3, and operation costs are addressed in NRDC Set 2-RPD-6

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 2 – RPD-6 Referring to Appendix B-4 of Attachments A, B, and C, please provide a disaggregation of "2013-2015 Operations" costs into Utility labor, Marketing, EM&V, Conservation Service Provider Administration, Tracking and Reporting, and All Other Costs by measure or program.

Response: Objection. The requested information contains proprietary information that may adversely affect the Companies' ability to competitively bid for implementation service providers in the 2013 to 2015 Plan period. The Companies will not provide this information absent a signed confidentiality agreement.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 2 – RPD-7 Referring to Appendix B-4 of Attachments A, B, and C, please provide an estimate of the Full-Time-Equivalent FirstEnergy employees assigned or allocated to each Segment or Program

Response: With exception of the Low Income Program, the plan budgets for internal labor costs were not based on estimates for each segment or program, but were instead based on the Companies' estimated total to support the Ohio EE&C Portfolio, allocated to each Operating Company based on Company accounting practices. These costs were then allocated to each program, with exception of the Low Income Program where the internal labor costs were based on current operations., based on the CSP administration and M&V costs, as modeled. Due to these allocations, internal labor should be viewed at the total Ohio level, and is the equivalent of approximately 21 FTEs per year supporting all Ohio Companies.

NRDC Set 2
Witness: Edward Miller

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 2 – RPD-8 Referring to Appendix C-1 of Attachment C, provide any evaluation studies or other information to support the 1-year measure life for "Retrocommissioning – Large C&I."

Response: See response to NRDC Set 2-INT-11 for explanation of Company assumption for 1 year measure life.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 2 – RPD-9 Referring to Page 34 of the Market Potential Study, please provide any research or documentation describing the relationship between customer self-reported intentions and actions prior to program launch or design and actual realized participation in energy efficiency programs.

Response: The research and documentation describing the relationship between customer self-reported intentions and actions prior to program launch were provided in the Market Potential Study in Appendix D-1 and D-2.

Appendix D-1 and D-2 (The Survey Instruments) have detailed questions asking respondents to indicate if they have either participated in specific FirstEnergy programs or performed a specific energy saving action in the last two years.

Also, Black & Veatch referred to the Companies' estimates of program progress for existing energy efficiency programs.

Case No. 12-2190-EL-POR

In the Matter of the Application of Ohio Edison Company, The Cleveland Electric Illuminating Company, and The Toledo Edison Company For Approval of Their Energy Efficiency and Peak Demand Reduction Program Portfolio Plans for 2013 through 2015.

REQUEST FOR PRODUCTION OF DOCUMENTS

NRDC Set 2 – RPD-10 Referring to Section 8.1 of Attachments A, B, and C, please provide a machine-readable, Microsoft Excel-compatible spreadsheet of energy, capacity, and transmission and distribution costs used to value measures included in the EE&PDR Program Plan.

Response: Avoided costs for Energy, Generation capacity, and Transmission & Distribution capacity as used for Total Resource Cost test evaluation are included in the file "NRDC Set 2-RPD-10-Attachment 1"

Swisher Attachment 5

A Framework for Data Center Efficiency Strategy

Rocky Mountain Institute

January 14, 2009

Executive Summary

- IT systems are **becoming increasingly central** to companies' cost structures, environmental impacts, and hour by hour operational demands.
- Despite challenges, numerous **IT efficiency opportunities exist**, which can significantly reduce impacts and deliver substantial business value.
- In many data centers, **99% efficiency gains** are not only achievable with no radical new technologies but are supported by a strong business case.
- To capture these opportunities, a coordinated approach needs to focus programs in **existing facilities and future designs**.
- The following steps should inform a data center efficiency strategy:

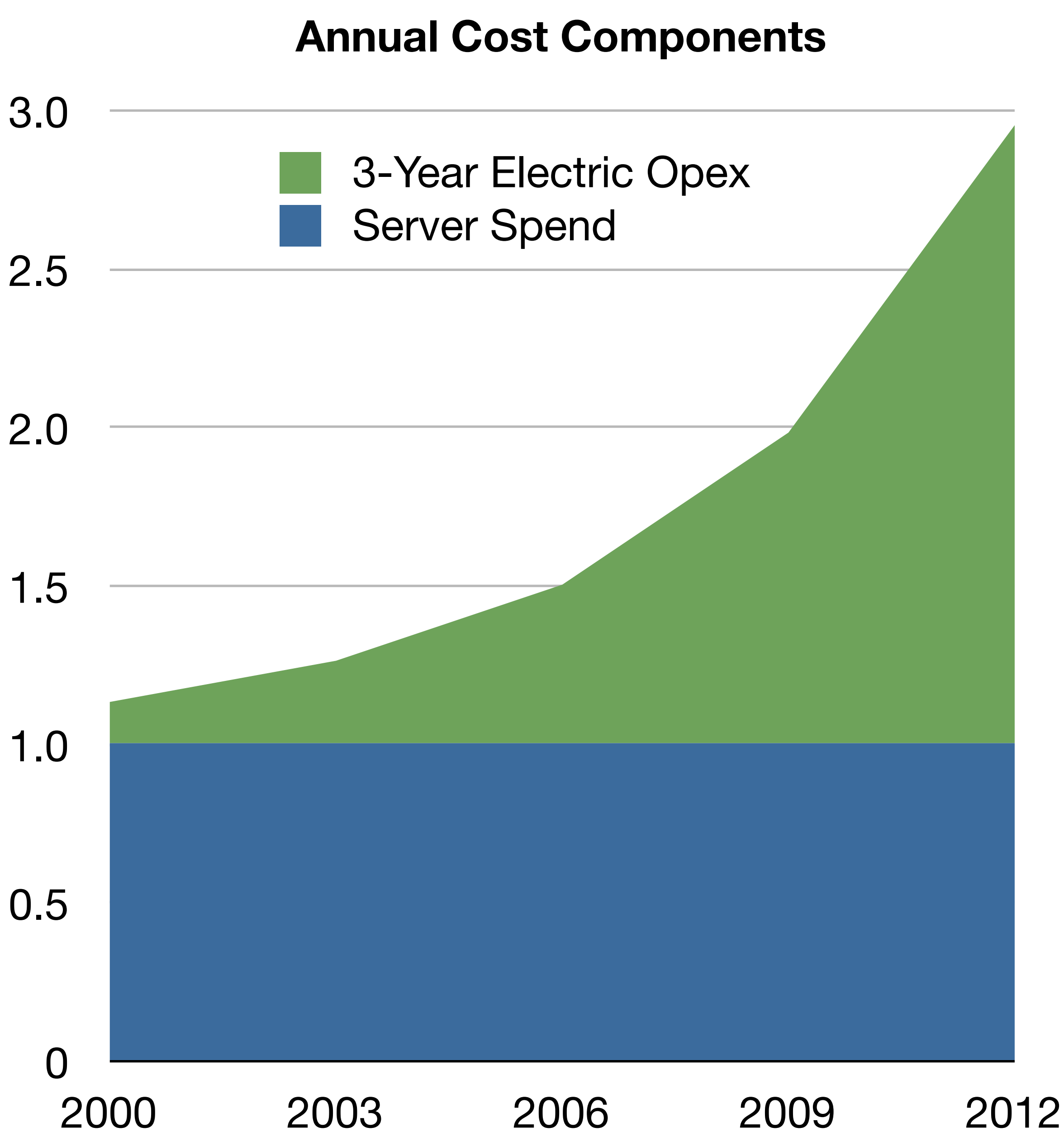
    1) Determine existing energy usage and cost impacts;

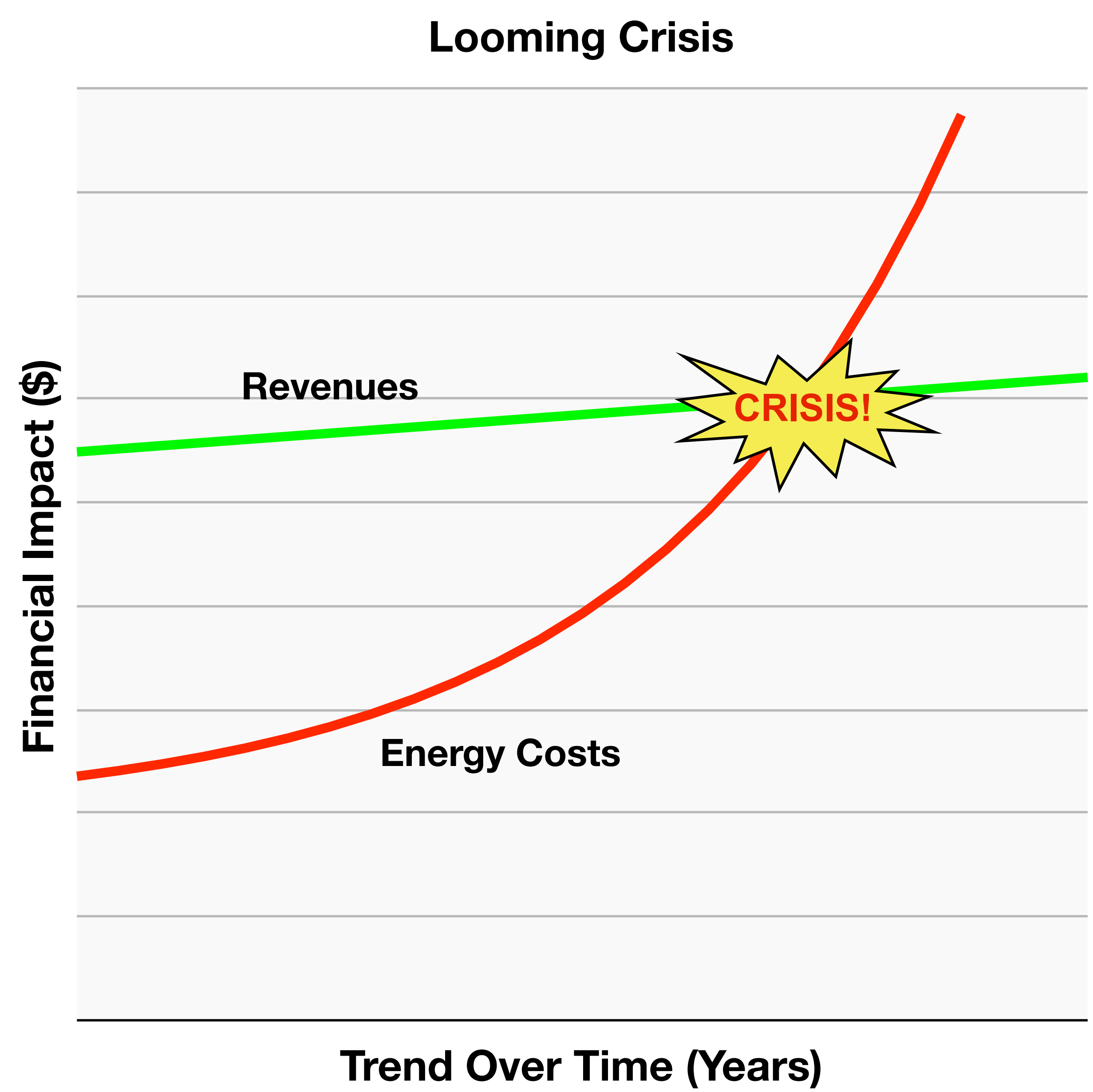
    2) Evaluate growth needs from an end-use perspective;

    3) Analyze potential impacts and relative value of efficiency levers;

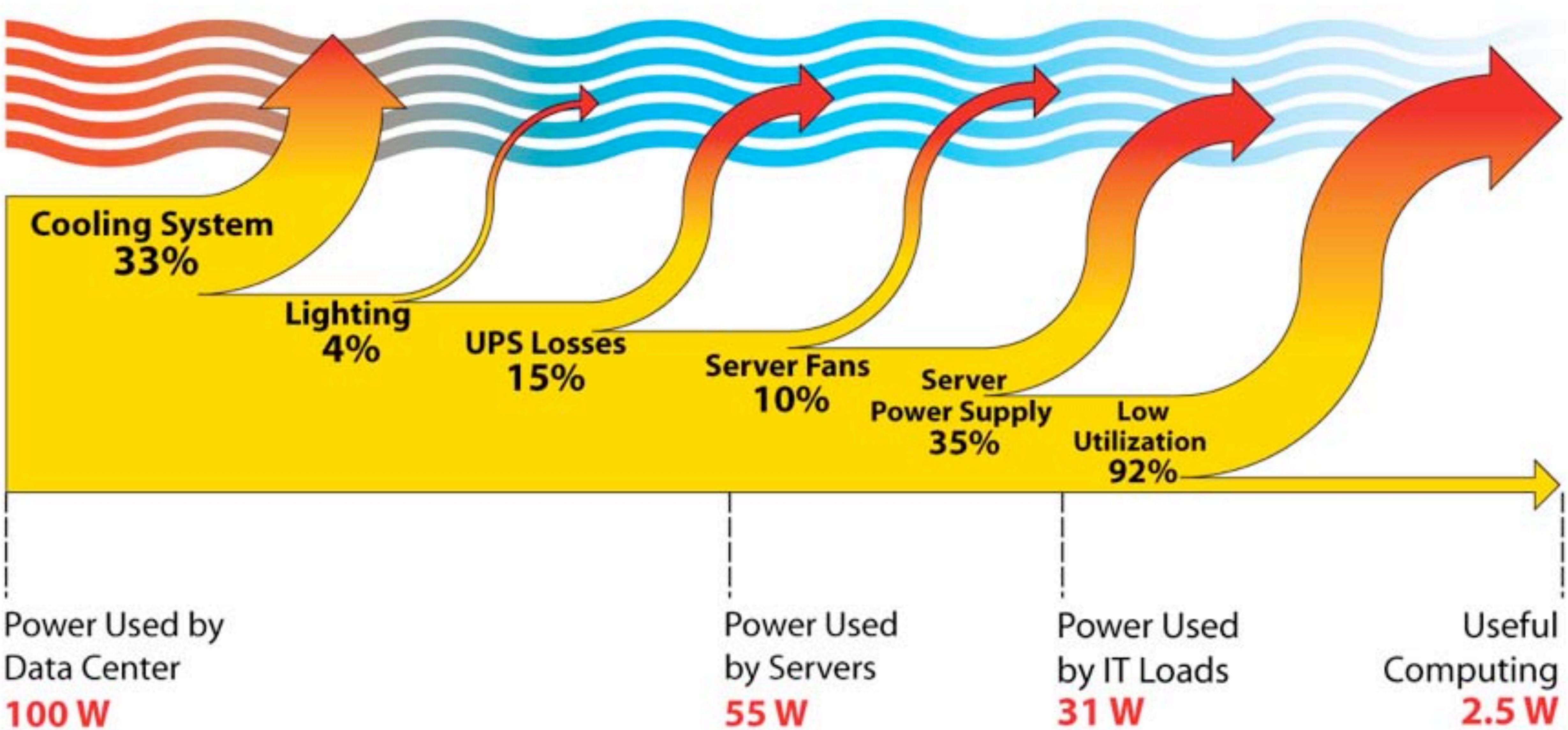
    4) Develop implementation strategy to capture potential.

Rising energy costs and growing capacity needs are leading to a crisis in data center business models.

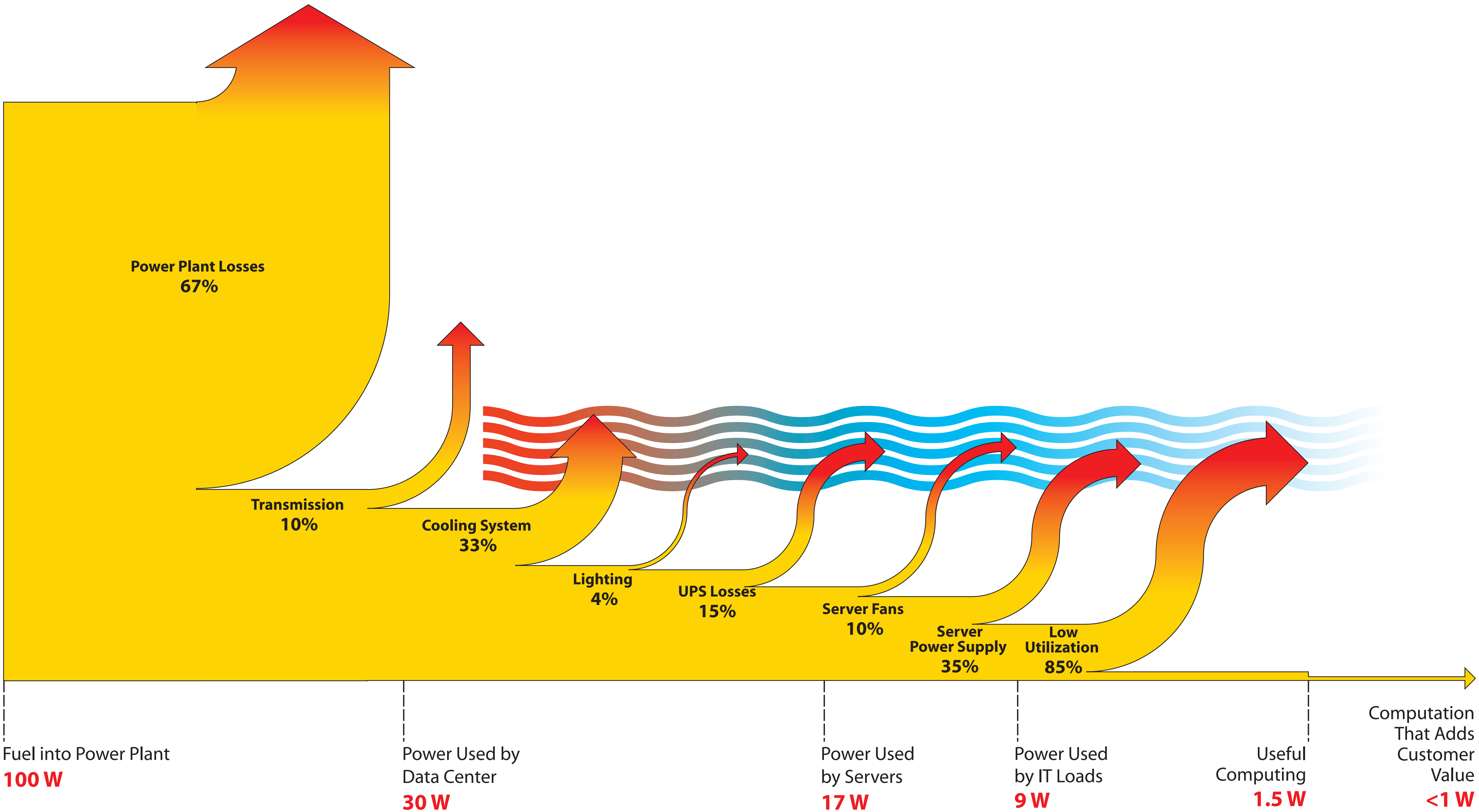




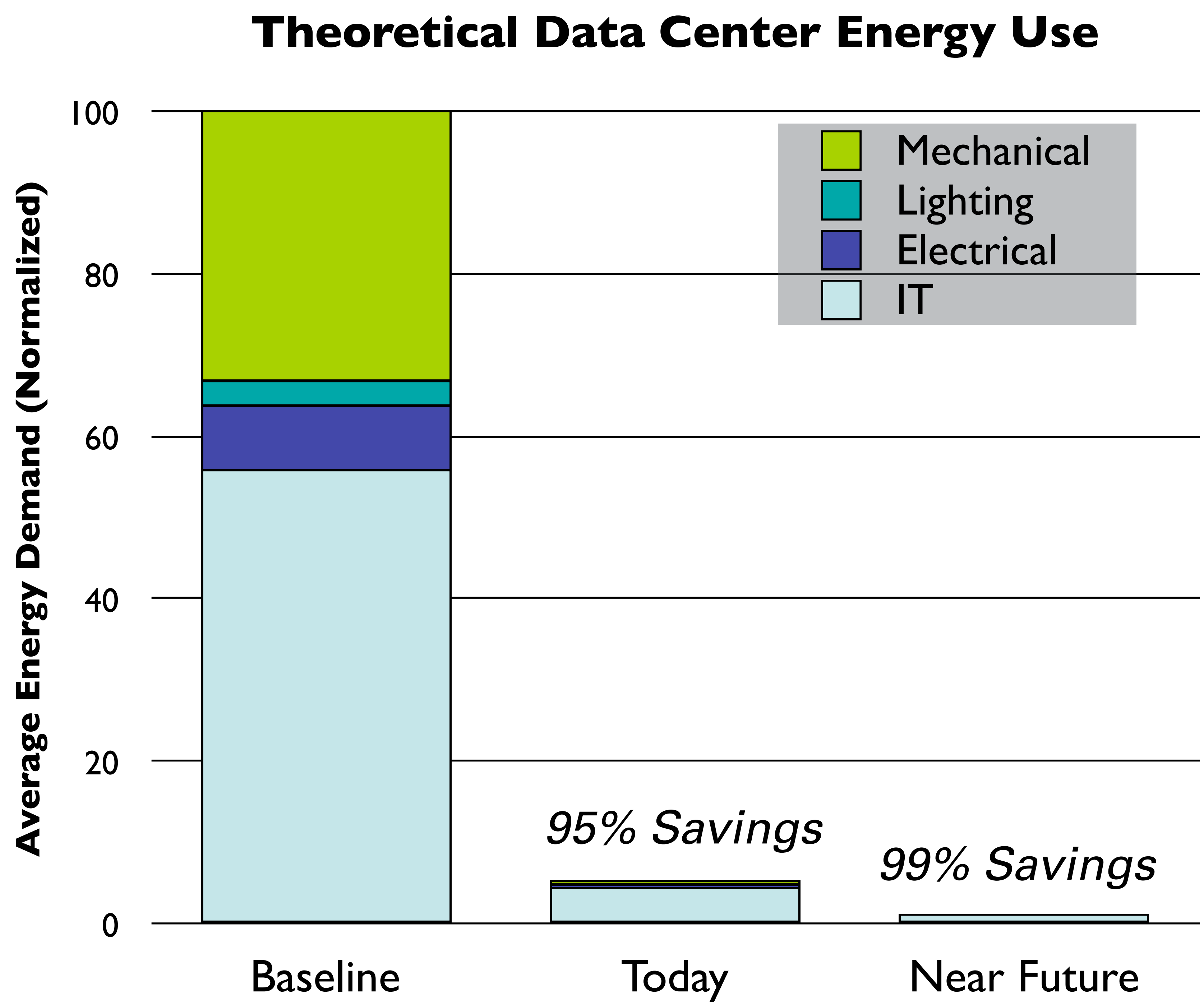
End-use efficiency savings compound upstream, leading to capex and opex reductions.



And the whole system view shows even lower efficiencies (greater opportunities).



The technical potential for efficiency is very large.



Levers are verified best practices:

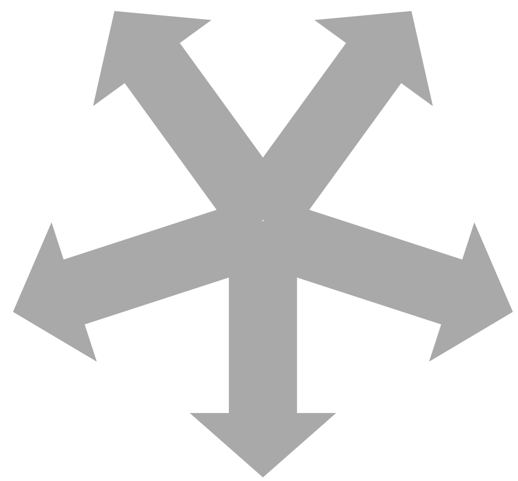
- Economizers
- Airflow management
- Virtualization
- Efficient hardware
- Lighting optimization
- Commissioning
- Centralized HVAC
- Software development
- Solid state storage
- Liquid cooling
- ...

Data center capacity may be constrained at a number of levels.

In other words, why can't you add one more server?

Raised floor

Utility

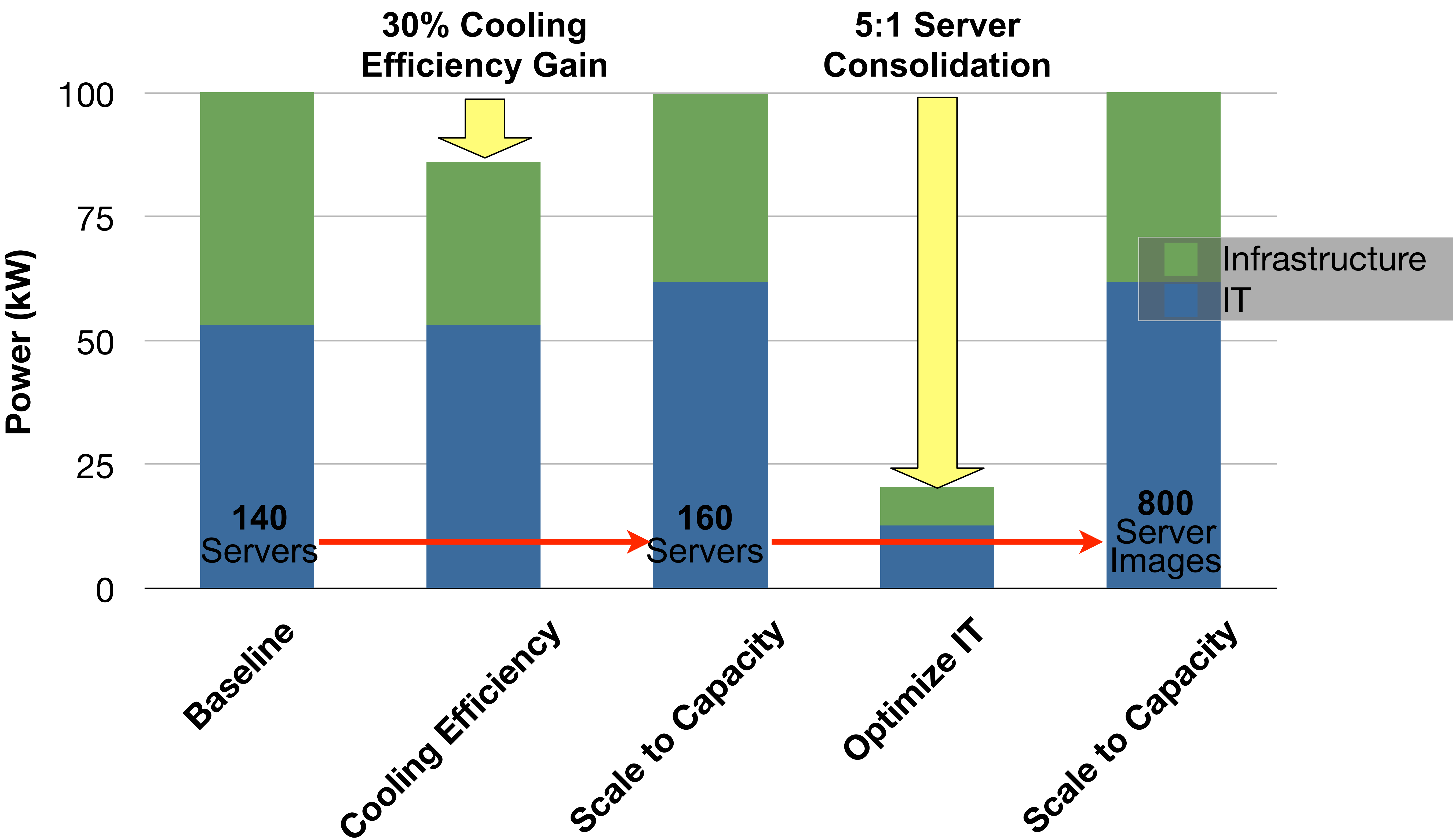


UPS

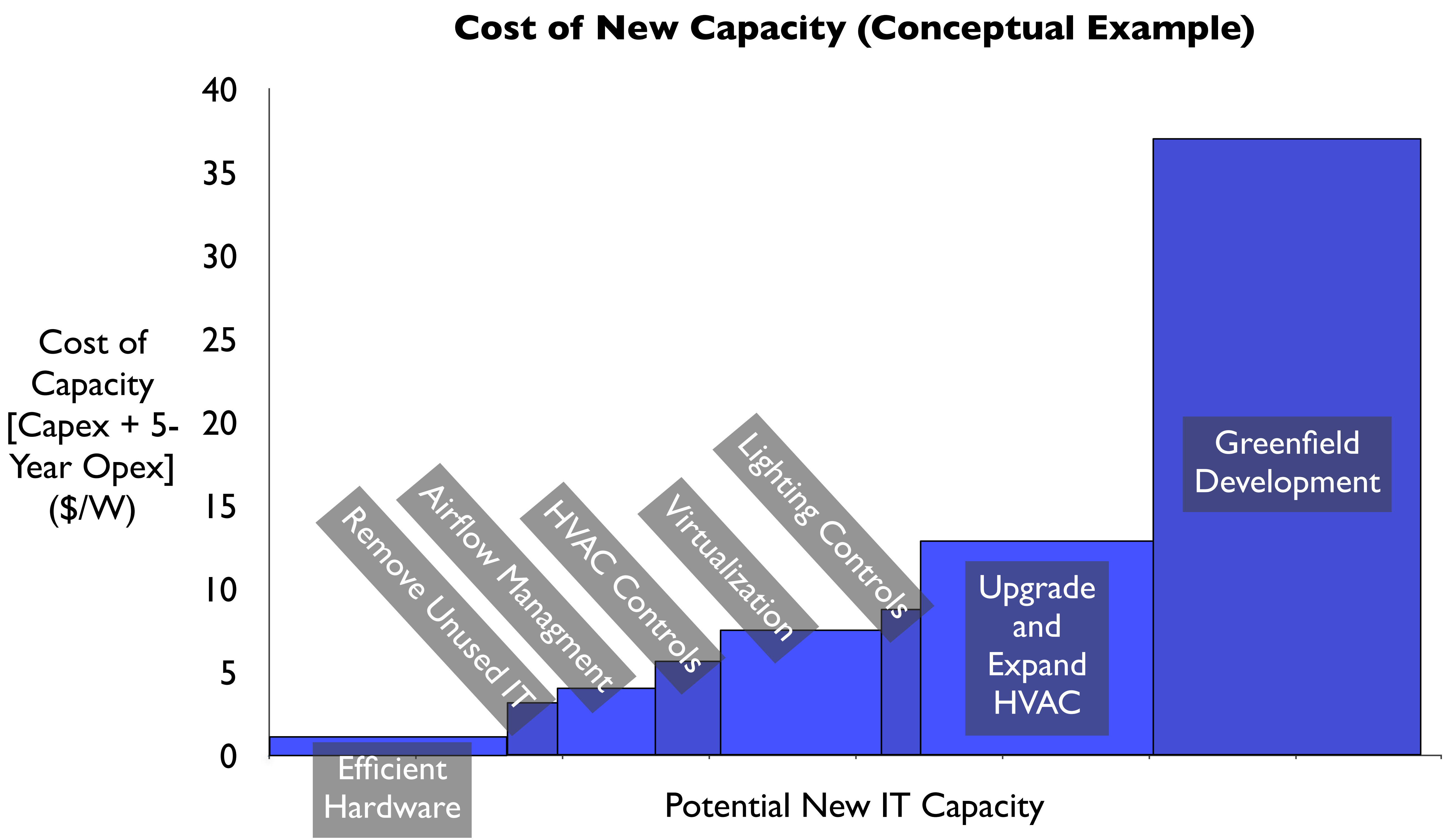
Cooling

Generator

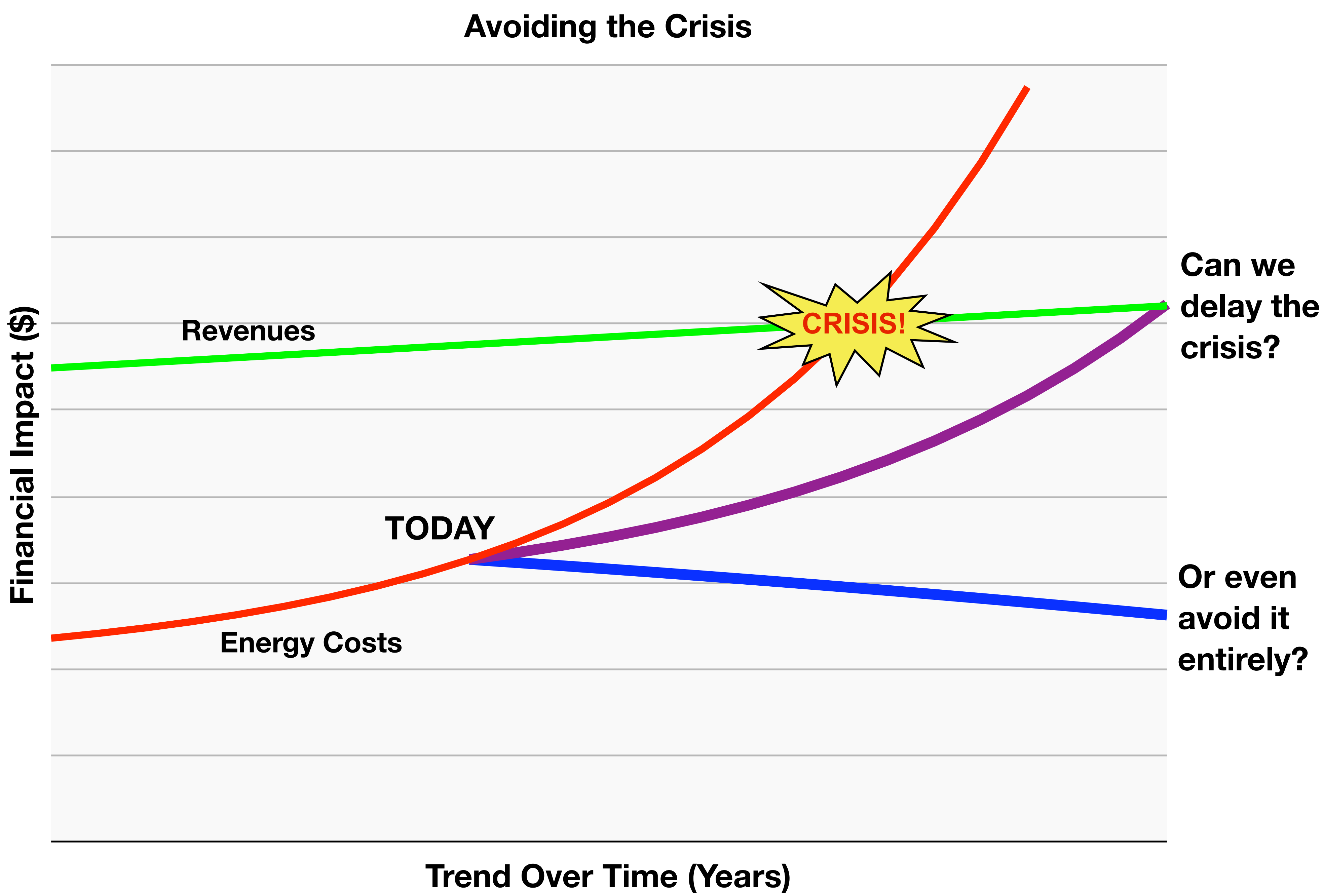
In constrained data centers, most efficiency gains have the effect of increasing facility computing capacity.



To prioritize first steps and optimize business value, use cost of capacity analysis.



An effective strategy will integrate retrofit programs with major renovations and build out plans.



Consortium for Energy Efficiency

ıta Centers & Business Computing Program Summary

Welcome to the Data Center and Business Computing Efficiency Program Summary. This file contains information about CEE member utilities and efficiency program administrators in the United States and Canada that offer support for improving data center or computing energy efficiency. The sheet is set up for easy filtering of information to find programs by organization name, state, or program type (choose non-blanks to see all programs for a specific type).

This information is intended as a reference guide. Each program has its own eligibility requirements, application process, incentive caps, and other terms and conditions that are not included in this summary. Please note that some programs offer commercial/industrial projects on a custom basis and that not all programs may not be reflected in this summary. Contact the local program administrator for more information.

Tips: To navigate this file easier, save it to your computer. You will then be able to sort, filter, follow links to program information easily. Remember to scroll left and right to see additional equipment categories, and up and down to see additional efficiency programs.

This information was compiled through internet research during November 2010. Information is provided "as is." For the most recent program information, follow the links to program websites or call your local utility or efficiency program administrator.

For **Terms and Conditions** go to: http://www.cee1.org/terms.php3.

CEE[SM] Data Centers & Business Computing Program Summary, 2010-2011

SCROLL FOR MORE CATEGORIES!

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring
Arizona Publice Service	AZ	Rebates for Energy Feasibility studies, Prescriptive projects, and Custom projects available. Prescriptive program covers up to 75% of incremental cost and is capped at $100,000, and custom program pays a one time incentive of 11 cents per annual kWh saved up to 50% of the incremental cost of the measure. Capped at $300,000 per customer per year.	General commerical building incentives are offered for design assistance related to energy savings -- 50% of cost of study up to $10K per study.	General commercial building incentives are offered for energy feasiblity studies -- 50% of cost of study up to $10K per study.	General commercial building incentives are offered for Commissioning and Retro-Commissioning as long as it relates to energy savings -- 50% of cost of Commissioning to $10K ($20K for Retro-Commissioning).
Austin Energy	TX	Rebates of up to $200,000 per site per fiscal year, including any eligible bonus payments. Requires a pre and post inspection.	General commercial building incentives are available for new construction projects. Incentives cover up to $200,000 per site per fiscal year, including any eligible bonus payments.	Free energy audit services are available for commercial buildings.	Commissioning services available for commercial buildings with a minimum of 100,000 square feet of conditioned space and a minimum summer peak demand of 200 kW. Covers up to 75% or $10,000 of cost to implement recommended measures.
AVISTA Utilities	ID	Prescriptive rebates for some measures are available. Custom measures are available to cover up to 50% of incremental costs.	Custom funding may be available - contact AVISTA.	Custom funding may be available - contact AVISTA.	Custom funding may be available - contact AVISTA.

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring
AVISTA Utilities	WA	Prescriptive rebates for some measures are available. Custom measures are available to cover up to 50% of incremental costs.	Custom funding may be available - contact AVISTA.	Custom funding may be available - contact AVISTA.	Custom funding may be available - contact AVISTA.
Bonneville Power Administration	ID	BPA is a wholesale power provider to over 130 customer utilities in the Pacific Northwest. Incentives are available for existing facilities and new construction through member utilities. Contact local utility for details.	Commercial new construction incentives are available. Contact local utility for details.	Contact local utility for details.	Contact local utility for details.
Bonneville Power Administration	MT	BPA is a wholesale power provider to over 130 customer utilities in the Pacific Northwest. Incentives are available for existing facilities and new construction through member utilities. Contact local utility for details.	Commercial new construction incentives are available. Contact local utility for details.	Contact local utility for details.	Contact local utility for details.

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring
Bonneville Power Administration	OR	BPA is a wholesale power provider to over 130 customer utilities in the Pacific Northwest. Incentives are available for existing facilities and new construction through member utilities. Contact local utility for details.	Commercial new construction incentives are available. Contact local utility for details.	Contact local utility for details.	Contact local utility for details.
Bonneville Power Administration	WA	BPA is a wholesale power provider to over 130 customer utilities in the Pacific Northwest. Incentives are available for existing facilities and new construction through member utilities. Contact local utility for details.	Commercial new construction incentives are available. Contact local utility for details.	Contact local utility for details.	Contact local utility for details.
BC Hydro	British Columbia	Product Incentive Program is available to all BC Hydro commercial customers whose annual electricity bills total less than $200,000. Energy studies through the Power Smart Partner Program are available to commercial facilities spending more than $50,000 per year on electricity (up to 100% of costs covered).	Assistance is available for commercial facilities in general through the Commercial New Construction Program.	Eligible customers may qualify for funding towards an in depth data centre assessment study through the Power Smart Partner Program.	N/A (exploring for future program)

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring
City of Palo Alto Utilities	CA	Prescriptive and custom incentives are available through the Commercial Advantage Program. Cusom incentives pay a minimum of $250 for 2,500 kWh per year up to 50% of project cost.	New construction assistance is available for commercial facilities in general.	Audit assistance is available for commercial faciligies in general.	N/A
Efficiency Vermont	VT	Program is still in development, though several prescriptive commercial incentives are available. Efficiency Vermont is currently working to support more efficient practices and equipment in existing and new data centers.	Custom assistance is available for commercial new construction in general.	Can assist with preapproved studies to identify electricity saving measures.	Contact Efficiency Vermont regarding potential commissioning incentives.
Energy Trust of Oregon	OR	Various prescriptive incentives are available, and custom incentives are available to cover up to 50% of incremental cost (not exceeding $.025/annual kWh saved or $1.00/annual therm saved).	Incentives of up to $2,500 are available for conducting and reporting the results from an early project team meeting that addresses energy efficiency.	Energy modeling assistance is available to cover at least 50% of assessment costs up to $25,000.	Commissioning incentives of up to $40,000 are available and are based on the annual energy savings approved by ETO during installation.
Eugene Water & Electric Board	OR	Supports incentives for measures where energy savings can be documented. Prescriptive computing support is available, as are custom rebates and loans for projects that save energy.	Custom funding may be available - contact EWEB.	Custom funding may be available - contact EWEB.	Custom funding may be available - contact EWEB.

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring
Idaho Power	ID	Prescriptive incentives available through the Easy Upgrade Program, including for PCs. Custom funding available through the Custom Efficiency Program at 12 cents per kWh saved per year up to 70% of project cost.	Several new construction incentives for commercial facilities in general are available through the Building Efficiency Program.	Commercial energy consultations are available.	N/A (custom incentives may be available)
Los Angeles Deptartment of Water & Power	CA	PC power management incentive available through the Custom Express Program. Custom Performance Program offers custom incentives for other commercial equipment and systems.	Incentives for commercial new construction in general are available through the New Construction Incentive Program.	Commercial energy use analyses are available. Energy Load Monitoring Program provides ability to monitor energy use.	N/A
New York State Energy Research & Development Authority (NYSERDA)	NY	NYSERDA's FlexTech program provides opportunities for affordable audits and retro-commissioning. The Existing Facilities Program offers pre-qualified and performance-based prescriptive incentives, as well as custom incentives. Performance-based incentives for electric efficiency cover up to $2,000,000 or 50% of the project cost.	Incentives for commercial new construction in general are available through the New Construction Incentive Program.	Assistance with data center efficiency analyses is available to customers eligible for the FlexTech program. In addition, NYSERDA offers energy audits for facilities spending less than $75,000 per year on electricity.	Retro-commissioning services are available through the FlexTech program.

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring
Oncor Electric Delivery	TX	Oncor is offering rebates for energy reduction in Data Centers to qualifying projects based on potential server virtualization projects, UPS upgrades, Controls, and Cooling Optimization replacement and retrofits resulting in a reduction of base lined consumption.	Supports assistance from the contracted implementer on energy efficient data center strategy and best practices. Tour the DC and recommend strategic implementation to reduce energy and reference past projects and successes and assist with procurement of technical, engineering, product and installation resources.	Assistance with opportunity assessment; Reports identifying targeted energy efficiency measures; assistance to help calculate energy savings; estimation of rebate/incentives to help offset measure costs and deliver incentive.	N/A
Pacific Gas and Electric	CA	Prescriptive incentives are available, as are numerous custom incentives (including those specifically for data centers) through the Customized Retrofit Incentives Program. Commercial facilities are also eligible for incentives under the Customized Retrofit - Demand Response program.	New construction and design assistance for commercial facilities in general is available through the Savings by Design Program.	Free energy audit services are available for commercial buildings.	Retrocommissioning services are available for commercial facilities in general. Incentives are paid at $0.09/kWh, $1.00/therm, and $100/on-peak kW*, capped at 50% of cost.
Puget Sound Energy	WA	Offers several prescriptive measures and custom grants which typically cover between 50% and 70% of project cost.	Prescriptive and custom grants available for commercial new construction; custom grants cover up to 70% of cost.	Online energy audit available for commercial buildings in general.	Incentives for third-party commissioning up to $0.50 per square foot. Additional incentives covering up to 100% of costs of design and post-occupancy phase commissioning.

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring
Sacramento Municipal Utility District	CA	Prescriptive and custom incentives are available for commercial facilities in general and data centers in particular.	New construction and design assistance for commercial facilities in general is available through the Savings by Design Program.	On site and online energy audits are available.	Retro-commissioning incentives available to cover uop to $50,000 or 20% of cost.
San Diego Gas & Electric (Sempra)	CA	Prescriptive and custom incentives are available, including for PC power management and occupancy sensors. Low interest financing options also exist for efficient upgrades.	New construction and design assistance for commercial facilities in general is available through the Savings by Design Program. Sustainable Communities Program also provides green building incentives.	On site energy consultation and online Energy Challenger tool are available for commercial facilities in general.	Retrocommissioning services are available for large commercial facilities through the RCx Program.
Snohomish County Public Utility District	WA	Prescriptive rebates and incentives are available, including for PC power management.	New construction assistance is available for commercial buildings in general. Incentive for projects other than lighting is $0.20 per kWh of annual savings for systems at least 10% better than the Washington standard.	Auditing services for commercial facilities are available through the Incentives for Existing Buildings offering.	Commissioning services for commercial facilities are available thorugh the Incentives for Existing Buildings offering.

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring
Tacoma Public Utilities	WA	Prescriptive and custom measures are available, including for PC power management. Zero-interest loans are also available to cover up to $500,000 or 70% of cost for efficiency upgrades at existing commercial facilities.	New construction assistance is available for commercial buildings in general.	Free walk through energy audits are available for commercial facilities in general.	Commissioning incentives may be available for commercial facilities greater than 30,000 square feet and whose projects exceed the Tacoma Energy Code by 30% or more.
Wisconsin Focus on Energy	WI	Prescriptive measures are available for data centers, and custom measures are available for commercial buildings in general.	New construction assistance is available for commercial buildings in general.	Free energy assessments available for commercial buildings in general.	Retrocommissioning services are available for commercial facilities in general.
Xcel Energy	CO	Prescriptive incentives are offered for data centers after completion of an energy assessment (for new or existent data centers). Custom computing incentives are also available.	Covers $25,000 worth, or up to 75%, of data center efficiency study (including new data centers) performed by third party. Requires preapproval.	Covers $25,000 worth, or up to 75%, of data center efficiency study performed by third party. Requires preapproval.	Recommissioning and retrocommissioning services offered for commercial facilities in general. Facility must be greater than 50,000 square feet. Incentive covers up to $25,000 or 75% of study cost.
Xcel Energy	MN	Prescriptive incentives are offered for data centers after completion of an energy assessment (for new or existent data centers). Custom computing incentives are also available.	Covers $25,000 worth, or up to 75%, of data center efficiency study (including new data centers) performed by third party. Requires preapproval.	Covers $25,000 worth, or up to 75%, of data center efficiency study performed by third party. Requires preapproval.	Recommissioning and retrocommissioning services offered for commercial facilities in general. Facility must be greater than 50,000 square feet. Incentive covers up to $25,000 or 75% of study cost.

CEE Member	State or Province	General Program Information	New Data Center (DC) Design Assistance	DC Assessment, Audit Assistance	DC Commissioning, Monitoring

SCROLL FOR MORE CATEGORIES!

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)
N/A (custom incentives may be available)	1. Chillers and Package Units 2. Variable speed drives 3. High efficiency motors 4. Lighting measures 5. HVAC measures	N/A (custom incentives may be available)	IT Systems: http://www.aps.com/main/services/SolutionsForBusiness/it.html Solutions for Business Program: http://www.aps.com/main/services/SolutionsForBusiness/default.html
1. Massive array of idle disk (MAID) storage systems 2. Virtualized servers (existing data centers, retrofit only)	1. Uninterruptible power supplies 2. Chillers / Cooling Towers (latter are custom) 3. Thermal energy storage systems 4. Variable frequency drives 5. High efficiency motors 6. ECM motors 7. Lighting measures 8. Wire Up-Sizing	Power management software for PC Networks at $5/seat that achieve at least 120 annual kWh savings per controlled PC. Capped at 50% of invoiced cost.	Data Center Rebate: http://www.austinenergy.com/energy%20Efficiency/Programs/Rebates/Commercial/Commercial%20Energy/dataCenter.htm Commercial Power Saver Program: http://www.austinenergy.com/Energy%20Efficiency/commIndex.htm
N/A (custom incentives may be available)	1. Side stream filtration (cooling towers) 2. Demand controlled ventilation 3. Premium efficiency motors 4. Variable frequency drives 5. Lighting measures	Software solutions that provide power management, have certain capabilities are potentially eligible for a $10 incentive per controlled PC.	PC Power Management: https://www.avistautilities.com/business/rebates/washington_idaho/Pages/incentive_14.aspx Business Energy Efficient Initiatives: https://www.avistautilities.com/business/rebates/washington_idaho/Pages/default.aspx

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)
N/A (custom incentives may be available)	1. Side stream filtration (cooling towers) 2. Demand controlled ventilation 3. Premium efficiency motors 4. Variable frequency drives 5. Lighting measures	Software solutions that provide power management, have certain capabilities are potentially eligible for a $10 incentive per controlled PC.	PC Power Management: https://www.avistautilities.com/business/rebates/washington_idaho/Pages/incentive_14.aspx Business Energy Efficient Initiatives: https://www.avistautilities.com/business/rebates/washington_idaho/Pages/default.aspx
Contact local utility for details.	Lighting, HVAC, motor, variable frequency drive, and smart power strip incentives are available. Contact local utility for details.	Network computer power management incentives are available. Contact local utility for details.	Commercial Sector Programs: http://www.bpa.gov/Energy/N/commercial.cfm Technical Services Request: https://secure.bpa.gov/EE_TechServiceProposals_Ext/ All other comments should be directed to the local utility.
Contact local utility for details.	Lighting, HVAC, motor, variable frequency drive, and smart power strip incentives are available. Contact local utility for details.	Network computer power management incentives are available. Contact local utility for details.	Commercial Sector Programs: http://www.bpa.gov/Energy/N/commercial.cfm Technical Services Request: https://secure.bpa.gov/EE_TechServiceProposals_Ext/ All other comments should be directed to the local utility.

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)
Contact local utility for details.	Lighting, HVAC, motor, variable frequency drive, and smart power strip incentives are available. Contact local utility for details.	Network computer power management incentives are available. Contact local utility for details.	Commercial Sector Programs: http://www.bpa.gov/Energy/N/commercial.cfm Technical Services Request: https://secure.bpa.gov/EE_TechServiceProposals_Ext/ All other comments should be directed to the local utility.
Contact local utility for details.	Lighting, HVAC, motor, variable frequency drive, and smart power strip incentives are available. Contact local utility for details.	Network computer power management incentives are available. Contact local utility for details.	Commercial Sector Programs: http://www.bpa.gov/Energy/N/commercial.cfm Technical Services Request: https://secure.bpa.gov/EE_TechServiceProposals_Ext/ All other comments should be directed to the local utility.
N/A (custom incentives available for eligible server consolidation projects that save up to 100,000 kWh per year per project)	1. Lighting measures 2. HVAC measures 3. Motors (custom) 4. Adjustable speed drives	$6 incentive per software license for power management for PC networks. $7 incentive per energy efficient power bar.	Data Centre & Server Initiative: http://www.bchydro.com/powersmart/commercial/data_centre_and_server.html Product Incentive Program: http://www.bchydro.com/rebates_savings/product_incentive_program.html

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)
$215 incentiver per server removed for virtualization projects.	1. Lighting measures 2. HVAC measures 3. Chillers	$15 incentive per license for PC power management. $15 incentive for infrared and/or ultrasonic management software (must control electric equipment in offices or cubicles or control shared copy machines and/or printers).	Commercial Advantage Program: http://www.cityofpaloalto.org/news/displaynews.asp?NewsID=471&targetid=139
Contact Efficiency Vermont regarding potential incentives for virtualization and virtual desktop infrastructure.	1. Lighting measures 2. HVAC measures 3. Motors 4. Variable frequency drives 5. UPS systems 6. Contact Efficiency Vermont regarding potential incentives for efficient CRACs, PDUs, and economizers.	Contact Efficiency Vermont regarding potential incentives for server and PC power management.	Data Centers & IT: http://www.efficiencyvermont.com/pages/Business/SavingEnergy/DataCenters/ Commercial Rebates: http://efficiencyvermont.com/pages/Business/HVAC/
Server virtualization incentive available at $350 per server (10 server minimum)	1. Lighting measures 2. HVAC measures 3. UPS systems 4. Motors 5. Variable speed drives	PC power management incentive available at $10 per license (20 desktop minimum)	IT / Power: http://energytrust.org/business/incentives/Hospitality/equipment-upgrades/Software/it-power/ Business Program: http://energytrust.org/business/
N/A (custom incentives may be available)	1. Lighting measures 2. HVAC measures 3. Motors	Network Control of PC Power Management offered at $10 per workstation. $50 incentive available for replacing desktop CPU with laptop and docking station.	Miscellaneous Equipment Catalog 2010: http://www.eweb.org/public/documents/energy/MiscellaneousEquipmentCatalogWebsite.pdf Business Program: http://www.eweb.org/saveenergy/business

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)
N/A (custom incentives may be available)	1. Lighting measures 2. HVAC measures 3. Motors 4. Variable speed drives	$10 incentive for ENERGY STAR® PC or 80 Plus® PC server. $5 incentive for 80 Plus PC desktop.	Easy Upgrade Program: http://www.idahopower.com/EnergyEfficiency/Business/Programs/EasyUpgrades/default.cfm Custom Efficiency Program: http://www.idahopower.com/EnergyEfficiency/Business/Programs/CustomEfficiency/default.cfm
N/A	Lighting measures are available.	Custom Performance Program offers $10 incentive per computer for the purchase of power management software and $15 for infrared and/or ultrasonic plug load occupancy sensors controlling a minimum of 50 watts (must control electric equipment in offices or cubicles or control shared copy machines and/or printers).	Custom Express Program: http://www.ladwp.com/ladwp/cms/ladwp012689.jsp Custom Performance Program: http://www.ladwp.com/ladwp/cms/ladwp008836.jsp
N/A (custom incentives may be available through the Performance-Based Initiatives)	1. Lighting measures 2. HVAC measures 3. Motors 4. Variable frequency drives 5. Chillers	N/A (custom incentives may be available through the Performance-Based Initiatives)	Flex Tech program: http://www.nyserda.org/programs/flextech.asp Existing Facilities Program: http://www.nyserda.org/programs/Existing_Facilities/default.html

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)
Incentives for server consolidation are available.	1. UPS systems 2. Controls 3. Cooling optimization 4. CRACs	N/A	Jay Brummett is the program contact: 214.274.8092 – cell jay.brummett@gmail.com. The Oncor program website is in development.
Incentive of $200 per server removed for virtualization project.	1. Lighting measures 2. HVAC measures 3. Variable frequency drives (custom only) 4. Chillers (custom only) 5. UPS (custom only) 6. CRACs (for large data centers through Data Center Cooling Control Program)	$15 incentive per PC for power management software. $15 incentive for passive infrared and/or ultrasonic plug load occupancy sensors (must control electricity using equipment in offices or cubicles, including shared copiers and/or printers). Other offerings available for efficient computers, servers, LCD monitors, and thin client systems.	High Tech Information: http://www.pge.com/mybusiness/energysavingsrebates/incentivesbyindustry/hightech/relatedinfo/ Business Computing: http://www.pge.com/includes/docs/pdfs/mybusiness/energysavingsrebates/incentivesbyindustry/businesscomputing_final.pdf Customized Retrofit Incentives: http://www.pge.com/mybusiness/energysavingsrebates/rebatesincentives/ief/
N/A (custom grant incentives may be available)	1. Lighting measures 2. HVAC measures 3. Motors 4. Variable speed drives 5. Building envelope	$8 rebate for PC power management software.	Business Energy Management: http://www.pse.com/SiteCollectionDocuments/business/4355.pdf Commercial Rebates and Grants: http://www.pse.com/solutions/forbusiness/Pages/efficiencyComPrograms.aspx

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)
N/A (custom virtualization incentives available to cover up to $150,000 or 20% of project cost)	1. Lighting measures 2. HVAC measures 3. Motors (custom) 4. Variable speed drives (custom) 5. Data center cooling optimization incentives (custom - up to $50,000 or 20% or cost)	$7.50 incentive per installed license for PC power management software (must automatically control the power settings of networked personal computersat the server level). $16.50 incentive for infrared and/or ultrasonic plug load occupancy sensors (must control minimum of 50 watts and must control electric equipment in offices or cubicles or control shared copy machines and/or printers).	Business Rebates and Incentives: http://www.smud.org/en/business/rebates/Pages/index.aspx
N/A (Custom high tech rebates for server virtualization are available. Custom business incentives pay $0.09 per kWh, and Energy Savings Bid pays $0.10 per kWh.)	1. Lighting measures 2. Motors 3. Variable frequency drives	$15 incentive per desktop computer for network power management software. $15 incentive for plug load occupancy sensor.	Energy Efficiency Business Rebates: http://www.sdge.com/business/rebatesincentives/programs/energyEfficiency.shtml High Tech Rebates: http://www.sdge.com/business/rebatesincentives/programs/highTech.shtml
N/A (custom funding may be available through Incentives for Existing Buildings offering)	1. Lighting measures 2. HVAC measures 3. Chillers 4. Motors 5. Variable frequency drives	$8 rebate for PC power management software.	Rebates for PC Power Management: http://www.snopud.com/business/bizrebates/cipcpm.ashx?p=1130 Incentives for Existing Buildings: http://www.snopud.com/business/ciincent/ciretrofit.ashx?p=1576

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)
N/A	1. Lighting measures 2. HVAC measures 3. Motors 4. Variable frequency drives	$8 rebate per computer for PC power management software.	PC Power Management Rebates: http://www.mytpu.org/tacomapower/conserve-energy/conserve-in-your/equipment-rebates/office.htm Business Incentives: http://www.mytpu.org/tacomapower/conserve-energy/conserve-in-your/Default.htm
$250 incentive per server removed for virtualization project.	1. Lighting measures 2. HVAC measures 3. Chillers 4. Variable frequency drives	$6 incentive per PC for installation of energy management software up to 50% of project cost. $60 per PC removed under thin client conversion pilot program up to 50% of cost.	PC Network Energy Management: http://www.focusonenergy.com/Business/Commercial-Business/desktop.aspx Business Incentives: http://www.focusonenergy.com/Incentives/Business/
$400 rebate offered for implementation of measures recommended through efficiency study.	$400 rebate offered for implementation of measures recommended through efficiency study. General commercial incentives are also available for lighting, HVAC, chillers, motors, and variable frequency drives.	N/A (custom incentives available for office equipment)	Data Center Efficiency: http://xcelenergy.com/Colorado/BUSINESS/PROGRAMS_RESOURCES/CONSERVATIONREBATES_INCENTIVES_BUSINESS/Pages/DataCenterEfficiency.aspx
$400 rebate offered for implementation of measures recommended through efficiency study.	$400 rebate offered for implementation of measures recommended through efficiency study. General commercial incentives are also available for lighting, HVAC, chillers, motors, and variable frequency drives.	N/A (custom incentives available for office equipment)	Data Center Efficiency: http://xcelenergy.com/Minnesota/BUSINESS/PROGRAMS_RESOURCES/CONSERVATIONREBATES_INCENTIVES_BUSINESS/Pages/DataCenterEfficiency.aspx

Prescriptive IT Measure Support (Servers, Storage)	Prescriptive Facilities Measure Support (CRACs, Chillers, UPS, Power Distribution, etc.)	Prescriptive Computing Support	Program Website(s)

Building Commissioning:

A Golden Opportunity for Reducing Energy Costs and Greenhouse Gas Emissions

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Public Interest Energy Research (PIER)

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http://cx.lbl.gov/2009-assessment.html

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A number of individuals exerted considerable effort on gathering and tabulating data used in this study or augmenting previously published information. They include John Bynum (TAMU), Michael Anderson and Anna Levitt (Newcomb Anderson McCormick), Narendra Amarnani (County of Los Angeles), Eliot Crowe and Emilia Sibley (PECI), Geoffrey Bell and Steve "Futzmeister" Greenberg (LBNL), Jim Bradford (Nexant), Len Beyea (RetroCom Energy Strategies), Kimberlie Lenihan and Natasha Malik (NYSERDA), David McIntosh (Connecticut Power & Light), Margot Rode (Architectural Energy Corporation), and David Sellers (Facility Dynamics).

The following individuals provided data for the 2004 study (which remains part of our analysis): Edward Allen and David Jump (Quantum Consulting), Adam Benzuly (Affiliated Engineers, Inc.), Daren Goody (PECI), Martha Hewett (Minnesota Center for Energy and Environment), John Jennings (Northwest Energy Efficiency Alliance), Bing Tso (SBW Consulting), Jeffrey Warner (LBNL), and Phoebe Caner Warren (Seattle City Light).

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Contents

Executive Summary

The aim of commissioning new buildings is to ensure that they deliver, if not exceed, the performance and energy savings promised by their design. When applied to existing buildings, commissioning identifies the almost inevitable "drift" from where things should be and puts the building back on course. In both contexts, commissioning is a systematic, forensic approach to quality assurance, rather than a technology per se. Although commissioning has earned increased recognition in recent years—even a toehold in Wikipedia—it remains an enigmatic practice whose visibility severely lags its potential.

Over the past decade, Lawrence Berkeley National Laboratory has built the world's largest compilation and meta-analysis of commissioning experience in commercial buildings. Since our last report (Mills et al. 2004) the database has grown from 224 to 643 buildings (all located in the United States, and spanning 26 states), from 30 to 100 million square feet of floorspace, and from $17 million to $43 million in commissioning expenditures. The recorded cases of new-construction commissioning took place in buildings representing $2.2 billion in total construction costs (up from 1.5 billion). The work of many more commissioning providers (18 versus 37) is represented in this study, as is more evidence of energy and peak-power savings as well as cost-effectiveness. We now translate these impacts into avoided greenhouse gases and provide new indicators of cost-effectiveness. We also draw attention to the specific challenges and opportunities for high-tech facilities such as labs, cleanrooms, data centers, and healthcare facilities.

The results are compelling. We developed an array of benchmarks for characterizing project performance and cost-effectiveness. The median normalized cost to deliver commissioning was \$0.30/ft^2 for existing buildings and \$1.16/ft^2 for new construction (or 0.4% of the overall construction cost). The commissioning projects for which data are available revealed over 10,000 energy-related problems, resulting in 16% median *whole-building* energy savings in existing buildings and 13% in new construction, with payback time of 1.1 years and 4.2 years, respectively. In terms of other cost-benefit indicators, median benefit-cost ratios of 4.5 and 1.1, and cash-on-cash returns of 91% and 23% were attained for existing and new buildings, respectively. High-tech buildings were particularly cost-effective, and saved higher amounts of energy due to their energy-intensiveness. Projects with a comprehensive approach to commissioning attained nearly twice the overall median level of savings and five-times the savings of the least-thorough projects

It is noteworthy that virtually all existing building projects were cost-effective by each metric (0.4 years for the upper quartile and 2.4 years for the lower quartile), as were the majority of new-construction projects (1.5 years and 10.8 years, respectively). We also found high cost-effectiveness for each specific measure for which we have data. Contrary to a common perception, cost-effectiveness is often achieved even in smaller buildings.

Thanks to energy savings valued more than the cost of the commissioning process, associated reductions in greenhouse gas emissions come at "negative" cost. In fact, the median cost of conserved carbon is *negative*— -$110 per tonne for existing buildings and -$25/tonne for new construction—as compared with market prices for carbon trading and offsets in the +$10 to +$30/tonne range.

Further enhancing the value of commissioning, its non-energy benefits surpass those of most other energy-management practices. Significant first-cost savings (e.g., through right-sizing of heating and cooling equipment) routinely offset at least a portion of commissioning costs—fully in some cases. When accounting for these benefits, the net median commissioning project cost was reduced by 49% on average, while in many cases they exceeded the direct value of the energy savings. Commissioning also improves worker comfort, mitigates indoor air quality problems, increases the competence of in-house staff, plus a host of other non-energy benefits.

These findings demonstrate that commissioning is arguably the single-most cost-effective strategy for reducing energy, costs, and greenhouse gas emissions in buildings today. Energy savings tend to persist well over at least a 3- to 5-year timeframe, but data over longer time horizons are not available. It is thus important to "Trust but Verify," and indeed the field is moving towards a monitoring-based paradigm in which instrumentation is used not only to confirm savings, but to identify opportunities that would otherwise go undetected. On balance, we view the findings here as conservative, in the sense that they likely underestimate the actual performance of projects when all costs and benefits are considered. They certainly underestimate the technical potential for a scenario in which best practices are applied.

Applying our median whole-building energy-savings value (i.e. not best practices) to the stock of U.S. non-residential buildings corresponds to an annual energy-savings potential of $30 billion by the year 2030, which in turn corresponds to annual greenhouse gas emissions of about 340 megatons of CO_2 each year. The commissioning field is evolving rapidly. The delivery of services must be scaled up radically if the benefits are to be captured.

The fledgling existing-buildings commissioning industry has reached a size of about $200 million per year in the United States. Based on a goal of commissioning each building every five years, the potential size is about $4 billion per year, or 20-times the current number. To achieve the goal of keeping the U.S. building stock commissioned would require an increase in the workforce from about 1,500 to 25,000 full-time-equivalent workers, a realistic number when viewed in the context of the existing workforce of related trades.

Commissioning is more than "just another energy-saving measure." It is a risk-management strategy that should be integral to any systematic approach to garnering energy savings or emissions reductions. Commissioning ensures that a building owners get what they pay for when constructing or retrofitting buildings, it provides insurance for policymakers and program managers that their initiatives actually meet targets, and it detects and corrects problems that would eventually surface as far more costly maintenance or safety issues.

Commissioning is an underutilized strategy for saving energy and money and reducing greenhouse gas emissions while managing related risks. Reasons for this underutilization include a widespread lack of awareness of need and value on the part of prospective customers, insufficient professionalism within the trades, splintered activities and competition among a growing number of trade groups and certification programs, a misperception that it is not cost-effective in smaller buildings, the absence of commissioning-like requirements in most building codes, and omission or obfuscation of the strategy in most energy-efficiency potentials studies. It is important to strike a healthy balance between standardization and recognition that each building is unique and must be approached with an open mind.

"Commissioning America" in a decade is an ambitious goal, but "do-able" and very consistent with this country's aspirations to simultaneously address energy and environmental issues while creating jobs and stimulating economic activity.

Commissioning: The Stealth Energy-Saving Strategy

Walk into almost any home-improvement store today and be met by aisles brimming with compact fluorescent lamps. Climb atop a green building and behold a vegetated roof. Energy efficiency is all of a sudden commonplace with iconic imagery, or at least more so than it was just a few years ago. Yet, an equally important pathway to energy savings and greenhouse gas emissions reductions is virtually invisible to the typical building occupant, and too often even to the operators: the *commissioning* of new buildings and *retrocommissioning* of existing ones.[1]

For centuries, ship builders have "commissioned" vessels to ensure that they are ready for service; a risk-management process that includes installation and testing of equipment and ensuring that problems are corrected and the crew trained to maintain performance (Haasl and Heinemeier 2006a). After initial commissioning, ships are routinely inspected and serviced ("retrocommissioned") to maintain their performance. In this sense, people even routinely commission (inspect/service) their cars. Early forms of commissioning in buildings date to the 1950s in Europe, but arguably did not appear in the United States for several more decades (NEMI 2001). The commissioning of buildings for energy savings transitioned from being the subject of research projects in the 1980s, to a constellation of one-off pilot projects among a small vanguard of top-flight engineers in the 1990s, to ambitious scale-up efforts today.

The translation of this concept to buildings encompasses issues as diverse as access, safety, mechanical, landscaping, acoustics, water use, indoor air quality, and energy performance. This report focuses on commissioning as it pertains to energy performance in buildings, although other themes (particularly indoor environment) are often intertwined. While commissioning may seem like something that would be "standard practice" (and many building owners erroneously assume that it is), buildings are *rarely* commissioned, especially for energy savings. As a result, buildings are riddled with problems (Figure 1).

This situation is changing, albeit slowly. Commissioning is today used to save energy in ordinary buildings where no particular effort has previously been made to utilize energy-efficiency strategies, or to ensure and maximize performance of targeted energy-efficiency measures. The results are highly impressive. Case studies of large-scale commissioning efforts show attractive energy savings and payback times (Table 1).

[1] Complicating an already difficult value proposition, the commissioning field is littered with competing terminology, naming systems, and proprietary marks. To avoid clutter, when discussing the topic we simply use the term "commissioning." If the reference is solely to new or existing buildings and that is not clear by the context, then we add clarifying language.

Figure 1. *Hall of shame – Visible evidence of problems addressed by commissioning*

Hot water valve motion impeded by piping layout [EMC no date (a)]

Damage to brick façade of pool building due to lack of proper sealing and air management [Martha Hewet, Minnesota Center for Energy and Environment (MNCEE)]

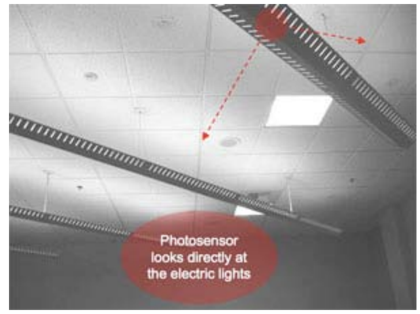
Inadequate fan cooling and excessive fan power due to poor fit between the light fixture and ducting, causing significant duct leakage [Martha Hewett, MNCEE]

Building envelope moisture entry [Aldous 2008]

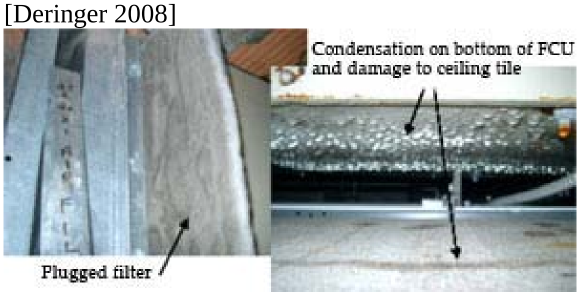
Rust indicates poor anti-condensation heating control setpoints in supermarket refrigeration cabinet [Sellers and Zazzara 2004]

Building envelope moisture entry [Aldous 2008]

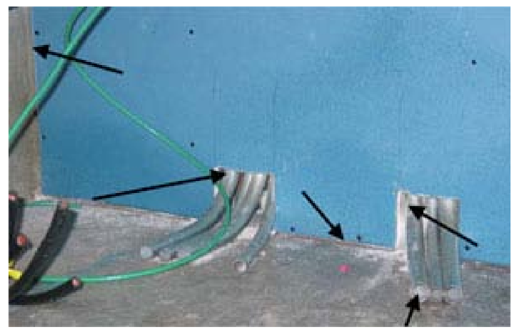
Photosensor (for daylight harvesting) shaded by duct [Deringer 2008]



Photosensor “sees” the electric lamps rather than task-plane illumination [Deringer 2008]



Plugged filter causing condensation on bottom of fan coil unit and damage to insulation coil resulting in poor air flow [Martha Hewett, MNCEE]



Air leakage in an underfloor air-distribution system [Stum 2008]

Zone damper actuator arm broken (no temperature control) [Martha Hewett, MNCEE]

Failed window film treatment.

Active humidification downstream of a condensing cooling coil at cleanroom facility [Sellers no date]

Exhaust fan hardwired in an “always on” position [Mittal and Hammond 2008]

Table 1. Examples of existing-building commissioning project costs and savings.

Target	Location	Sites	Energy Savings	Peak Demand savings	RCx Cost ($/sf)	Payback time (years)*	Source
Local government buildings	California	11 sites; 1.5 MSf	14.3% source energy (11% electric; 34% gas)		1.01	3.5	Amaranani et al (2005); Amarani and Roberts (2006); Pierce and Amarani (2006)
Offices and hotels	New York	6 sites; 6 MSft		10%	0.34	2.0	Lenihan (2007) - projected
Offices	Connecticut	5 buildings; 2 MSf	8.5% electricity (3% to 20%)			0.5	Building Operating Management (2006)
Class A Offices	Connecticut	3 bldgs; 1.2 MSF	7.3% electric		0.62	1.37	McIntosh (2008)
Mixed comercial	Colorado	27 buildings; 10 MSf	7% elect	4.2% (0-26%)	0.185	1.51	Franconi et al. (2005)
Three offices + hospital	Colorado	4 buildings; 1.8 MSf		6%	0.026	0.38	Mueller et al. (2004)
University buildings	California	26 buildings; 3.4 MSf	10% total source (2-25%)	4% (3-11%)	1.00	2.5	Mills & Matthew (2009)
Elementary schools	Michigan	4 schools			0.38	2.5	Freidman (2004)
Supermarkets	Central California	10 stores; 0.5 MSf	12.1% elect (4.3-18.3%)		0.14	0.25	Zazzara and Ward (2004); Emerson (2004)
Mixed commercial	Northwest	8 buildings			0.221	3.2	Tso et al (2003)
Mixed commercial	Oregon	76 projects	10-15% electric (5%-40%)		0.175	1.24	Peterson (2004)
Mixed commercial and educational	California	All California Programs (2007-2008)	1.7-8.1% electric		0.40	3.0	PECI and Summit Building Engineers (2007) - estimates
Total or simple average values		**186**	**~10-15%**	**~7%**	**0.41**	**1.8**	

Notes: All impacts shown using local energy prices and commissioning costs; averages are floor-area-weighted averages.

Commissioning is one of the most potent and yet least understood strategies for managing energy use, costs, and associated greenhouse gas emissions in the buildings sector. Emblematic of the problem, commissioning is rarely if ever explicitly included in energy-efficiency-potential studies. An encouraging sign of the gradual mainstreaming of commissioning is the appearance of an article on the topic in Wikipedia in 2008.[2]

An industry survey in 2005 estimated that well-below 5% of existing buildings and as much as 38% of "commissionable"[3] new construction had been commissioned (NEMI 2005). An earlier survey in California estimated that 0.03% of existing buildings and 5% of new construction had been commissioned (PECI 2000). The former survey probably addressed all types of commissioning, whereas the latter focused on energy issues.

There is no national census defining how many buildings are candidates for commissioning, but practitioners say they are hard-pressed to find buildings that would not benefit from the practice. The National Oceanic and Atmospheric Administration (NOAA) stated that 88 of its 122 weather-forecasting data centers are in need of commissioning, and had completed 47 of these by 2004 (Lundstrom 2004).

[2] See http://en.wikipedia.org/wiki/Building_commissioning

[3] The definition used here appears to be broader than just energy-driven commissioning, e.g., including safety systems. The share of buildings retrocommissioned for energy savings as thoroughly as many of those documented in this report could be lower by a factor of ten. The study assumes that one-third of all new construction (21% in the "commercial" sector, 25% multifamily, 34% industrial, and 54% institutional) is commissionable. The basis for this assumption is not clear, and, in this author's opinion the share could be far higher.

The commissioning practitioner community recognizes that market uptake has been slow. This is attributed to lack of understanding about what commissioning is and why it is needed, combined with a lack of a financial business case (*Cx Journal* 2005). Commissioning is most widely practiced in public buildings.

In addition to lack of awareness, commissioning is also a "stealth" energy-saving strategy in the sense that the deficiencies it corrects are almost always invisible to the casual observer, and unfortunately also to building designers, operators, and owners. Contributing to this state of affairs, these problems often do not present noticible symptoms such as occupant discomfort or noise (although in some cases these are indeed important clues and corresponding "non-energy" benefits of the fixes).

Momentum for commissioning is increasing. The impetus is coming from energy and environmental policymakers and the private sector, and is increasingly resonating with building owners' interest in greening their properties. Commissioning is required for buildings seeking the increasingly popular LEED (Leadership in Energy and Environment Design) rating, and building code officials (Kunkle 2005; Gowri 2009) are gradually studying and adopting mandatory commissioning or "commissioning-like" requirements. State-level initiatives such as California's Green Building Action plan are also promoting the practice. Meanwhile, in the private sector, energy utilities are rolling out increasingly ambitious incentive programs for commissioning, with at least 12 such programs currently in place (Criscione 2008). In one example, as of March 2008 the Southern California Edison commissioning program had secured 83 projects representing 25.5 million square feet of floorspace (Long and Crowe 2008a). Xcel Energy had a similar target in Colorado as of 2005 (Franconi et al. 2005). Other industries are also getting involved, notably insurance companies who are viewing commissioning as a risk-management strategy, and tailoring their insurance products and terms to encourage and reward it (Mills 2009a).

Commissioning is still far from mainstream. The untapped potential is huge. In 2004, Lawrence Berkeley National Laboratory estimated $18 billion per year of potential savings from commissioning throughout the United States (Mills et al. 2004). Analysis of a study published a year later suggests a potential savings for the top 13 (of 100) typical commercial buildings faults alone at $3.3–$17 billion per year (Table 2). As will be shown in the following pages, the potential is considerably higher today.

Table 2. Top faults causing energy inefficiencies in commercial buildings (top 13 of 100+).

	National Energy Waste (Quads, primary/year)	Electricity equivalent (BkWh/year)	Cost ($billion/year)
Duct leakage	0.3	28.6	2.9
HVAC left on when space unoccupied	0.2	19.0	1.9
Lights left on when space unoccupied	0.18	17.1	1.7
Airflow not balanced	0.07	6.7	0.7
Improper refrigerant charge	0.07	6.7	0.7
Dampers not working properly	0.055	5.2	0.5
Insufficient evaporator airflow	0.035	3.3	0.3
Improper controls setup / commissioning	0.023	2.2	0.2
Control component failure or degradation	0.023	2.2	0.2
Software programming errors	0.012	1.1	0.1
Improper controls hardware installation	0.01	1.0	0.1
Air-cooled condenser fouling	0.008	0.8	0.1
Valve leakage	0.007	0.7	0.1
Total (central estimate)	1.0	94.6	9.6
Total (range)	0.34-1.8	32.4-171.4	3.3-17.3

Adapted from Roth et al. (2005) assuming 10,500 BTU/kWh, and $0.10/kWh

What Commissioning Is (and Is Not)

Despite its 30-year history in the United States,[4] and hundreds of millions of square feet of floor area commissioned, most mainstream industry professionals would be hard-pressed to define building commissioning. A vanishingly small fraction of building owners/managers know what it is. Even efforts to explain it can leave many a listener mystified.

At the highest level, building commissioning brings a holistic perspective to design, construction, and operation that integrates and enhances traditionally separate functions. It does so through a meticulous "forensic" review of a building's disposition to identify suboptimal situations or malfunctions and the associated opportunities for energy savings.

The California Commissioning Collaborative has laid out plain-English definitions of the various forms of commissioning, which we quote verbatim in Box A (Haasl and Heinemeier 2006a-b). As can be surmised from these definitions, commissioning is necessarily a team effort, and usually led by a specialist but including the traditional trades such as designers, engineers, contractors, onsite operations and maintenance staff, and, hopefully, building owners.

[4] A detailed historical timeline is provided here: http://www.peci.org/ncbc/cx_history.html

Box A. Commissioning Defined

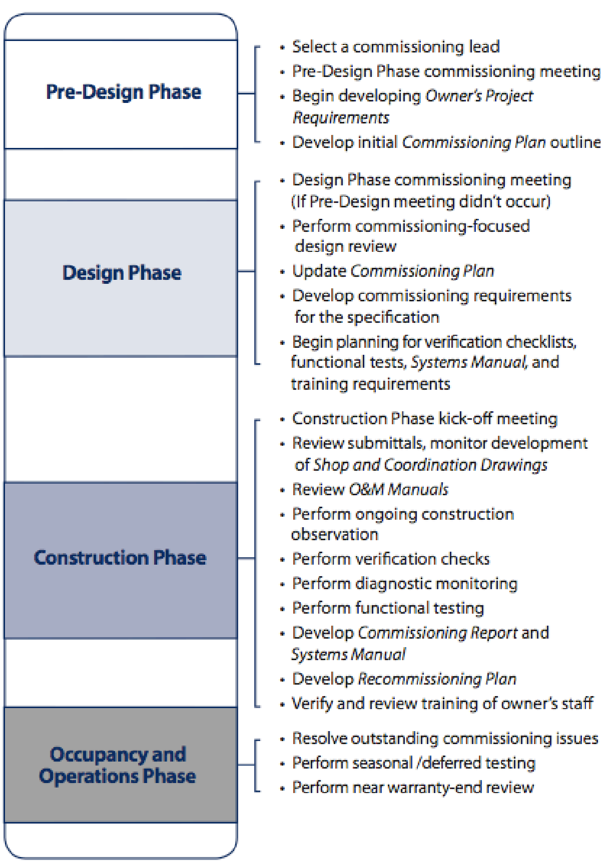
The term commissioning comes from shipbuilding. A commissioned ship is one deemed ready for service. Before being awarded this title, however, a ship must pass several milestones. Equipment is installed and tested, problems are identified and corrected, and the prospective crew is extensively trained. A commissioned ship is one whose materials, systems, and staff have successfully completed a thorough quality assurance process.

Building commissioning takes the same approach to new buildings. When a building is initially commissioned it undergoes an intensive quality assurance process that begins during design and continues through construction, occupancy, and operations. Commissioning ensures that the new building operates initially as the owner intended and that building staff are prepared to operate and maintain its systems and equipment.

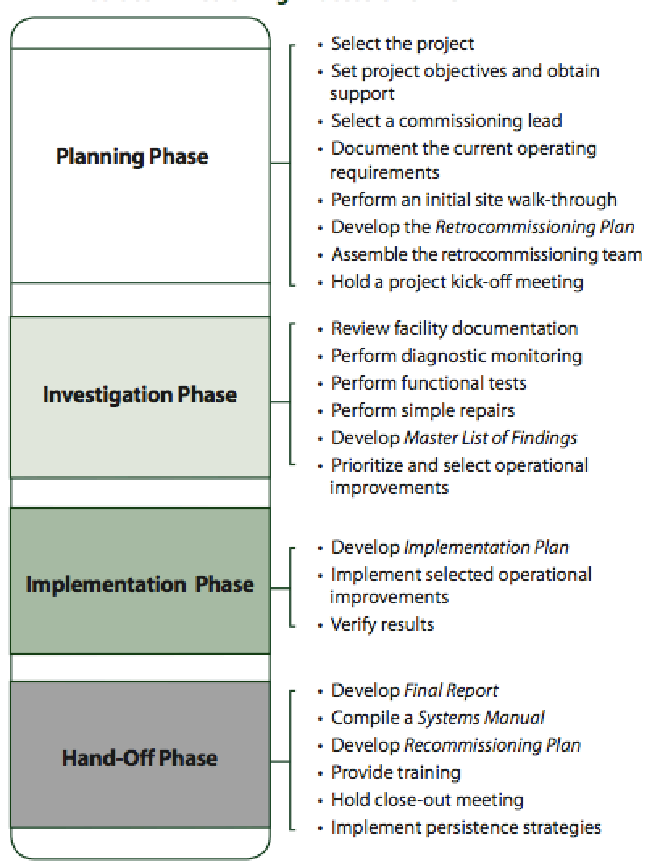
Retrocommissioning is the application of the commissioning process to existing buildings. Retrocommissioning is a process that seeks to improve how building equipment and systems function together. Depending on the age of the building, retrocommissioning can often resolve problems that occurred during design or construction, or address problems that have developed throughout the building's life. In all, retrocommissioning improves a building's operations and maintenance (O&M) procedures to enhance overall building performance.

Recommissioning is another type of commissioning that occurs when a building that has already been commissioned undergoes another commissioning process. The decision to recommission may be triggered by a change in building use or ownership, the onset of operational problems, or some other need. Ideally, a plan for recommissioning is established as part of a new building's original commissioning process or an existing building's retrocommissioning process.

Commissioning Process Overview



Retrocommissioning Process Overview

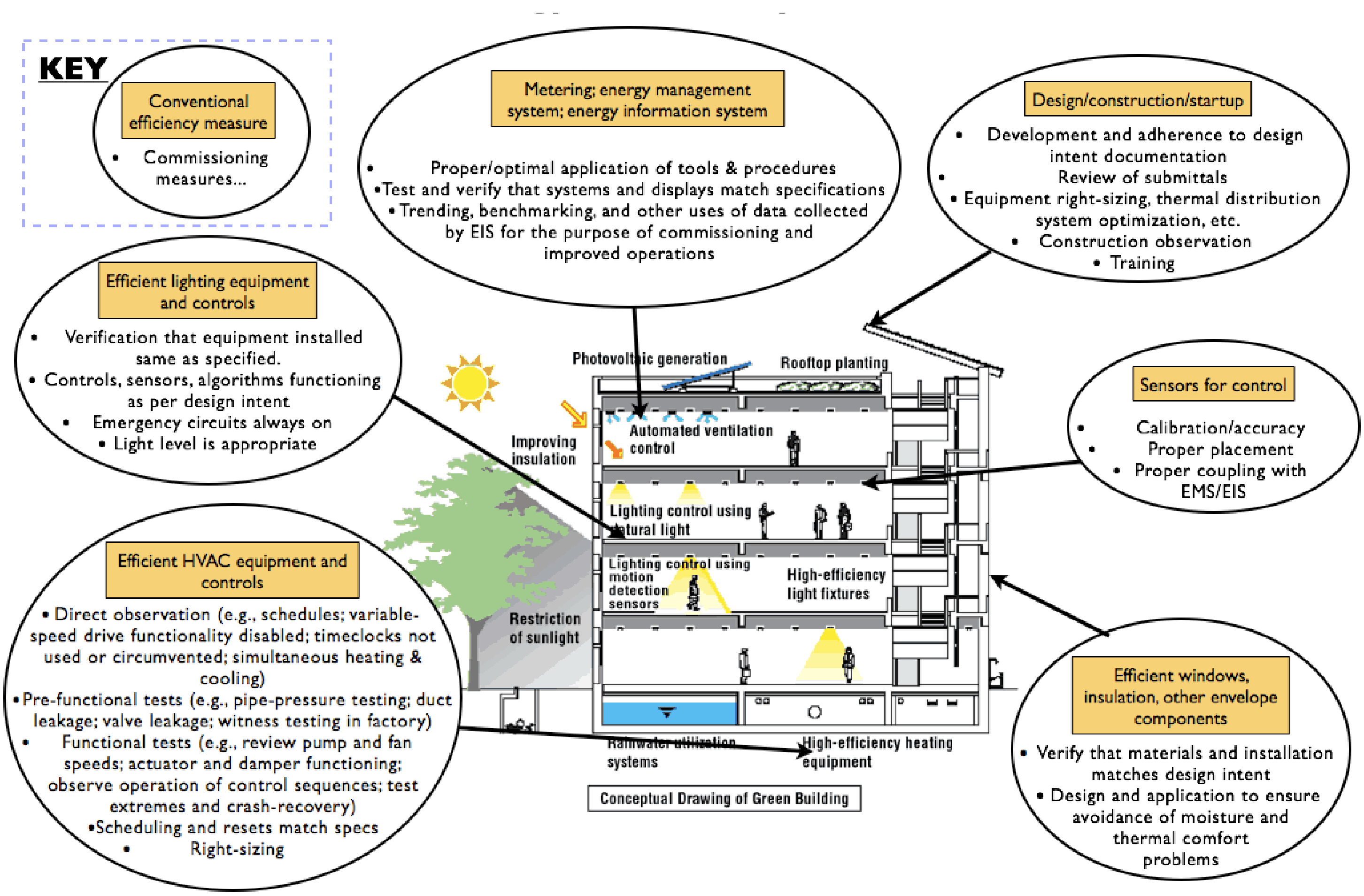


CSI for Energy Efficiency – Commissioning as Forensics

Unlike an efficient light bulb, commissioning is not a "commodity" product (or process). Each building is unique and presents unique problems for unique owners. Aspiration and budget can also vary; commissioning is performed at widely varying levels of effort and applied buildings as a whole (preferred) or to a specific sub-system or energy end-use.

Commissioning thus differs fundamentally from constructing or retrofitting facilities with better energy-using equipment (Figure 2). Commissioning complements these relatively familiar practices by ensuring and maintaining building energy performance (and other benfits, such as indoor environmental qulaity). On the same token, it can simply focus on saving energy by improving conventional building systems, irrespective of whether or not the building is equipped to be particularly energy efficient.

Figure 2. *Illustrative relationships between commissioning and energy-efficiency measures*



Commissioning improves on design and execution in new construction, or "tunes" the existing system (the metaphor to diagnosing and tuning a car is a loose but useful analogy). The costs of commissioning are thus largely time and labor, as opposed to materials or capital equipment. Persistence of the corrections (and associated energy savings) tends to be a concern, as many commissioning measures are operational and thus easily reversed if not monitored.

While the focus includes individual pieces of energy-using equipment, it is also a decidedly wholistic approach emphasizing the connections between components into systems.[5] Thus, "softer" elements are addressed, such as control logic or even the effectiveness of computer user interfaces or other communication systems used to visualize the building's disposition and energy use trends and make design and design intent unambiguous (Pollard 2009). Commissioning also differs from other energy-savings strategies in that it does not accept what is in a building (or design) as optimal (or even necessary), but, rather, asks fundamental questions such as "is that pump needed?" as opposed to "can we make that pump more efficient?"

While commissioning is not a panacea for the world's energy and climate problems, it is an element of a best-practices approach to achieving quality and high performance, while managing information and energy use throughout a building's lifecycle.

Commissioning as Risk Management

The world has become a riskier place, and buildings are no exception. With the enthusiasm and naivete about energy efficiency in the 1970s and 1980s, it was easy to assume that energy savings could be estimated with simple slide-rule methods and that promised energy savings would always materialize. Many studies and estimates of savings potential still assume that everthing works perfectly, an implicit inference that commissioning is universally applied (when in fact it rarely is).

The case of a data center provides a good illustration of these risks (Nodal 2008). Engineering calculations led the team to believe that electricity savings of 14.3% were being attained by a retrofit project. On closer inspection the savings were found to be exactly zero. Subsequent commissioning of the facility unearthed the causes of the lost savings, and not only restored them but boosted them to 19.2% (and 26% for peak demand).

Buildings are increasingly more complex than meets the eye, and many factors must fall into place (and stay there) in order for energy savings to manifest. And the consequences of underattainment are increasing as projects are structured such that energy-savings streams service the debt incurred to finance the efficient technologies, greenhouse gas reductions credited to energy efficiency are taken to markets with the desire that they be converted to "offsets" and then money, and regulators strengthen their oversight. Meanwhile, new technologies for saving energy have an intrinsic degree of risk simply

[5] There is an enormous literature on commissioning practices and case studies. Beyea (2009) provides very thorough review of the kinds of issues discovered and remedied during commissioning.

due to the lack of field experience and because some are more complex than the traditional technologies they replace.

As green buildings become a more significant part of the building stock, the insurance industry has been reasonably supportive of (Mills 2009a), but it is also very focused on changing "risk profiles." Reports from the world's largest brokers Marsh (2008) and Aon (Taylor 2008) encourage the practice, but also site concerns about issues ranging from unfulfilled energy warranties, to business interruptions, to liabilities posed by exotic materials and equipment that do not have the same track record as (less efficient) standard practices.

Jump (2007) notes that commissioning itself is vulnerable to similar risks if performance disappoints or if measurement and verification is inadequate:

- Risks to Owner:
    - Savings not delivered, no return on investment
    - No ability to track actual savings
    - Savings do not last, especially for "soft" measures that can be and often are defeated
- Risks to Energy-Efficiency Programs:
    - Claimed savings do not stand up to third-party review
    - Savings lifetimes are short
    - Negative impact on program realization rates
- Risk to Regulatory Agencies
    - Unreliable basis for program planning and accurate forecasting

As discussed later in this report, commissioning approaches that incorporate in-depth monitoring and verification can offer significantly enhanced risk-management benefits. The commissioning provider for one such project noted that:

> [Typical] savings are based on estimates, and rarely verified. In the long run, this can lead to problems with the perception of RCx [retrocommissioning] projects and programs. Monitoring-based commissioning programs provide the opportunity to develop tools to monitor and track savings, and notify operators when savings diminish. …[P]rojects … with the added metering and analysis, remain cost-effective, and provide added benefits of rigorous savings verification, energy tracking, diagnostic capabilities, and long-term persistence tracking. This provides added security for owners, energy efficiency program implementers, and their regulatory agencies, that the savings are real and last over time. (Jump et al. 2007).

Irrespective of the degree of monitoring and verification, to not commission at all is to invite a multitude of risks and underattainment of goals. It can be argued that commissioning is an essential risk-management component of any policy or program that aspires to attain a specific level of energy savings. Some have attempted to quantitatively define the relevant risks to formalize the process of targeting commissioning activities (Berner et al. 2006).

As will be demonstrated below, commissioning is also a tool for managing non-energy risks. Indeed, prevention of indoor-air-quality problems, premature equipment failure, and litigation are among the reasons commonly given for commissioning.

Quantifying Commissioning: A Meta-Analysis

There is a growing literature on commissioning, including large numbers of disparate case studies. Many of these case studies present some form of information on the costs of commissioning and resulting energy savings in actual buildings. However, the underlying methods, assumptions, data completeness, and level of data quality vary widely and are not always revealed. The goal of this study is to prepare a "meta-analysis" of this body of experience in order to benchmark and chart the overall trends across a variety of geographies, building types, and other variables. This requires applying decision rules in determining which projects qualify for inclusion together with methods for normalizing and standardizing the data to facilitate benchmarking and inter-comparisions.[6]

As with any evaluation activity, data quality control and quality assurance are essential. Our experience with doing this firsthand with many of the projects in this compilation did reveal (and correct) dozens of issues with math errors, incorrect units, conversions, or underlying assumptions.[7]

Data Sources and Analysis Methods

We build on our original compilation published in 2004 (Mills et al. 2004), which contained information and analysis for 224 buildings. We subsequently released a call for more data to hundreds of stakeholders in the commissioning community, including practitioners. The response was meager. Real-world projects rarely have budget or a client able to pay for data collection, let alone preparation of publications. Proprietary considerations also keep certain data out of the public domain.

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[6] Engineering assumptions: Basic assumptions: Electricity heat rate 10,400 British thermal units per kilowatt-hour (BTU/kWh). Greenhouse gas emissions factors (in carbon dioxide emissions equivalent, i.e., including other major greenhouse gases): electricity (2.0331 pounds/kWh), natural gas (112.49 pounds per million BTUs). Economic assumptions: Costs normalized to 2009 price levels ("US$2009"). Energy prices per U.S. Department of Energy, Energy Information Administration (USDOE/EIA- averages 5/2008-4/2009): electricity ($0.1043/kWh, and $120/kW-month demand charge), natural gas ($12.32/MBTU), central hot water ($15.26/MBTU), central chilled water ($16.21/MBTU), central steam ($17.12/MBTU). Where savings by fuel are not available, we use nominal reported total cost savings, inflation-adjusted per the energy price deflator and weighted electricity/fuel price by the relative national consumption per DOE/EIA's 2003 Commercial Buildings Energy Consumption Survey, CBECS. Measure lifetime for cost-benefit analysis: five years. General inflation correction using gross domestic product deflators from the U.S. Department of Commerce. Building construction costs inflation-corrected using Engineering News Record (McGraw-Hill), Engineering News Record, Building Cost Index. Commissioning costs inflation corrected using Engineering News Record (McGraw-Hill) Skilled Labor, and total Construction Cost indices. More detailed documentation is provided at http://cx.lbl.gov/2009-assessment.html.

[7] Recommended quality assurance procedures are noted here: http://cx.lbl.gov/qa.html

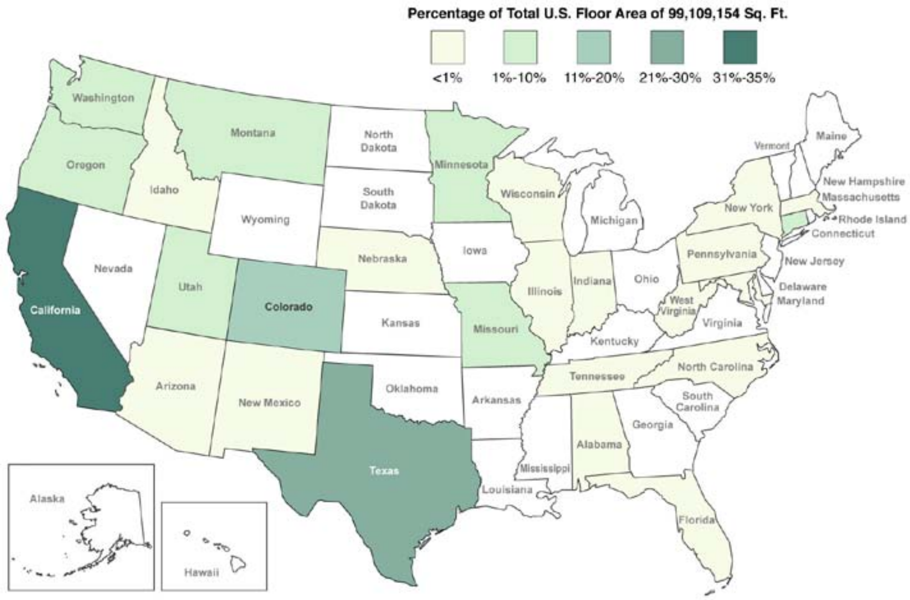
Several substantial cohorts of projects were ultimately recruited. We enlisted one large commissioning provider (Texas A&M University) to extract previously unpublished data from 63 prior projects around the country. Results from an evaluation of “monitoring-based commissioning” at 21 University of California and California State University sites were also migrated into the database (Mills and Mathew 2009). PECI provided data on 64 projects conducted under utility programs in California. Some projects from the original 2004 compilation were revisited, and missing information obtained, thereby upgrading that cohort of buildings.

We also combed the commissioning literature for individual or sets of candidate projects and obtained supplemental information by contacting authors, utility partners, or building owners. Many case studies we encountered did not qualify for inclusion. Many lacked critical information, such as the costs of commissioning or energy savings. Others included hypothetical savings from planned projects that had not yet been realized. Many included incomplete information, a common example of which is the fee paid to the commissioning provider but not the other costs incurred in-house or by other parties to deliver the complete commissioning service. In some cases retrofit costs and savings are mixed in with commissioning case studies, and we exclude these cases as well. For such projects, other useful data may still be available and included in the analysis (e.g., types of problems found or measures implemented).

To facilitate comparisions, the raw data are normalized to a standard U.S.-average commercial sector energy prices, and costs are inflation-corrected to 2009 levels. This is an important correction, as prevailing local energy prices for the projects in the database range from $0.02/kWh to $0.30/kWh for electricity and $0.62/MBTU to $10.22/MBTU for fuel. For energy use and savings data to be included, the data must be weather-normalized or based on engineering calculations indexed to standard weather conditions for the given location.

The resulting sample includes 332 commissioning projects in existing buildings and 77 in new-construction, spanning 26 states, representing a total of 643 buildings, 99 million square feet, and $43 million invested in the commissioning work (Figures 3 and 4).

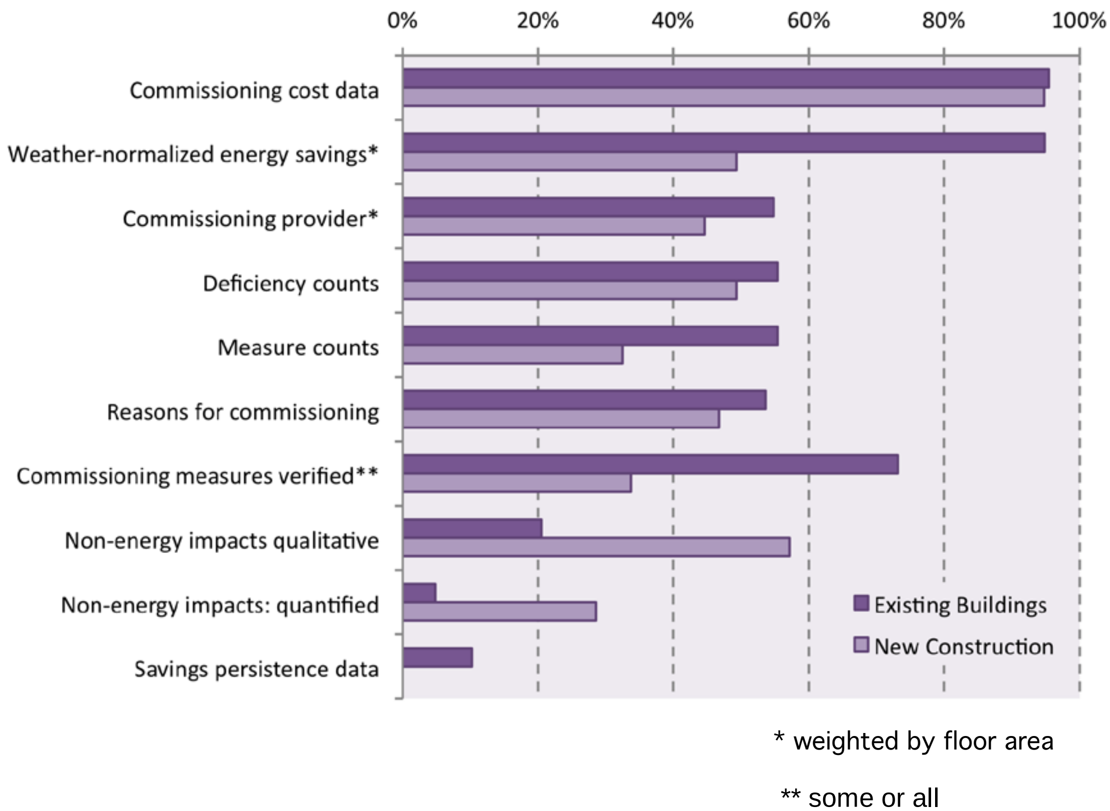
Figure 3. *Sample by location, type, and size (square feet)*



	Total	Existing	New Construction
Education			
K-12	3,123,754	2,467,661	656,093
Higher education	12,029,520	11,401,833	627,687
Food Sales	983,402	848,039	135,363
Food Service	187,724	187,724	-
Health Care			
Outpatient healthcare	4,525,424	4,319,124	206,300
High-tech Facilities	-	-	-
Cleanrooms	301,000	-	301,000
Data Center	12,888	12,888	-
Laboratory	6,526,658	4,561,593	1,965,065
Inpatient	7,478,988	6,791,029	687,959
Lodging	10,037,291	9,880,307	156,984
Mercantile			
Retail	2,926,038	2,926,038	-
Service	227,000	227,000	-
Office	40,867,062	39,972,765	894,296
Public Assembly	3,166,611	2,476,985	689,626
Public Order and Safety	4,756,949	2,485,277	2,271,672
Religious Worship	12,500	12,500	-
Warehouse and Storage	175,379	13,500	161,879
Industrial	475,000	475,000	-
Other	1,411,622	1,351,622	60,000
Vacant	-	-	-
Total	**99,224,809**	**90,410,884**	**8,813,925**

* Note in some cases floor area is apportioned among more than one building type.

Figure 4. *Sample depth.*



Our sample includes data representing 37 commissioning providers covering about half of the floor area in the database, with only 1% known to be done in-house. The provider is unknown for the balance of the projects (Table 3). It is unknown how many providers exist in the market. The California Commissioning Collaborative presently recognizes 53 providers across the country.8

[8] As of June 20, 2009. See http://www.cacx.org/resources/provider_list.html. Some providers in our study are not on this list.

Table 3. Commissioning providers in this study, by floor area.

	Existing Buildings (square feet)	%	New Construction (square feet)	%	Total	%
Abacus Engineered Systems, Inc.	95,405	0.1%	-	0.0%	95,405	0.1%
Affiliated Engineers, Inc.	-	0.0%	774,000	8.8%	774,000	0.8%
Architectural Energy Corporation	1,278,620	1.4%	230,000	2.6%	1,508,620	1.5%
Arup	176,000	0.2%	-	0.0%	176,000	0.2%
Casault Engineering	-	0.0%	170,566	1.9%	170,566	0.2%
CH2M Hill	-	0.0%	340,000	3.9%	340,000	0.3%
Cogent	1,900,200	2.1%	-	0.0%	1,900,200	1.9%
CTG Energetics	327,717	0.4%	-	0.0%	327,717	0.3%
Ecube	220,000	0.2%	-	0.0%	220,000	0.2%
EMC Engineers	1,506,188	1.7%	8,467	0.1%	1,514,655	1.5%
Energy Engineering & Design	490,000	0.5%	-	0.0%	490,000	0.5%
Environmental and Engineering Services, Inc.	-	0.0%	160,000	1.8%	160,000	0.2%
Facility Dynamics	1,014,133	1.1%	-	0.0%	1,014,133	1.0%
Facility Improvement Corporation	230,380	0.3%	-	0.0%	230,380	0.2%
Farnsworth Group	-	0.0%	767,176	8.7%	767,176	0.8%
HEC	376,500	0.4%	165,000	1.9%	541,500	0.5%
Henrikson	107,184	0.1%	-	0.0%	107,184	0.1%
Herzog/Wheeler	44,000	0.0%	-	0.0%	44,000	0.0%
Keithly/Welsch Associates Inc.	713,610	0.8%	173,000	2.0%	886,610	0.9%
MN Center for Energy and Environment	525,000	0.6%	-	0.0%	525,000	0.5%
Nexant	480,406	0.5%	-	0.0%	480,406	0.5%
Northwest Engineering Service, Inc.	213,000	0.2%	-	0.0%	213,000	0.2%
Notkin Engineering	-	0.0%	65,000	0.7%	65,000	0.1%
PECI	4,345,810	4.8%	371,000	4.2%	4,716,810	4.8%
Quantum Energy Services and Technologies, Inc. - QuEST	2,354,111	2.6%	-	0.0%	2,354,111	2.4%
RetroCom Energy Strategies	2,655,800	2.9%	-	0.0%	2,655,800	2.7%
Salas O'Brian	222,070	0.2%	-	0.0%	222,070	0.2%
Sebesta Blomberg	287,117	0.3%	-	0.0%	287,117	0.3%
Sieben Energy	623,000	0.7%	-	0.0%	623,000	0.6%
Solarc Architecture & Engineering	-	0.0%	96,500	1.1%	96,500	0.1%
Strategic Building Solutions	480,248	0.5%	-	0.0%	480,248	0.5%
Summit Building Engineering	90,712	0.1%	90,712	1.0%	181,424	0.2%
Systems West Engineers	172,400	0.2%	-	0.0%	172,400	0.2%
TAMU/ESL	26,429,206	29.2%	-	0.0%	26,429,206	26.6%
TESTCOMM, LLC	-	0.0%	195,390	2.2%	195,390	0.2%
UNL/ESL	675,885	0.7%	-	0.0%	675,885	0.7%
Van Zelm	765,064	0.8%	-	0.0%	765,064	0.8%
Western Montana Engineering	-	0.0%	23,300	0.3%	23,300	0.0%
Sub-total	48,799,766	54.0%	3,630,111	41.2%	52,429,877	52.8%
In-house	773,988	0.9%	301,000	3.4%	1,074,988	1.1%
Unknown	40,837,130	45.2%	4,882,814	55.4%	45,719,944	46.1%
Total	90,410,884	100%	8,813,925	100%	99,224,809	100%

Caveats and Conservatisms

The persistence of commissioning energy savings is perhaps the most significant caveat in analyses such as that presented in this report, although some concerns about the issue are ill-founded. Indeed, commissioning itself is needed largely *because* system performance does not persist. Commissioning can arguably increase the persistance of other energy measures (Pollard 2009). We acquired data on energy savings over multi-year periods following some of the projects, and this is summarized below. Negligible post-commissioning energy use/savings data have been collected for timeframes more than five years. However, the payback times we observe are within the likely period of savings persistence.

Some commissioning recommendations are implemented in "real time" by the commissioning provider. It cannot necessarily be assumed that all remaining commissioning recommendations are ultimately implemented by the building owner. Analytical and evaluation efforts can thus be complicated by the fact that measures may be implemented gradually, and the commissioning reports may be completed before the client has finished implementation. We endeavor to report savings from measures that are verified to have been installed, if the information is clear in the source materials. The distinction can be important, as shown in one study where the savings from measures that were identified, implemented, and then "verified" to have been implemented were about 30% lower than the savings "identified" for subsets of 63 buildings in Colorado (Franconi et al. 2005). In another more dramatic example, peak-demand savings of 112 kW were identified but only 3.5 kW captured (Mueller et al. 2004). In another example, the Southern California Edison (SCE) program is reported to have captured 83% of the potential savings identified (Long and Crowe 2008). Conversely, ultimate outcomes can be better than anticipated, as was seen in the University of California/California State University (UC/CSU) Monitoring-Based Commissioning program, where achieved savings routinely exceeded projected savings (Mills and Mathew 2009). In our compilation, 230 of the existing-buildings projects and 22 of the new-construction projects had the implementation of some or all measures verified. In most of the remaining cases, information was not available on the status of implementation. Of those submissions providing detailed data on measures recommended during the commissioning process, only 2% were reported to have been rejected.

Perhaps the largest single undercounting of benefits is in the area of non-energy impacts. In many cases, the benefits are real, yet difficult (if not impossible) to quantify, e.g., in the case of improved indoor air quality. In most cases, no effort is made to quantify these benefits, and thus the overall benefits are understated.

Net commissioning costs can easily be overestimated because non-energy objectives (e.g., commissioning fire and safety systems) are frequently combined with the costs reported for commissioning projects. The level of documentation provided often provides no way to back these costs out of the calculation.

Also of importance, commissioning projects vary widely in their scope and ambition. Some projects are relatively comprehensive, while others may target only a single system (e.g., electrical heating, ventilating, and air conditioning (HVAC), but not lighting or other loads or fuels). Thus, energy savings attained are less than they might otherwise be with a more comprehensive approach. In some cases a commissioning program design can intrinsically limit the level of effort applied to achieving savings. In some of the California utility programs, budgets for investigation were fixed at $0.10 per square foot by the utility contracts, limiting the ability of commissioning providers to identify savings opportunities (Crowe 2009). In the UC/CSU program, sites could qualify for incentives with relatively low projected savings, and there was no requirement to exceed those savings, although many sites did so (Mills and Mathew 2009).

In determining the percentage savings, we divide the reported savings by whole-building energy use, even if every system in the building has not been addressed in the commissioning process. In come cases, data on all fuels are not reported, meaning that some savings may be uncounted. Commissioning can easily spur downstream energy savings that would not be captured in analyses that follow shortly upon completion of the initial commissioning. Such savings could arise from the training that commissioning projects often provide, as well as those from improved maintenance procedures and energy data monitoring, benchmarking, and feedback that should be instituted during commissioning.

Every effort is made to isolate the commissioning costs associated with energy savings and associated non-energy benefits, but it is likely that there are cases where unrelated objectives (e.g., ensuring functionality of security systems) have been included. Similarly, we seek to exclude costs associated with traditional retrofit or maintenance, but reporting is no doubt imperfect in practice. These effects would tend to inflate the cost and savings used in our analysis. We believe that the level of undocumented retrofit is very minimal.

On balance, we view the findings here as on the "conservative" side in the sense that they likely underestimate the actual performance of projects when all costs and benefits are considered. They certainly underestimate the technical potential for best practices.

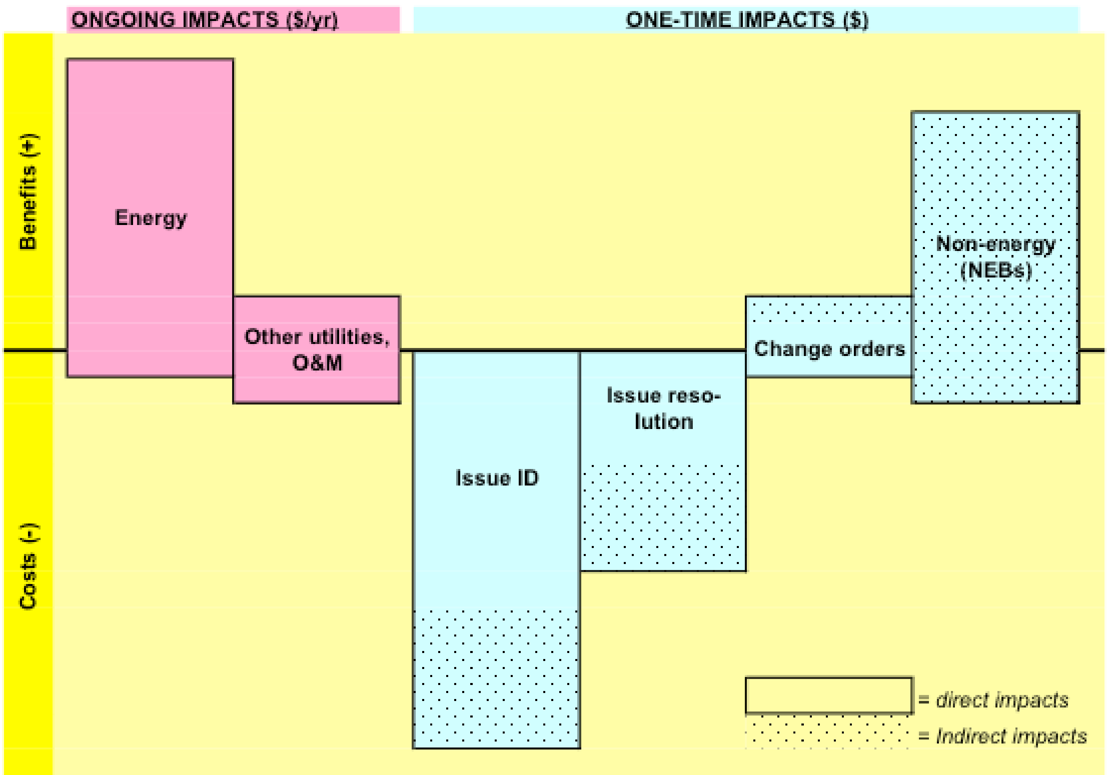
Commissioning Economics

The economic analysis of commissioning projects is arguably more complex than that applied to conventional energy-efficiency investments.

Commissioning can be said to have both costs and benefits (Figure 5). Benefits can include energy savings (although sometimes consumption increases when problems are fixed), reductions in other utilities or operations and maintenance costs. Costs include the identification and resolution of deficiencies (which can be paid through by a combination multiple parties, e.g., owners, utility incentives, or grants). Commissioning can influence the type and number of change orders or other non-energy benefits, resulting in either net delivery costs or net savings. Costs and benefits can occur at one point in time or be ongoing. Most studies do not quantify these "secondary" effects, but we include them where available (38 cases).

In rare cases (0.8% of our projects), energy use can actually increase after commissioning. This is generally a "good thing" insofar as it results from correcting an important operational deficiency (e.g., non-functioning equipment or insufficient ventilation).

Figure 5. *Conceptual map of commissioning costs and benefits*



In the real world, energy-related commissioning measures are often combined with non-energy ones, particularly those related to fire and safety systems. For energy cost-benefit analysis, it is important to isolate the relevant costs. In one example, about 95% of the new-construction commissioning cost of a Caltrans office in California was for correcting non-energy construction defects. Using the total value would have yielded an apparent energy payback time of 41 years, while the proper allocation of costs and benefits yields a payback time of only 2 years.

Not to commission is to "kick the ball ahead," and defer costs to the future. By this perhaps generous definition, commissioning is not a "real" cost. For two buildings analyzed in detail, one author found that 46% and 62% of the deficiencies identified during commissioning would in the future manifest as higher repair and maintenance costs (Della Barba 2005). Similarly, 4% and 10% of the deficiencies would have resulted in shortened equipment life, while 13% and 5% would have adversely impacted occupant productivity. For comparison, only 11% and 10% were directly associated with energy costs. Friedman (2004) found over 500 deficiencies at four Detroit elementary schools and that correcting the problems avoided $100,000 in repair costs. Foregone energy savings amounted to an additional $110,000. In commissioning 10 schools in California's Folsom Unified School District, 32% of the issues identified would have increased operations and maintenance costs, 37% comfort and indoor air quality, 6% safety, and 26% energy (Mittal and Hammond 2008).

The Impact of Commissioning: A Golden Opportunity for Saving Energy, Money, and Greenhouse Gas Emissions

Our results are within the range of that observed in smaller studies (Table 1), but they provide a far more definitive and well-normalized assessment than the existing constellation of isolated studies. This is thanks to the large sample size and screening process used to determine which projects to include, the breadth of the sample, and normalization processes that remove "noise" from the costs and savings analyses.

Table 4 provides a high-level summary of the characteristics of our sample, the investment made in commissioning, as well as the energy and economic outcomes. Table 5 and Figure 6 give key results for building types for which we have more than five examples in the database. (In some cases, sample sizes were too small to allow analysis of the new-construction cohort.)

We found median[9] whole-building energy savings of 16% for existing buildings and 13% for new construction. Fuel savings for existing buildings were similar, while those for saving centrally generated thermal energy were significantly higher (31%). Savings in peak electrical demand were achieved in many cases—median value 5%—but were often not the main focus of the commissioning projects, and so the potential is probably considerably greater.

[9] The *median* value is often superior to the *average* (technically known as the "mean") for representing the central tendency of a data set. The median of a list of numbers can be found by simply arranging all the observations from lowest value to highest value and picking the middle one (or the average of the two middle values if the list contains an even number of entries). The average is the sum of all the values in the list divided by the number of values. Per Wikipedia: "Suppose 19 paupers and 1 billionaire are in a room. Everyone removes all money from their pockets and puts it on a table. Each pauper puts $5 on the table; the billionaire puts $1 billion there. The total is then $1,000,000,095. If that money is divided equally among the 20 people, each gets $50,000,004.75. This is the average amount of money that the 20 people brought into the room. But the median amount is $5, since that would be the middle value in a ranked list. In a sense, the median is the amount that the typical person brought in. By contrast, the average is not at all typical, since nobody in the room brought in an amount approximating $50,000,004.75. By using the median, extreme outlying values don't skew the result."

Table 4. Sample characteristics, investment, and outcomes.

	Total	Existing	New
Characteristics			
Number of projects	409	332	77
Number of buildings	643	561	82
Number of states	26	21	15
Identified commissioning providers [1]	37	28	15
Commissioned floor area			
total (square feet)	99,224,809	90,410,884	8,813,925
per building (median ksf)		190,907	67,987
Ownership (by % of floor area)			
Public	71%	69%	85%
Private	29%	31%	15%
Investment			
Commissioning Investment (US$2009) [2]			
total project cost (US$2009)	43,484,002	28,562,970	14,921,031
(US$2009/project)		49,075	86,546
(US$2009/ft^2)		0.30	1.16
cost as % of construction cost			0.4%
Outcomes			
Number of deficiencies identified [3]	10,180	6,652	3,528
Number of measures [3]	5,795	4,104	1,691
Energy Savings			
Total primary energy		16%	13%
Electricity		9%	*
Peak electrical demand		5%	*
Fuel		16%	*
Combined central thermal		31%	*
Central hot water		12%	*
Central chilled water		16%	*
Central steam		19%	*
Payback time (years) [4]		1.1	4.2
Cost-Benefit Ratio [4]		4.5	1.1
Cash-on-Cash Return [4]		91%	23%
Cost of Conserved Carbon ($/tonne) [4]		-110	-25

Notes: Statistics are median values. New values or ratios should not be computed by combining numbers in this table, as the sample sizes for which data are available vary by row.

[1] The provider is known for 55% of the floor area treated in existing-building projects and 43% in the new-construction projects.

[2] Gross costs (excluding non-energy impacts).

[3] Systematically undercounted because some projects reported "Yes/No" rather than absolute counts. These tabulated as 0.999 for tallying purposes.

[4] Including non-energy impacts for projects where the information is available.

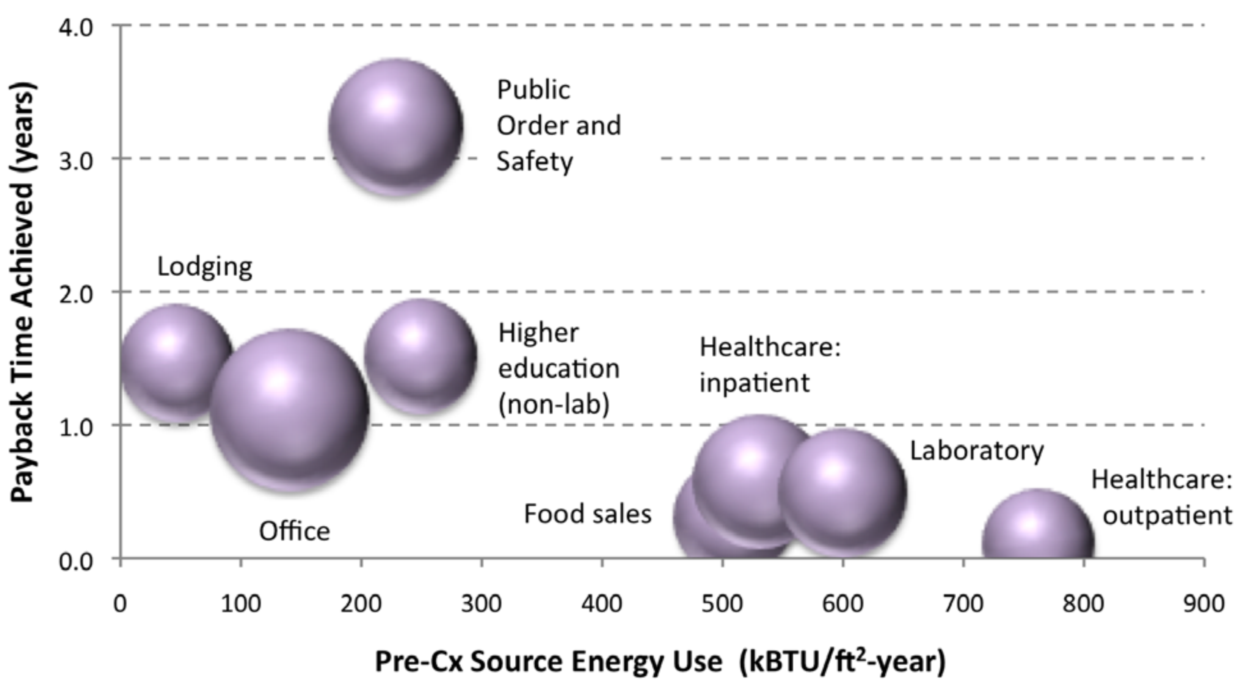
* no data

Table 5. Results by building type.

	Pre-Cx EUI (kBTU/ft^2-year)	Source Energy Savings (%)	Simple Payback Time (PBT - years)	Number of buildings (by PBT)
K-12			3.3	19
Higher education	250	11%	1.5	165
Food Sales	510	12%	0.3	10
Food Service				
Inpatient	532	15%	0.6	15
Outpatient	764	10%	0.1	13
Cleanrooms				
Data Center				
Laboratory	600	14%	0.5	50
Lodging	48	12%	1.5	38
Retail			1.4	9
Service				
Office	141	22%	1.1	145
Public Assembly			1.0	6
Public Order and Safety	229	16%	3.2	15

Values only shown when the sample size is five or more buildings.

Figure 6. *Results by building type. from Table 5. Circle diameter is proportional to percent energy cost savings. For reference, "Office" = 9%. Public order and Safety includes prisons.*



Deficiencies and Their Resolutions

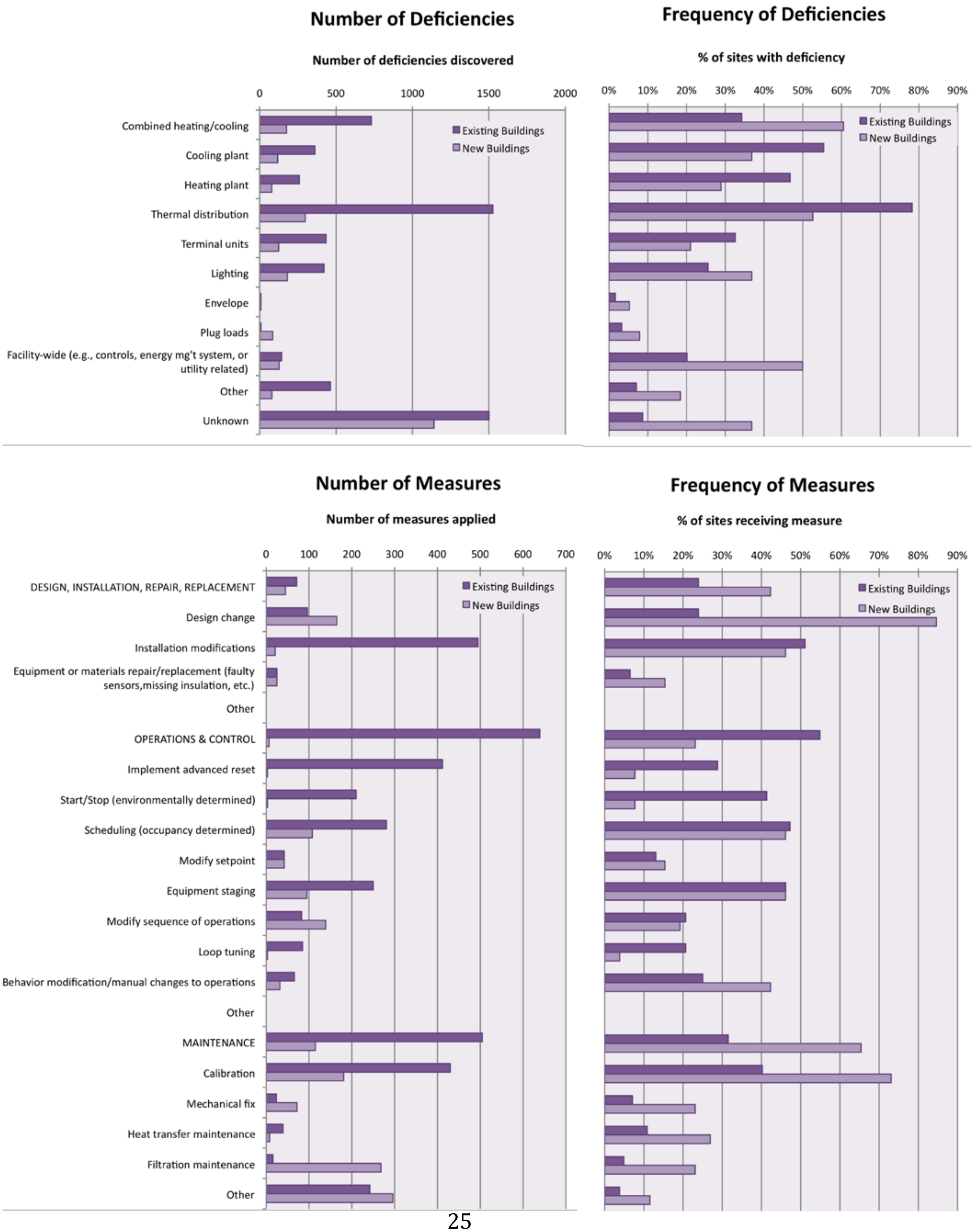
The initial payoff from the commissioning process is the unearthing of problems in the building that, remaining undetected, would burden the facility with higher operation and maintenance costs. In some cases the costs can expand to include hampered productivity or safety.

Many individual case studies delineate the deficiencies and how they were addressed. For example, Barr-Rague and Wilkinson (2005) provide a highly detailed case study of how almost 250 deficiencies were identified and remedied in a 150,000 square-foot middle-school building in New Jersey. Della Barba (2005) found almost 2500 deficiencies throughout 9 college buildings.

Information on the deficiencies and measures implemented to resolve them was available for 122 (about one-third) of the projects in the this study, and we have mapped them to a consistent framework (Figure 7). We identified 6652 deficiencies for existing buildings and 3528 for new-construction.[10] A wide diversity of problems was found. For existing buildings, problems were by far most common in air-handling and distribution systems. For new-construction, problems were most common in the mechanical systems. The low incidence of reported problems in plug loads and envelopes is probably a combined reflection of their relative simplicity (compared to HVAC systems) and that most commissioning providers are specialists in mechanical systems.

[10] For a subset of these (2145 cases in existing buildings, and 1186 cases in new construction), we have the exact correlation of deficiencies with the resolution. These are provided in the online supplementary information, at http://cx.lbl.gov/2009-assessment.html.[11] For more on the energy-efficiency potential in these facilities, see http://hightech.lbl.gov

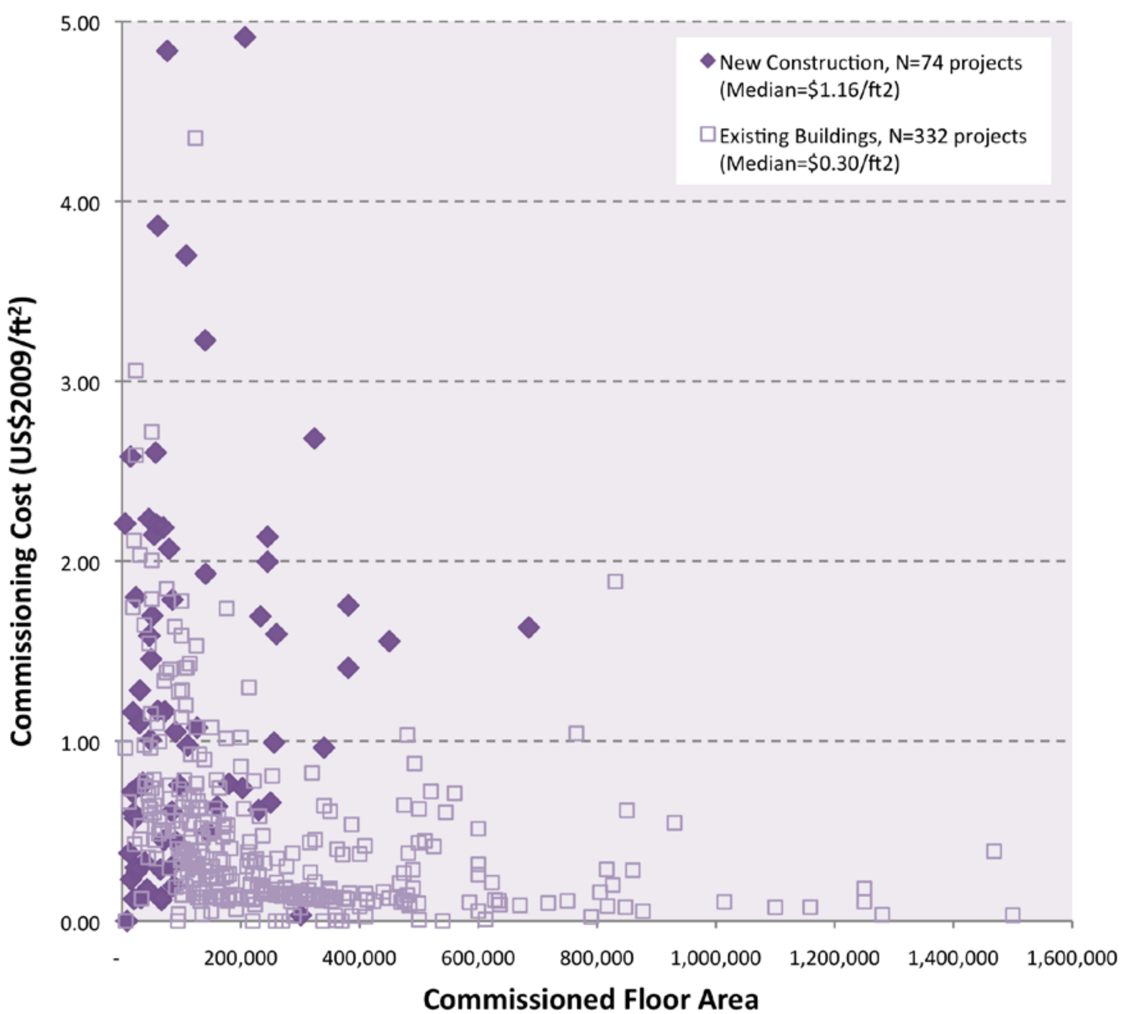
Figure 7. *Types of Problems (Deficiences) and their solutions (Measures)*



Energy, Economy, Environment

Approximately $43 million (inflation-adjusted 2009 USD) was spent on commissioning the projects in our database. The average investment per existing building was $49,000 and $87,000 for new construction. Across the 561 existing buildings for which commissioning-cost data are available, we find a median normalized cost of $0.30/square foot ($ft^2$) (inflation-adjusted to US$2009 currencies). The corresponding value for new-construction commissioning is $1.16/$ft^2$ (82 buildings). These values exclude non-energy benefits, which are in some cases quantifiable in economic terms. For existing buildings, normalized costs tend to decline with building size (Figure 8), but with large variances. In the case of new construction, pricing appears to be more proportional to total project cost. The nature of activities required for new-construction commissioning may be less dependent on project size.

Figure 8. *Commissioning cost as a function of building size*

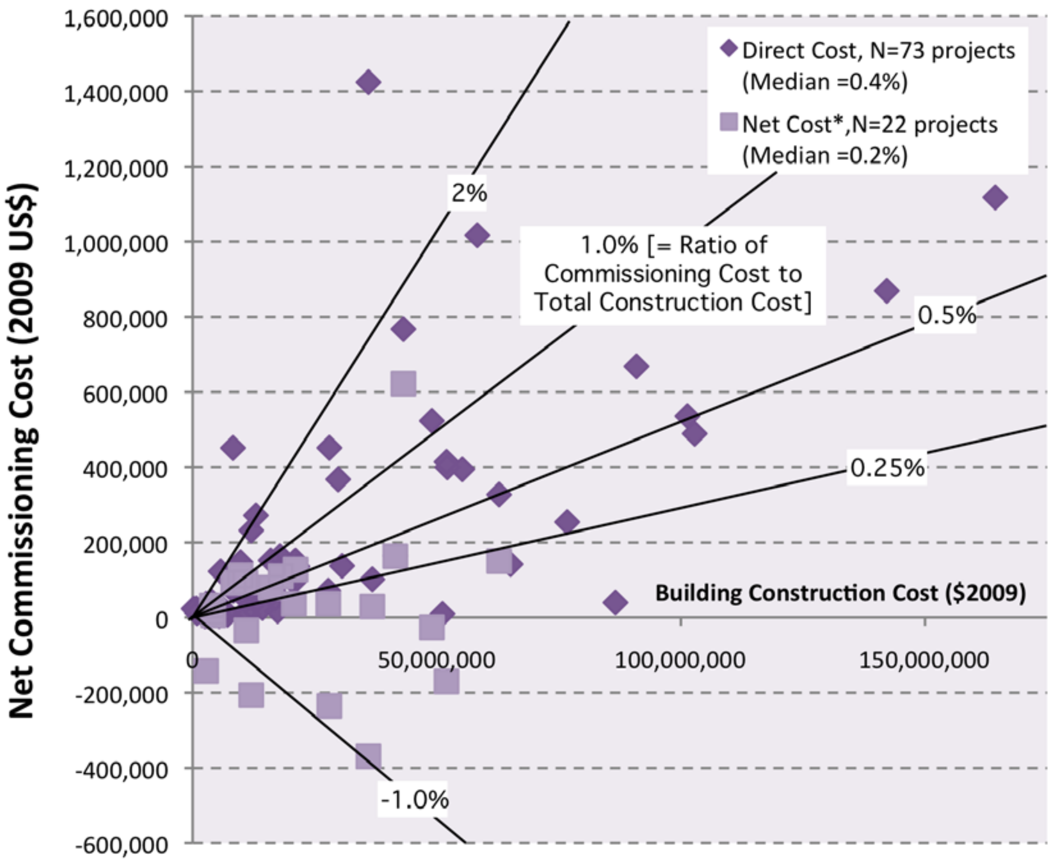


The higher normalized costs tend to correlate with projects having a substantial effort to measure and verify savings (Mills and Mathew 2009).

A more common cost metric in the case of new construction is the cost of commissioning as a percentage of total building construction cost, which has a median value of 0.4% for our sample. When non-energy impacts are included, the values decline significantly, becoming zero or even negative in many cases (Figure 9).

In evaluating commissioning cost-effectiveness, it is important not to mistake or use as a surrogate the commissioning provider's fees for total project costs. We have seen this done in other studies, and often not disclosed to the reader. For the 32 cases where we had the information on external commissioning provider fees for existing-building projects, the fees averaged 45% of total costs, with a minimum value of 9%. For the 44 cases where we had the information for new-construction projects, the fees averaged 85% of total costs, with a minimum value of 56%.

Figure 9. *New-construction commissioning cost as a fraction of total construction cost. "Net Cost" includes first-cost savings where applicable.*



The seven panels in Figure 10 summarize the core energy-savings and cost-benefit findings from our compilation. The charts show the median values for a series of metrics, together with the top and bottom twenty-fifth percentile for the set of projects as a whole. This provides an indication of the central tendencies of the results as well as the spread. The cost-benefit indicators combine all costs and benefits. Building owners enjoy even higher levels of cost-effectiveness where they receive rebates or other forms of incentives or subsidies. Across our sample, partial or full utility rebates were received in 84% of the cases in existing buildings projects, and 68% of the cases in new-construction projects. Where rebates were given, they represented about 80% of project costs for new and existing buildings alike.

The percentage weather-normalized *whole-building* energy savings was roughly similar between existing and new buildings, as was the variance, with median values of 16% and 13% (small sample size), respectively. More than a quarter of all buildings saved in excess of 30%.

While commissioning projects at one time focused exclusively on obtaining energy savings, they are increasingly also targeting peak-demand reductions (Franconi et al. 2005; Lenihan 2007; Mills and Mathew 2009). Within our database, 54 existing-buildings projects include savings in peak demand (median value 5.4%, with the upper quartile at 12%), and another 11 new-construction projects report savings but without pre-/post values (and thus the percentage savings cannot be determined).

Median commissioning costs were \$0.30/ft^2-year for existing buildings and \$1.16/ft^2 for new construction. Median cost savings were \$0.29/ft^2-year for existing buildings and \$0.18/ft^2-year for new construction. To address the needs of a diverse array of users, we employ four cost-benefit tests.

- **Simple Payback Time:** This is the project cost divided by the first-year cost savings. Where savings equal the cost, the payback time is one year. Where the payback time is the same or more rapid than that available through alternative investment options, the project can be deemed cost-effective. Median paybacks were 1.1 and 4.2 years, for existing buildings and new construction, respectively.

- **Benefit-Cost Ratio:** This is the sum of project benefits over the assumed measure lifetime divided by the project cost. If the ratio is greater than 1, the project can be deemed cost-effective. The median ratios were 4.5 for existing buildings and 1.1 for new construction.

- **Cash-on-Cash Return:** This is the ratio of first-year cost savings from the project divided by project cost, expressed as a percentage return (inverse of the payback time). If the return is equal to or greater than alternative investment returns (e.g., 10%) then the project can be deemed cost-effective. We offer this metric because it is widely used in the real estate industry. The median returns were were 91% for existing buildings and 23% for new construction.

- **Cost of Avoided Carbon:** This is the annualized project cost minus annual savings, divided by annual greenhouse gas emissions reductions (measured in carbon dioxide [CO_2] equivalents). The value can thus be negative—and in fact commonly is—when the cost of commissioning is exceeded by the energy savings. If the value is less than zero or less than the cost of purchasing emissions offsets in the marketplace, then the project can be deemed cost-effective. The median costs of avoided carbon were -$110/tonne for existing buildings and -$25/tonne for new construction.

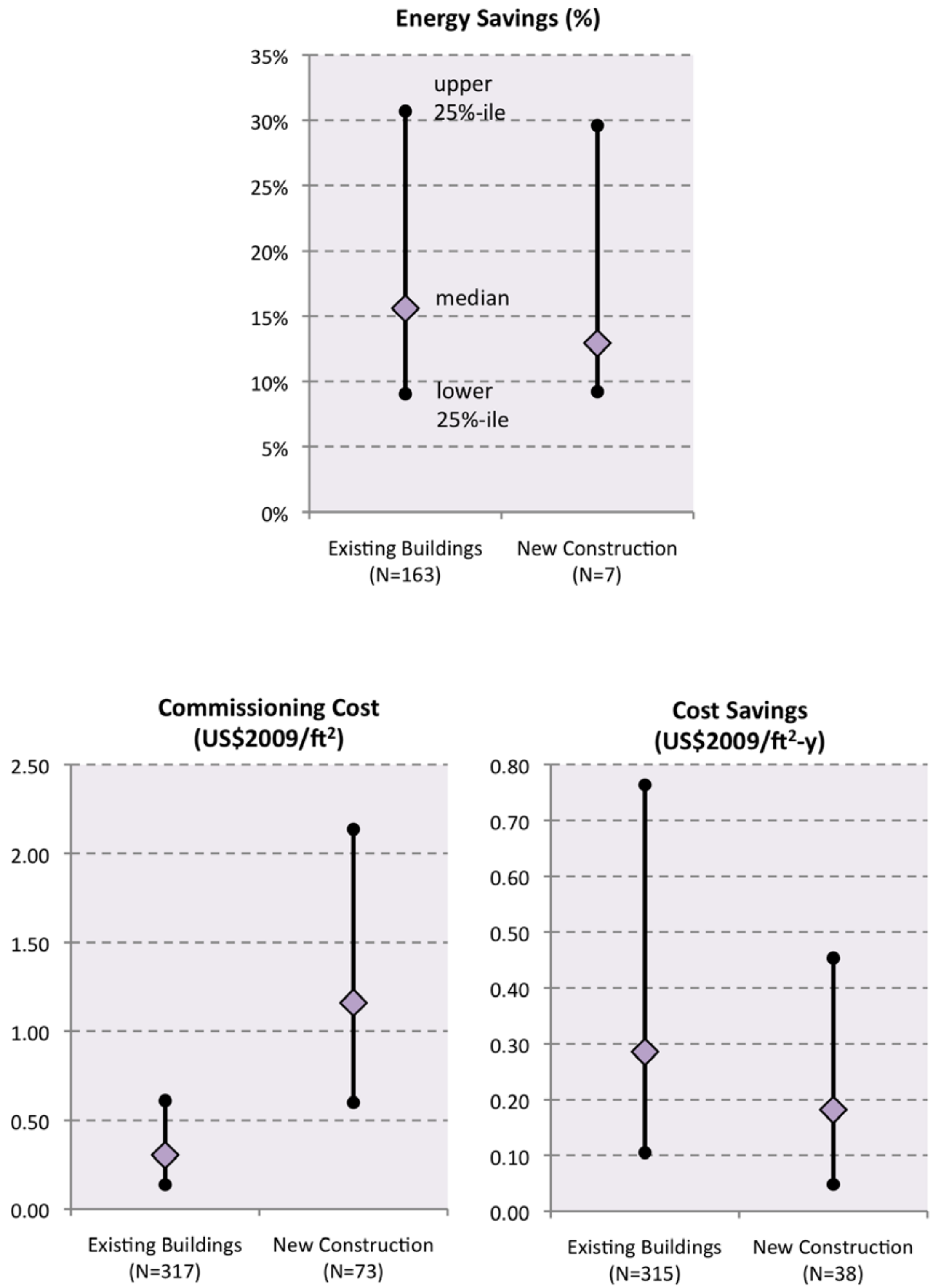
In each case, we adjust the project cost to include non-energy impacts (positive or negative) in the rare cases where the information is available. We assume that the project lifetime is 5 years, which means that savings accrue and project costs are amortized over a much shorter period of time than with long-lived energy retrofits. Measure life is not a factor for payback time or cash-on-cash return, which makes these particularly robust metrics. We assume that energy prices grow at the rate of general inflation, i.e., future energy savings are valued the same as savings today in inflation-adjusted terms.

These results are on a par with those we found with a smaller sample in 2004 (Mills et al. 2004). The variations have no practical significance in terms of the attractiveness of commissioning compared to other energy-efficiency measures.

It is noteworthy that virtually all existing building commissioning projects were cost-effective by each metric. We also found that commissioning was cost-effective for each specific measure for which we have data (Figure 11). The median performance was cost-effective for new-construction, although a number of cases would not be viewed as cost-effective by most building owners.

As shown in Figure 12, we observed a wide range of costs and savings. Payback times varied as well but were highly attractive in virtually all cases. It is notable that payback times showed little correlation with how much money was spent to conduct the commissioning, suggesting that skill plays a large role. Contrary to views that smaller buildings are not good candidates for commissioning, attractive payback times were achieved across our sample for buildings of all sizes (Figure 13). Unfortunately, many utility programs that promote and incentivize commissioning exclude smaller buildings. For example, the 2003 Xcel Energy program excluded buildings below 75,000 square feet (and preferred ones over 250,000 square feet) (Mueller et al. 2004).

Figure 10. *Benchmarks for energy savings and cost-effectiveness*



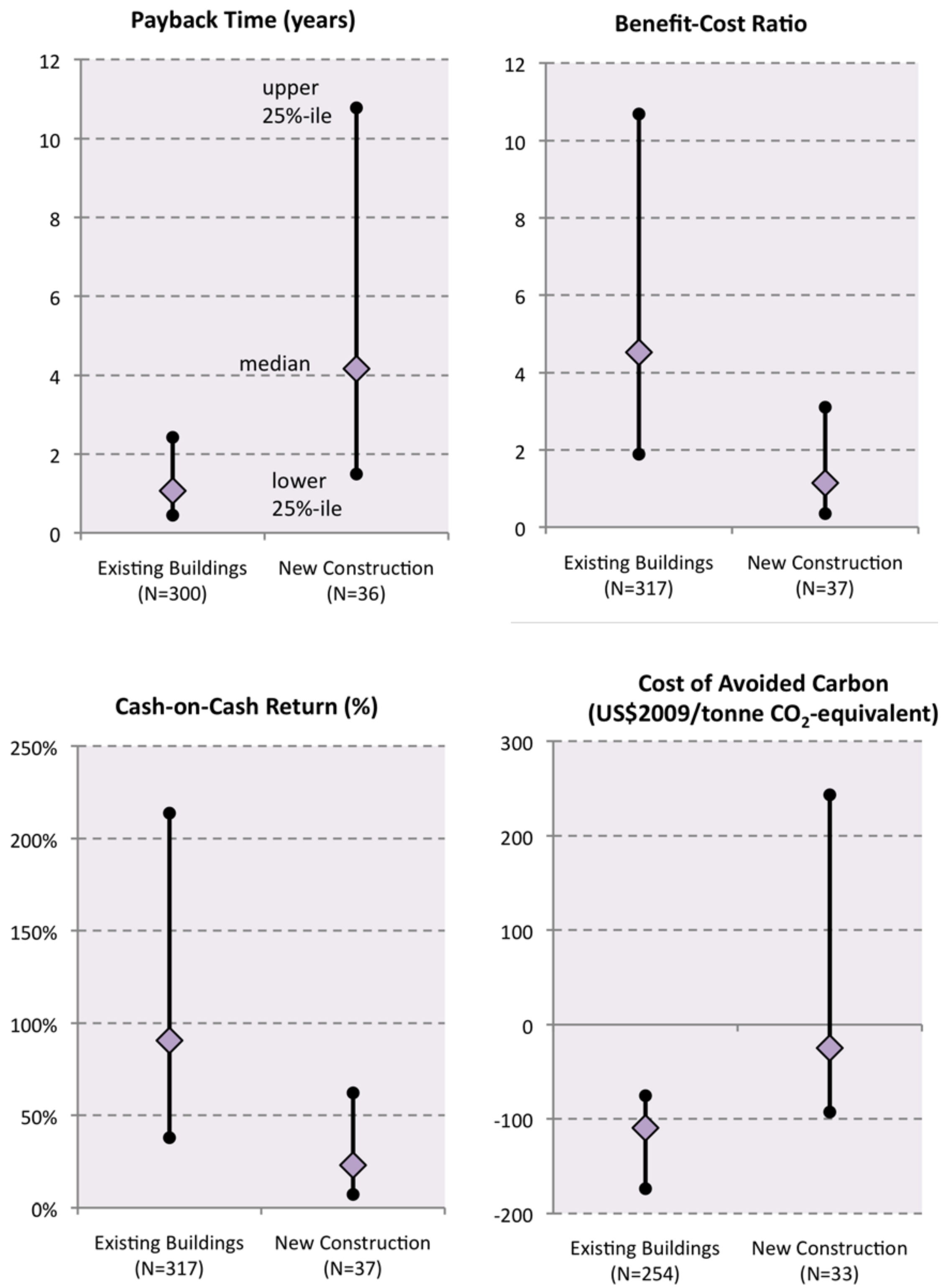

Payback Time (years)
upper 25%-ile
median
lower 25%-ile
Existing Buildings (N=300)
New Construction (N=36)
Benefit-Cost Ratio
Existing Buildings (N=317)
New Construction (N=37)
Cash-on-Cash Return (%)
Existing Buildings (N=317)
New Construction (N=37)
Cost of Avoided Carbon (US$2009/tonne CO_2-equivalent)
Existing Buildings (N=254)
New Construction (N=33)

Figure 11. *Payback times by type of problem (“Deficiencies”) and by resolution (“Measures”)*

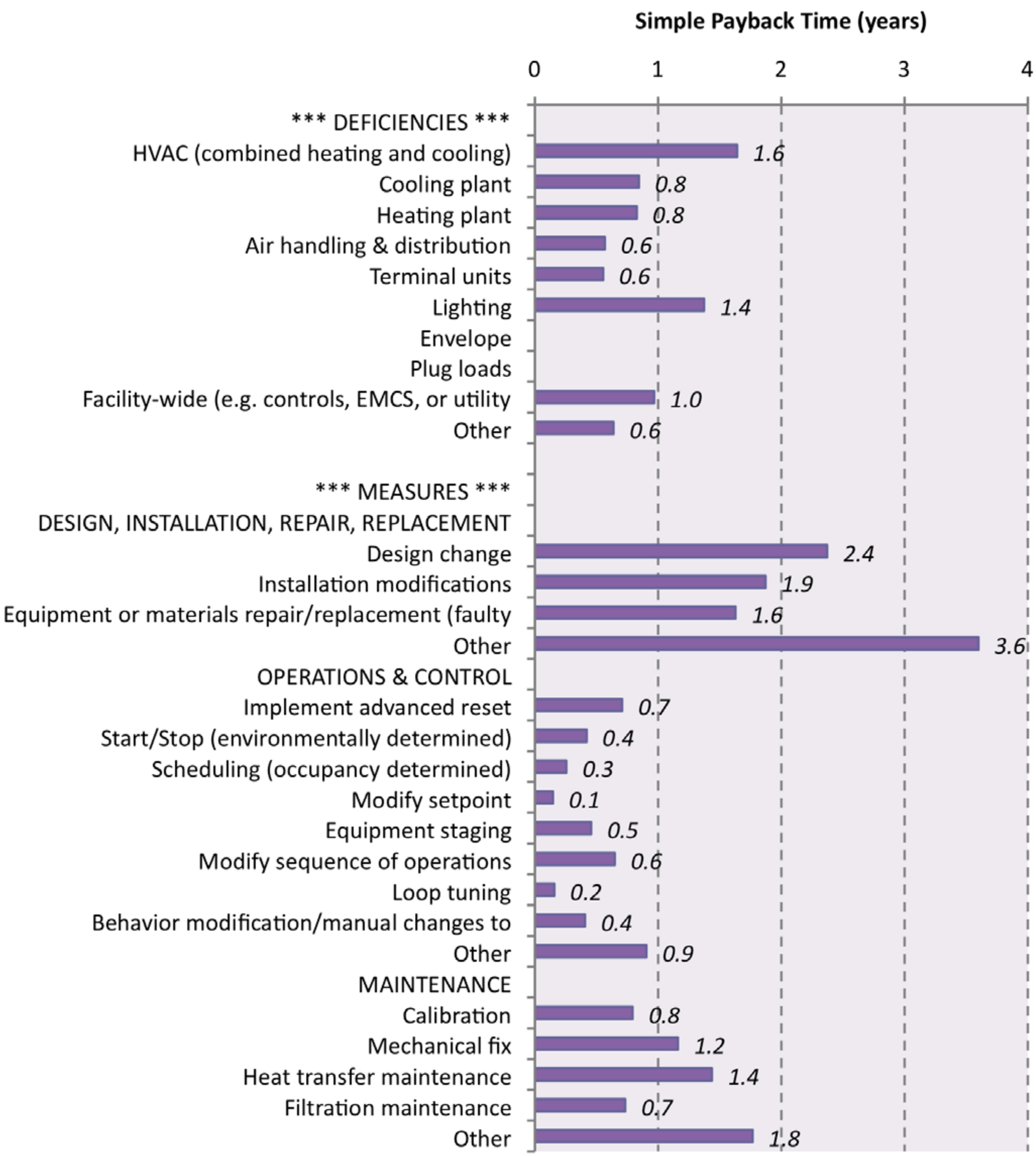


Figure 12. *Commissioning costs, savings, and payback times: existing buildings (above) and new construction (below)*

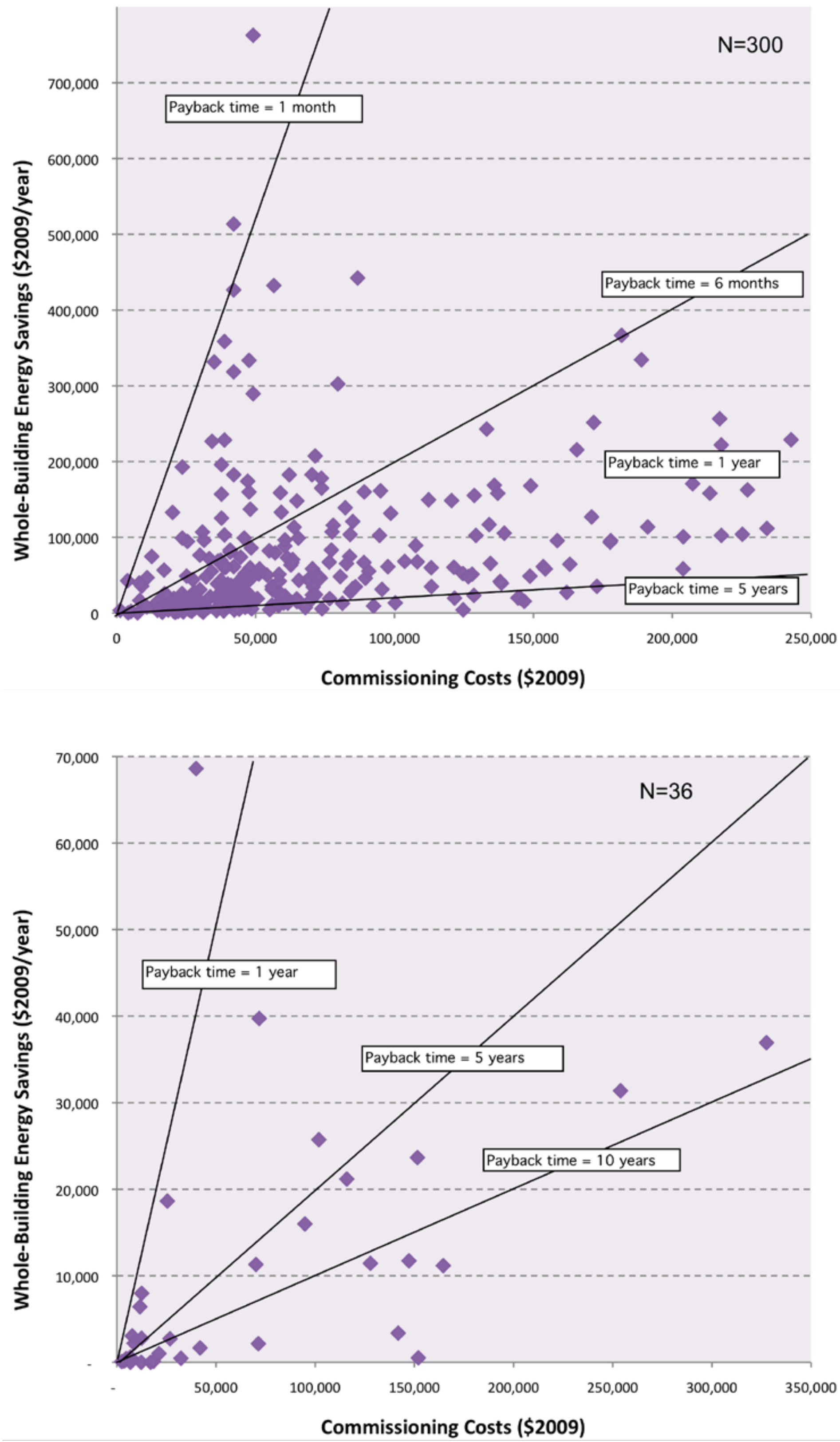
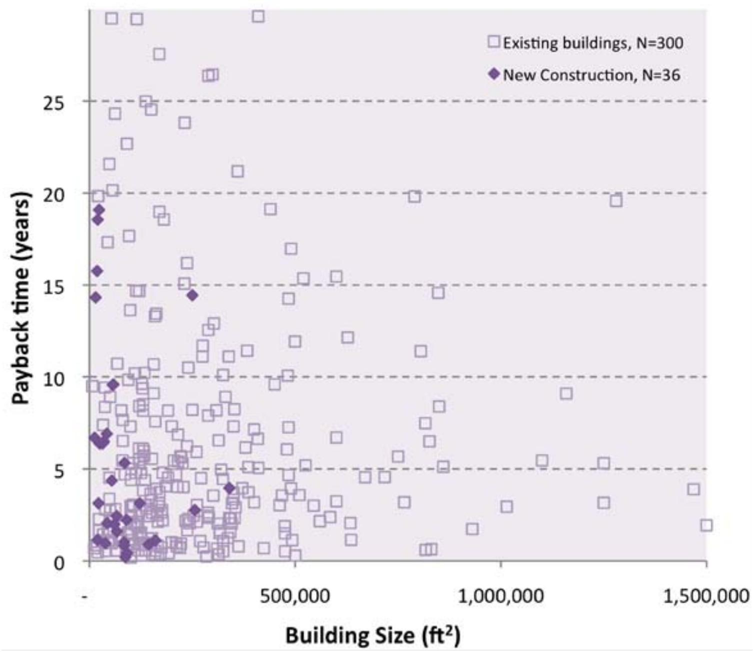
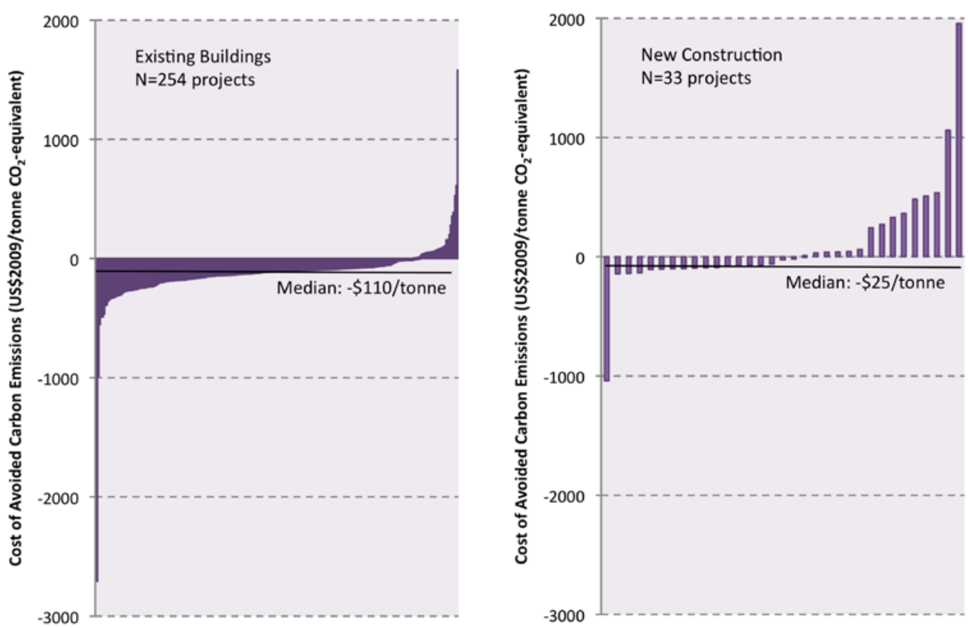


Figure 13. *Commissioning payback time versus building size*



Project costs and energy savings can be cross-referenced with the forms of energy saved (e.g., electricity versus fuel) to determine the amount of greenhouse gas reductions achieved. In almost 90% of the existing-building cases, the cost of avoided carbon was negative, as was the case for over half of the new-construction cases (Figure 14). This metric has been used to rank various emissions-reduction strategies in "carbon abatement curves," as will be discussed below.

Figure 14. *The ranked cost of conserved carbon for existing-building projects in the database: Existing buildings and new construction.*



Non-Energy Impacts

Non-energy benefits are a major driver of decisions to utilize commissioning, although adverse non-energy outcomes should also be studied (hence our use of the neutral term "impacts"). The importance of these impacts is evidenced in the titles from the following BetterBricks case studies:

- "Community Colleges of Spokane –Enhancing Teaching and Learning for Health Care Professionals"
- "Othello Community Hospital – Insuring Operation of Critical Systems"
- "Riverside School District – Correcting Mechanical and Indoor Air Quality Problems"

Indeed, non-energy benefits are in many cases the primary reason—or the *only* reason—for embarking on commissioning projects. Customers are often surprised to find, after the fact, that energy savings were achieved. The utility commissioning programs in Nebraska attribute part of their success on focusing first on improving building comfort (Criscione 2008).

We gathered qualitative data on the reasons for commissioning for 178 existing buildings projects and 36 new-construction projects. While energy savings are cited as a driver in 90% of the cases, this is followed by a desire to ensure or improve thermal comfort, productivity, and indoor air quality for occupants (Figure 15). Ensuring system performance per se is an driver in about half of the cases, and training and occupant operators or occupants is a driver in about a third of the cases. For new construction, ensuring equipment performance, indoor environmental quality, and occupant productivity are cited more often than is obtaining energy savings.

We obtained data on observed post-project non-energy impacts for 68 existing building commissioning projects and 44 new-construction commissioning projects, representing a total of 480 identified non-energy benefits. For existing buildings, improved thermal comfort and extended equipment life are among the most cited non-energy benefits experienced after the projects are completed (Figure 16), while equipment life is the most-cited benefit for new construction, followed by improved thermal comfort.

In 38 cases, the non-energy impacts were quantified. As seen in Figure 17, these can significantly offset the direct cost of the commissioning. Where the value shown in the diagram is less than zero, the non-energy benefits exceeded the first costs. In some cases, the benefits exceed the costs, rendering the projects instantaneously cost-effective. The actual net median commissioning project cost was reduced 49%.

Figure 15. *Reasons for commissioning*

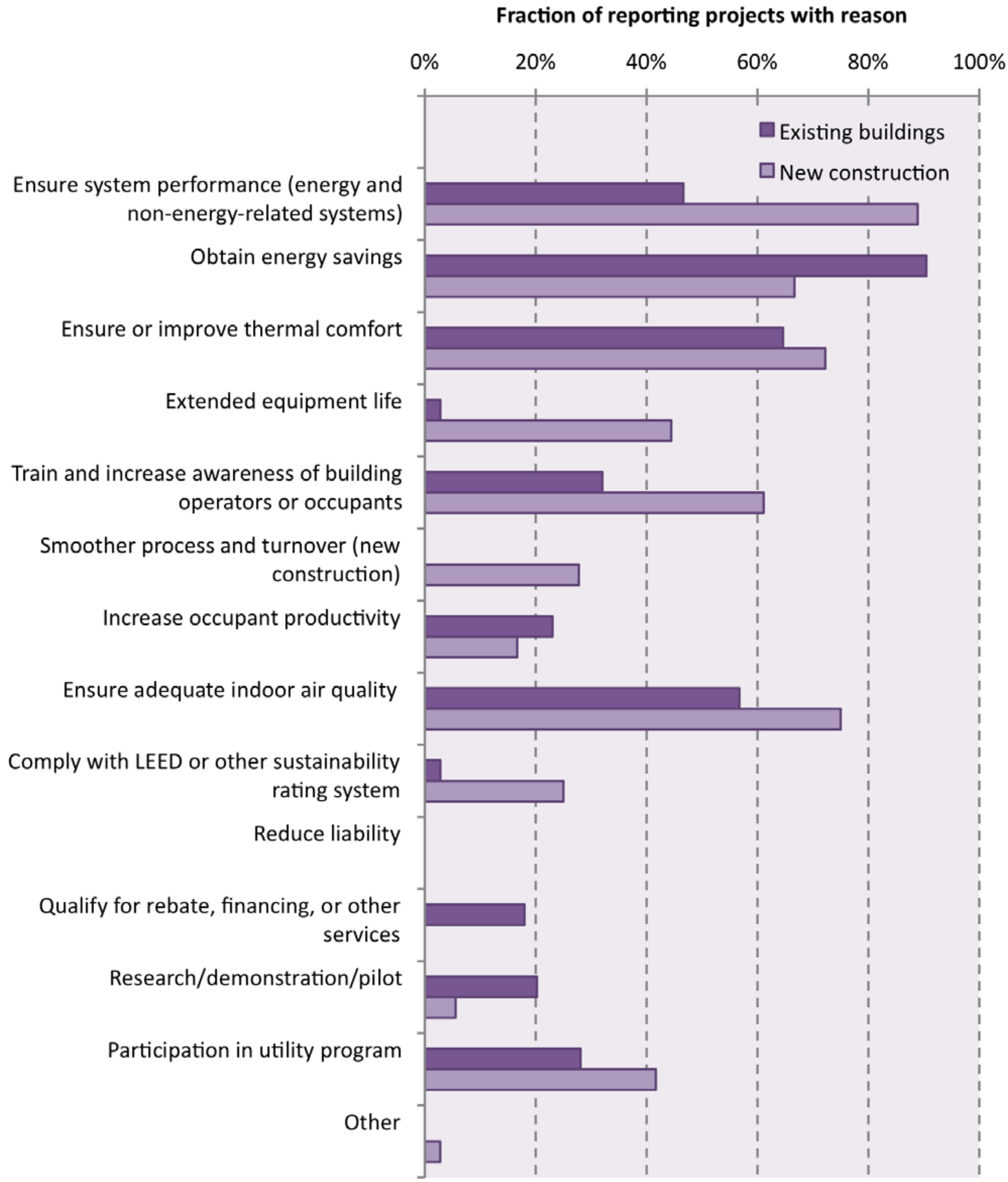


Figure 16. *Non-energy benefits observed following commissioning.*

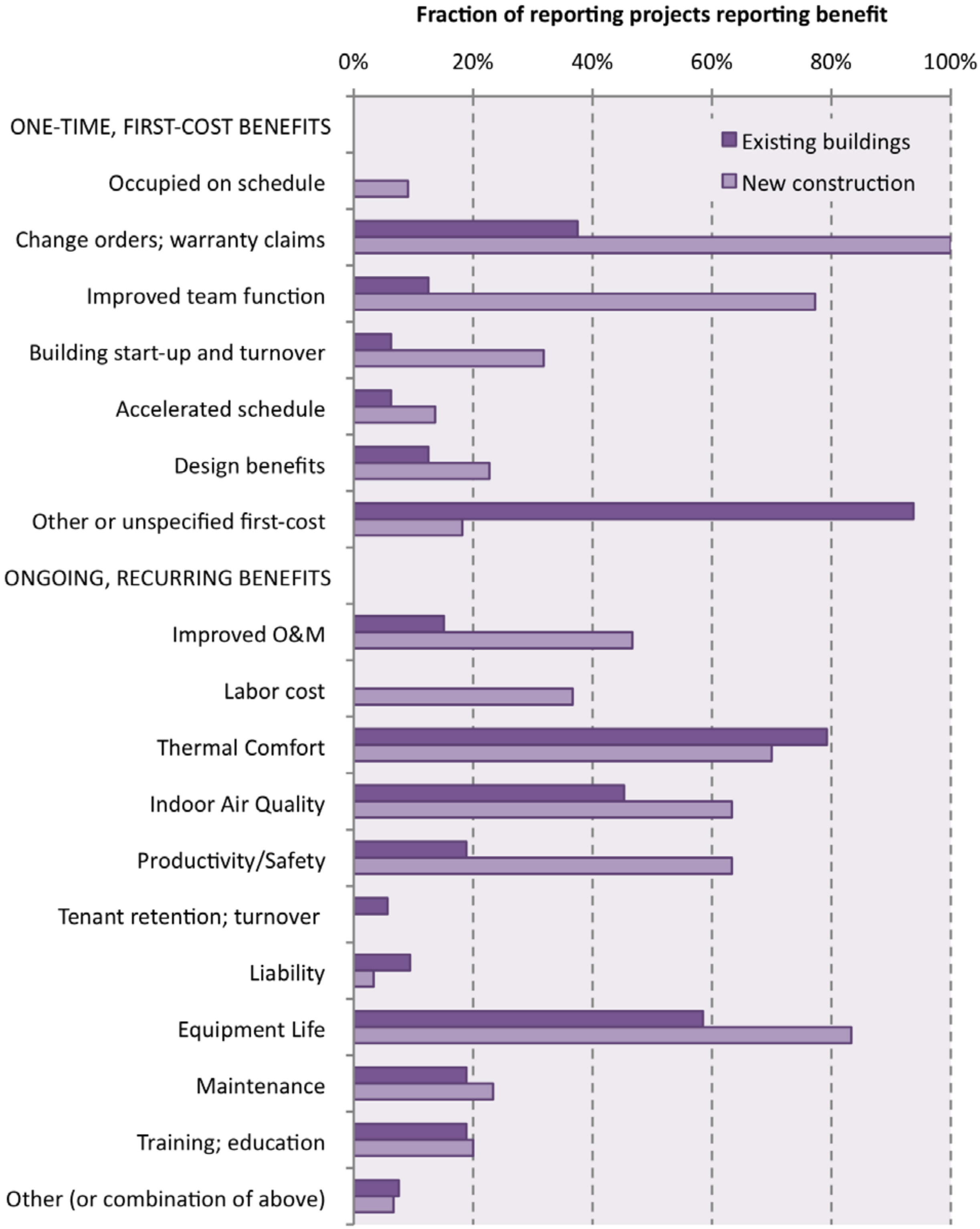
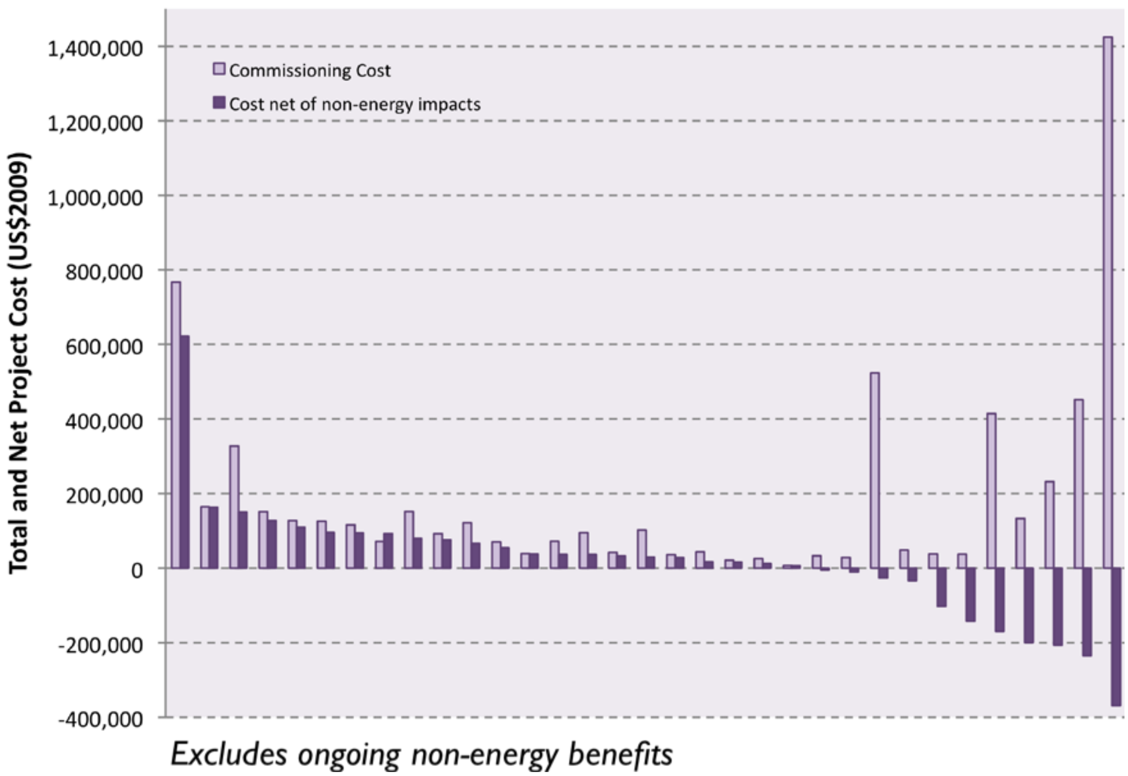


Figure 17. *First-cost savings often offset part or all nominal commissioning project costs*



High-Tech Facilities: The Commissioning Mother Lode

High-tech facilities have at times been passed over in the quest for energy savings, often under the pretense that they "must" already be optimized, and other times under the pretense that they are mission-critical and should not be disturbed. Observers sometimes incorrectly assume that these facilities are routinely commissioned for energy savings. While it is true that they receive a far higher level of quality assurance in construction and operation than traditional buildings, energy performance *per se* is usually not a central focus.

For the purposes of this report, "High-tech" facilities include labs, data centers, cleanrooms, healthcare, and specialized research facilities such as particle accelerators. While specialized on the one hand, these facility types are also pervasive, occurring in private industry (from semiconductor fabs to hospital operating rooms) to educational institutions (from high school to university labs), and in the public sector (from agricultural research labs to high-energy physics facilities). Across the United States, high-tech facilities in the private and public sector have been estimated to spend upwards of $10 billion per year on energy (Mills 2009b).

They have a number of common characteristics, including: around-the-clock operation, high air-change rates and critical activities and safety requirements that rely on proper indoor environmental control building performance. In some cases all of the air is "once-through" and/or requires dehumidification, with far larger volumes of air needing to be treated than in conventional buildings. Taken together, these requirements tend to translate into particularly high energy-intensities, and correspondingly large opportunities for energy savings (Mills et al. 2007).[11] There are a number of articles and reports addressing commissioning in high-tech facilities, although many of them are not focused on energy issues and indeed many make no mention whatsoever of energy.

However, while we have found that commissioning can be cost-effective in virtually any building type or size, the results are particularly impressive in high-tech facilities. For example, one of the data centers analyzed for this report (Nodal 2008) had a pre-comissioning energy intensity of over 900 kWh/ft^2-year (or almost $100/ft^2-year), which is about 100 times the energy bill of a typical office building. Just the savings ultimately achieved by commissioning this one facility—173 kWh/ ft^2-year—is 10 times the median *pre*-commissioning energy use for the non-high-tech buildings in our database.

A small proportion of reports in the commissioning literature address the specific needs of these facilities. Many of those that do so focus on non-energy issues, rather than energy (Ross 2008; Hydeman et al. 2005). However, some energy-specific resources do exist, such as the Labs21 guide to commissioning existing laboratories for energy efficiency (Bell 2007), which, for example, cites the special importance of fume hoods and specialty pressure- or volume-controlled HVAC systems used for safety purposes.[12]

While problems identified in the commissioning of high-tech facilities can appear in ordinary buildings, the cost—in terms of excessive energy use—when they occur in high-tech facilities is far, far higher. Some technical issues and opportunities are unique to these facilities, as are some of the barriers. Because these facilities are also highly mission-critical, the non-energy benefits having to do with factors such as safety, equipment life, and reliability often associated with energy-related commissioning can be very substantial.

Laboratory facilities are the most widely documented type of commissioning case studies in high-tech facilities. As an example of the scores of deficiencies discovered in the construction of a laboratory facility, Pinnix et al. (2004) found that none of the 163 fume hoods had properly installed alarm monitors (a serious safety issue), while many had faulty control devices and/or miscalibrations.

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[11] For more on the energy-efficiency potential in these facilities, see http://hightech.lbl.gov
[12] A bibliography of readings on commissioning high-tech facilities is located here: http://cx.lbl.gov/hightech.html.

The commissioning of data centers has been treated in exceedingly few publications and reports. Findings from a case study of commissioning the HVAC system of a data center at the NOAA weather forecasting office in Jacksonville, Florida (Lundstrom 2004) are indicative of the kinds of problems that can otherwise go undetected in these types of facilities:

- No balancing dampers were installed to the branch ductwork for balancing, making it impossible to balance the system to improve hot/cold spots.
- Some of the electric duct heater serving zones were significantly oversized.
- Condenser coils were corroded and need to be replaced (coils were not coated for high salt content atmosphere).
- The condensing units had incorrect head pressure control and hot gas bypass connections.
- The exhaust fan was only producing 33% of design flows.
- The access door on the air ductwork was removed during an inspection and was not reinstalled.
- The fan status controls were not responding to the control system.
- The discharge temperature was controlled off the zone with the lowest setpoint, not the zone with the highest actual temperature, causing many zones to be hot.
- The temperature and humidity sensors were out of calibration.
- The lead-lag operation of the redundant air-handler units (AHUs) was not functioning in a fail-safe manner.
- The control sequence was not operating correctly.
- Many of the electric duct heaters were not staging correctly, due to incorrect wiring.
- Cooling load calculations revealed that the requirements were 10% less than the original system design (a reflection at least in part of overestimation of internal loads at the time of design).

And, after the preceding items were fixed by a separate contractor, the commissioning authority reinspected and found the following new issues:

- OA damper drive motors on two AHUs were not installed properly on the shaft linkage.
- SCRs for electric duct heaters (EDHs) on two AHUs were not correctly set up.
- Temperature sensors were not correctly mounted downstream of EDHs.
- The damper jackshaft arm on the outside-air damper on the two AHUs was stripped at the damper connection.
- Direct digital control (DDC) programs for some zones were not responding correctly.
- Specific items in the operator workstation graphics were missing or mislabeled.
- The return air damper for one AHU was broken.

Cleanrooms are another important class of “high-tech” (and highly energy-intensive) facility. They, perhaps more than any other facility type, suffer from a misconception that they are routinely commissioned for energy savings. In fact, they are routinely "qualified" or "certified" to ensure that the manufacturing process within will be error-free and yield a predictably acceptable product (e.g., semiconductor wafers). However, the qualification process rarely includes energy performance. A cleanroom can be operating "perfectly" and yet use far more energy than necessary. Moreover, there are intense pressures to construct cleanrooms quickly, and there is well-founded apprehension about interventions that could compromise the process.

While attention on the commissioning of cleanrooms (and most other types of spaces) tends to focus on the mechanical systems, a recent report points out the importance of considering building envelopes. In this case (Sellers 2009), inspections of the envelope of a cleanroom in the final stages of construction found that 6% of the circulated air was leaking. Other end uses—such as plug loads or "tools"—get much less attention.

To our knowledge, quantification of energy-focused commissioning in cleanrooms has been offered only once in the open literature, in an important paper and associated presentations by Sellers and Irvine (2001). In that report, a cleanroom was traditionally "qualified" during construction and all was well. Symptoms began to emerge that the HVAC system was not functioning properly, which led to a series of discoveries and adjustments to the control system. To provide a frame of reference for the prodigious energy use by these types of facilities, electricity consumption of ~100,000 kWh per day and 1,800 therms of natural gas use per day translated to $5000 per day (at energy prices that are very low by today's standards – $0.039/kWh and $4.4/therm).

Following are some of the problems identified during commissioning this cleanroom:

- Key temperature sensors were out of calibration, by nearly 10^{o}F in one case.
- A critical valve was inadvertently not connected to control system, resulting in 24x7 heating and extensive simultaneous heating and cooling.
- A preheat coil controller had been set at 110^{o}F during a start-up test and associated control sequences were severely sub-optimized.
- The absence of alarms for pre-heat temperatures.
- Presence of frustrating controls and user interfaces that resulted in their being devalued and ignored.
- Air was over-dehumidified, and thus over-humidified in response.

The bottom line was $60,000 to $80,000 per year in energy savings (for a small fraction of the space that had been completed), at a one-time commissioning cost of $4,700 to $8,000. The corrections also yielded significant safety-enhancing benefits, which helped avoid costly future disruptions and potentially costly contamination of the process.

This project did not have the benefit of a measured baseline and post-commissioning measured savings. An estimate of savings was based on a calculated baseline rooted in an observed operating condition combined with calculated savings based on what engineering principles say will happen after correcting problems identified in the commissioning process. With this in mind, a very rough extrapolation of lessons learned to the rest of the facility (not yet completed at the time of the study), suggests annual savings of about $540,000, or about 30% of the facility's entire energy bill, and a payback time of 0.01 years (about 4 days). As with any case study, these specific results will not necessarily apply to other similar facilities, but this story serves as a clear indication that commissioning in cleanrooms should be taken quite seriously and that further study is merited.

Our database contains data for 115 high-tech facilities, representing 19 million square feet of floor area (Table 6). Percentage energy savings tended to be somewhat higher than other building types, while absoulte savings were significantly higher because of initial energy intensities. Payback times were also among the lowest of any building type we evaluated.

Table 6. High-tech facilities in the compilation.

	Existing Buildings		New Buildings		TOTAL	TOTAL
	# bldgs	ft^2	# bldgs	ft2	# bldgs	ft^2
Cleanrooms	0	0	1	301,000	1	301,000
Data Center	2	12,888	0	0	2	12,888
Laboratory	50	4,561,593	18	1,965,065	68	6,526,658
Healthcare: inpatient	17	6,791,029	9	687,959	26	7,478,988
Healthcare: outpatient	14	4,319,124	4	206,300	18	4,525,424
Total	83	15,684,633	32	3,160,324	115	18,844,957

The Value of First-cost Savings Can Eclipse Those of Ongoing Energy Savings

An oft-cited non-energy benefit from commissioning—and one of the largest in terms of economic value—is helping to right-size mechanical systems, thereby saving on capital costs during original construction or future retrofit/replacement.

We documented a dramatic example of this in the Advanced Light Source facility at Lawrence Berkeley National Laboratory (Box B) in which a huge cost savings was garnered by scaling back a new chiller from over 450 tons to 350 tons (thanks to the energy savings from commissioning). The corresponding one-time savings were four times the entire commissioning project cost.

Leading commissioning practitioners have gone as far as to say that all the costs of new-construction commissioning *should* be recovered through cost savings in project delivery (with energy savings being icing on the cake). Dorgan et al. (no date) cite seven examples in which these non-energy benefits amount to 1.7 to 22 times the cost of commissioning, with a combined value of over $2.2 million in savings before energy savings are even counted.

Dorgan et al. cite four examples in high-tech buildings in which new-construction commissioning saved $319,000, $400,000, $425,000, and $500,000 in project delivery costs, for a science center, hospital, vivarium, and science building, respectively (before energy savings were even counted). These benefits resulted from:

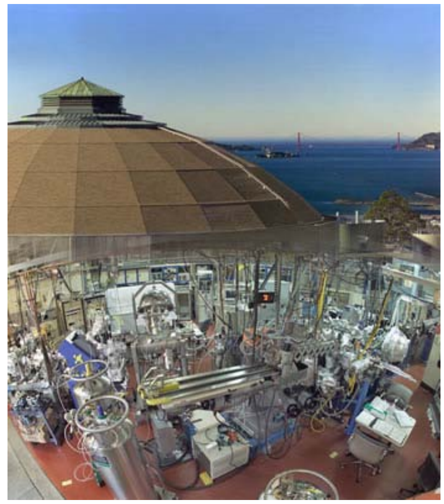
- Eliminating change orders
- Eliminating requests for information (RFIs)
- Proper system/component selection
- Reducing contracgtor callbacks and accelerated date of proper operation

Commissioning Continuity

We identified a rare opportunity to follow a high-tech building through both its initial commissioning process (during design, construction, and startup) and then its subsequent commissioning as an existing building. The data tell an important story of the importance of embedding commissioning throughout a building's lifecycle (Box C). This took place at Lawrence Berkeley National Laboratory's Molecular Foundry facility, a complex high-tech building containing laboratory spaces as well as data processing and cleanroom environments.

Considerable energy savings were garnered during new-construction phase, with a payback time of 0.4 years. A comparable level of savings was subsequently obtained when new commissioning opportunities arose after occupancy, and with an even shorter payback time of 0.2 years (Box C).

Box B. High-Tech Case Study: The Advanced Light Source



Project Summary:

- Floor area: 118,573 square feet
- Project cost: $32,000
- System commissioned: Chillers
- Energy savings: 45.7% (weather-normalized)
- Payback time (commissioning cost/annual energy savings) less than one year
- Avoided capital cost thanks to chiller replacement downsizing from 450 to 350 Tons: $120,000 (based on $1,200/tonne), i.e., four times the cost of the commissioning project

Drivers: Observed simultaneous heating and cooling

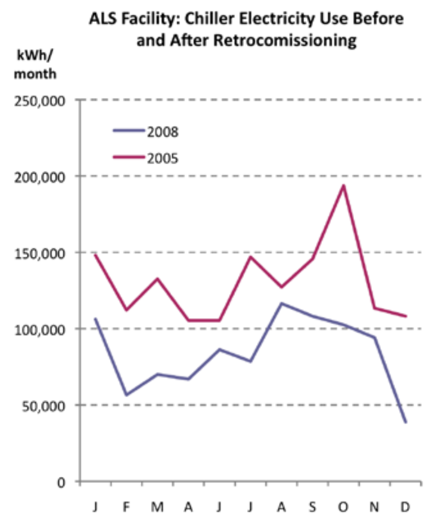
Deficiencies Identified through Commissioning:
- A false cooling load induced by the facility's temperature-stabilization reheat system.

- The main air handling units (AHUs), which provide outside air and cooling for the main experimental area, were not functioning properly. Cooling valves in all AHUs were frozen in full-cooling position, causing simultaneous heating and cooling throughout the facility. Outside air dampers not functioning.

- The central plant cooling and heating system's control programming did not optimize energy-efficiency performance or equipment longevity.

Measures Implemented through Commissioning:
- Fixed/replaced heating valve controllers and leaking valves; adjusted automated control parameters

- AHUs' cooling control valves and dampers repaired

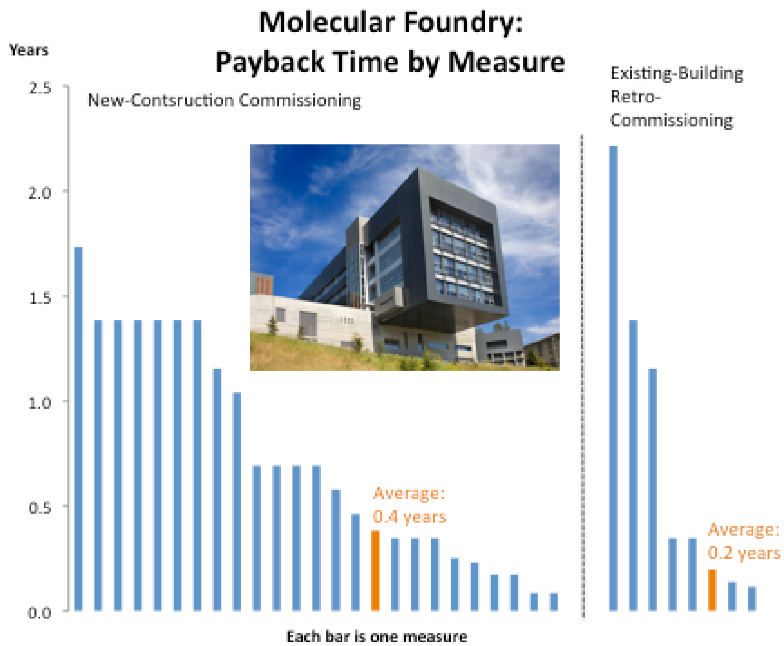


Outcomes
Energy Savings – Chiller plant cooling capacity requirements were reduced by 50 to 70 tons (10%–15%, weather corrected), which corresponded to a 45.7% (weather corrected) reduction in energy use.

O&M Improvements – The system was documented, and the staff was trained and became more able to operate the building.

Capital-cost Savings – The original chiller plant included a variable-speed 450-ton unit and an old, unreliable 350-ton unit. The commissioning project lowered chilled water needs so significantly that the 450-ton chiller went into a "surge" mode of operation that, and if allowed to continue, would damage the chiller. The operators/users believed that a new chiller with an even greater capacity than the 450-ton unit needed to be installed in place of the old 350-ton unit. However, due to the energy reductions achieved during the project, a chiller-replacement project was completed to install a new variable-speed 350-ton chiller to replace the old 350-ton unit. The new 350-ton unit provides the majority of annual chilled water needs, thus becoming the "baseload" chiller instead of the larger, less-efficient 450-ton unit.

Box C. Two Tales of One Building



The Molecular Foundry at Lawrence Berkeley National Laboratory is a 91,000-ft^2 high-tech research facility. As is often heard anecdotally, even though commissioned during construction, this building was immediately a candidate for commissioning upon completion and occupancy.

During the construction phase, problems where found in the HVAC system and plant, air-handling and distribution, terminal units, and lighting. Forty-eight specific deficiencies were discovered during the new-construction phase of the commissioning. When commissioning was performed, an additional fourteen deficiencies were discovered and corrected.

Both the phases were highly cost-effective, with the new-construction commissioning averaging a 0.4-year payback time and the existing-building building commissioning phase averaging 0.2 years.

	Commissioning (new Construction)	Retrocommissioning (post-construction)	Total
Year	2006	2006	
Measures Implemented to Resolve Problems	Modify controls' sequences of operations Modify setpoints; and start/stop operation Calibrate terminal unit damper position feedback Calibrate lghting occupancy sensors Bring air-compressor operation into spec	Replace inefficient, oversize cooling terminal units & perform other HVAC upgrades . Eliminate false loading of oversized chiller. Buffer tank modification to optimize return water temperature Modify air compressor system to reduce need for frequent blowdown.	
Electricity savings (kWh/year)	441,500	223,200	664,700
Fuel savings (MBTU/year)	3,840	4,370	8,210
Cost Savings ($/year)*	93,369	77,132	170,501
Commissioning Cost (US$2009)	39,932	16,992	56,924
Simple Payback Time (years)	0.4	0.2	0.3

* at standardized national prices

Persistence of Energy Savings

Concern is often voiced about the durability or "persistence" of energy savings from commissioning projects. The literature on the subject remains sparse, and the periods over which persistence has been tracked are mostly under five years. In a rare example of longer-term analysis, a large existing office building in Colorado originally commissioned in 1996 was reexamined in 2003, and it was found that most of the original measures were still in place and that 86% of peak-demand savings and 83% of electricity consumption savings had persisted (Selch and Bradford 2005). These eroded savings were recovered at the time by re-commissioning the original measures.

To our knowledge, we have assembled the largest available collection of persistence data for commissioned existing buildings. For a subset of 36 buildings, energy-savings data (total or for particular fuels) was available for two or more consecutive years following the project, allowing us to observe the persistence/durability of savings (Figure 18). Each project is represented in the figure by a grey line for the corresponding type(s) of energy for which persistence data were collected. The heavy red curves show the median trends for each type of energy.

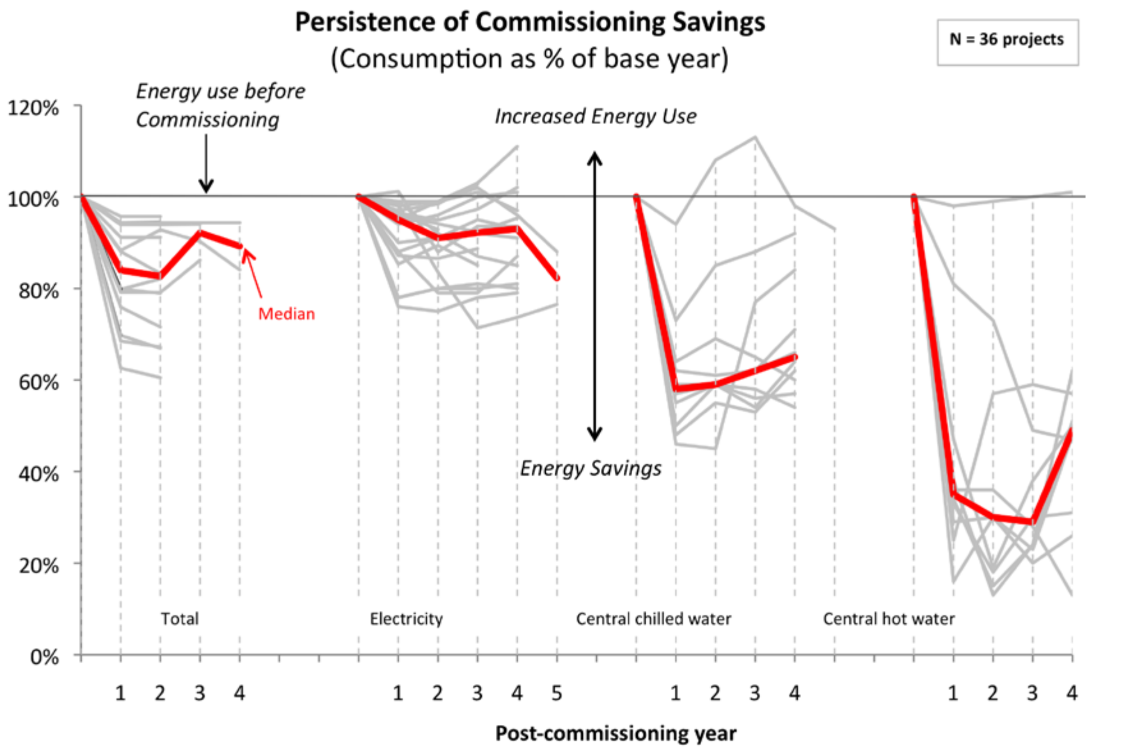
The first important observation is that savings in many cases increase in the second year, presumably a product of refinements in the commissioning or incomplete implementation in the first year. Savings from "static" commissioning measures can be expected to diminish over time. Indeed, the erosion of savings or other factors that tend to bring a building "out of tune" are the rationale for commissioning in the first place.

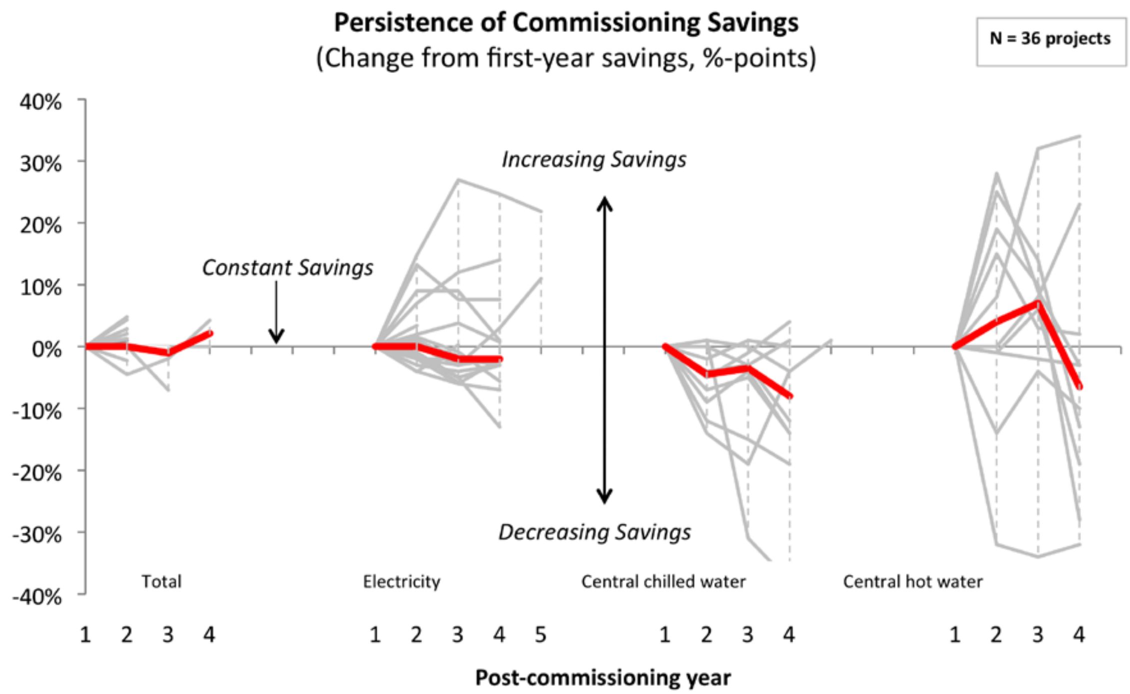
While some projects exhibit an erosion of savings over time, many do not. In fact, the tendency for the sample as a whole is for level or even slightly increasing savings over time. This perhaps counterintuitive outcome may be explained by the fact that comprehensive commissioning includes training, and, in some cases, installation of permanent metering and feedback systems. These improvements "live on" after the commissioning engineers leave the site, and, if properly utilized, can maintain and even help deepen savings. Many measures implemented in new-construction commissioning will tend to be very durable, e.g., properly sizing HVAC equipment.

To the extent that savings increase over time, our project cost-benefit estimates miss some of the true savings. This means that effective payback times could be even shorter than we have estimated.

The data underscore the importance of benchmarking performance over time and revisiting the need to commission with some frequency.

Figure 18. *Two views of the persistence commissioning energy savings: 36 projects.*





Note: The upper panel plots the energy use in each post-commissioning year, with the pre-commissioning value set at 100%. The lower panel plots the change in percentage savings for each year (starting with year 2 versus year 1). Note that the decline in "Total" savings in year three is attributed to the discontinuation of some of the "better" data series after two years.

Trust, But Verify

As with most other energy-efficiency measures, commissioning savings are often roughly estimated or out-and-out stipulated based on little more than best guesses.

The imperative for measurement has increased as energy prices soar, concerns intensify about securing reductions in greenhouse gas emissions, and demand-side programs come under closer scrutiny and expectations that savings be measured and verified. In addition, there are strong engineering arguments that better due-diligence during and after the commissioning project can identify deficiencies that would otherwise go undetected. Thus, a measurement-based paradigm certainly does not imply that savings will necessarily prove lower than estimates.

In a previously referenced example of the value of measurement, a data center was believed to be attaining 14% savings (Nodal 2008). Upon conducting a number of measurements within the commissioning process, it was discovered that there were actually no savings. Proper adjustments not only recovered the “lost” savings but actually *increased* them by a third, to a total savings of 19.2%.

In another example, the commissioning of an existing hospital was projected to garner annual savings of just over $56,000. A first-order calculation and inspection led to a revised savings estimate of under $53,000. The subsequent application of full “retrofit isolation” measurement technique, per the International Performance Measurement and Verification Protocols (IPMVP), identified additional savings opportunities, bringing the verified total to nearly $74,000—a 31% increase over the original estimate. The additional effort came at a price, but overall payback times remained well below one year (Chitwood et al. 2007).

The aforementioned issue of savings persistence has also contributed to the healthy interest in applying a higher level of measurement-based approach to commissioning than is typically the case. Program operators, however, have articulated various barriers, which include lack of staff, monitoring data that are useful and understandable, empowering those doing the monitoring to act on the results (to intervene if the data suggest that savings are being forfeit), and lack of information on the cost-effectiveness of monitoring (Long and Crowe 2008).

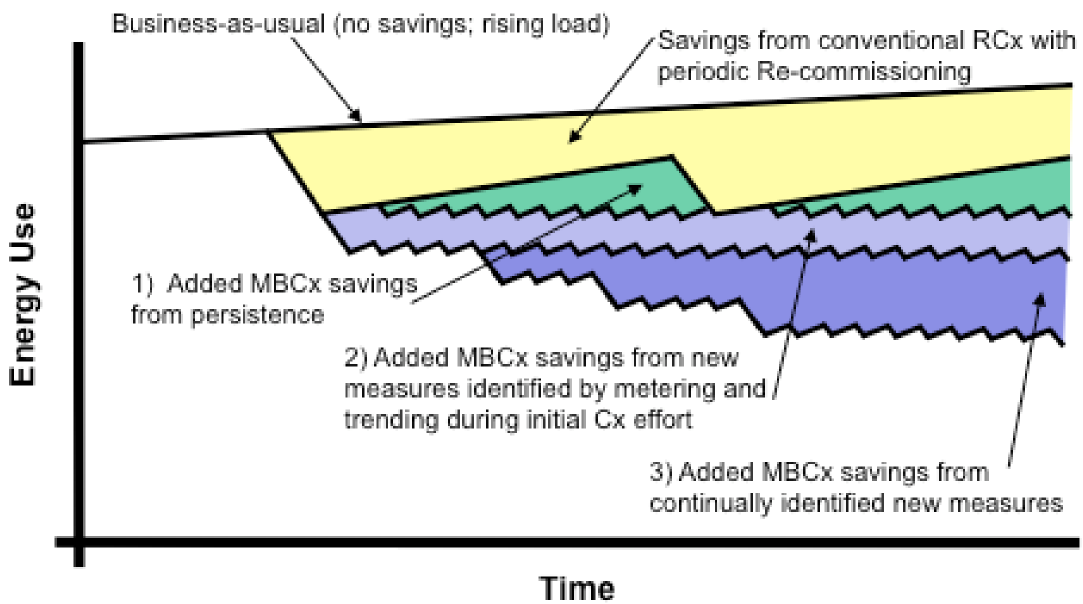
Monitoring is a tool for benchmarking and identifying savings opportunities that may otherwise go undetected. One of Xcel Energy’s most successful commissioning projects attributes its high peak-demand savings (221 kW) to the presence of a sophisticated energy monitoring and control system that was used to implement “creative control strategies at little cost” (Mueller et al. 2004).

The field has responded to this opportunity through increased use of monitoring, e.g., as practiced early on within various research-based projects by Texas A&M University and increasingly in projects within the University of California and California State University systems.

The Monitoring-based Commissioning Paradigm

An emerging formalization of measurement in the commissioning process is known as monitoring-based commissioning (MBCx). As discussed by Mills and Mathew (2009), monitoring-based commissioning can also be thought of as monitoring-enhanced building operation that incorporates three components: (1) permanent energy information systems (EIS) and diagnostic tools at the whole-building and sub-system level; (2) commissioning based on the information from these tools and savings accounting emphasizing measurement as opposed to estimation or assumptions; and (3) ongoing commissioning to ensure efficient building operations. MBCx is thus a measurement-based paradigm that affords better risk management and also helps to identify problems and opportunities that are missed with periodic commissioning. The fundamental goal is to garner more and more persistent energy savings (Figure 19).

Figure 19. *MBCx provides three streams of additional energy savings relative to conventional commissioning of an existing facility.*



An initial outline of the theory and practice, coupled with an evaluation of 13 projects was performed by Brown et al. (2006), followed by an evaluation of 21 projects by Mills and Mathew (2009). These projects have been integrated into our meta-analysis database. The analysis was based on in-depth benchmarking of a portfolio of MBCx energy savings for buildings located throughout the University of California and California State University systems. A total of 1120 deficiency-intervention combinations were identified (Mills and Mathew 2009). From these interventions flowed significant and highly cost-effective energy savings. For the MBCx cohort, source energy savings of 10% were achieved, with a range of 2% to 25%. Peak electrical demand savings were 0.2 watts per square foot per year (W/ft^2-year) (4%), with a range of 3% to 11%. Costs ranged from

\$0.37/ft^2 to 1.62/ft^2, with a median value of \$1.00/ft^2 for buildings that implemented MBCx projects. Half of the projects were in buildings containing complex and energy-intensive laboratory space, with the higher costs associated with these projects. Median energy cost savings were \$0.25/ft^2, for a median simple payback time of 2.5 years. The greatest absolute energy savings and shortest payback times were achieved in the subset of laboratory-type facilities.

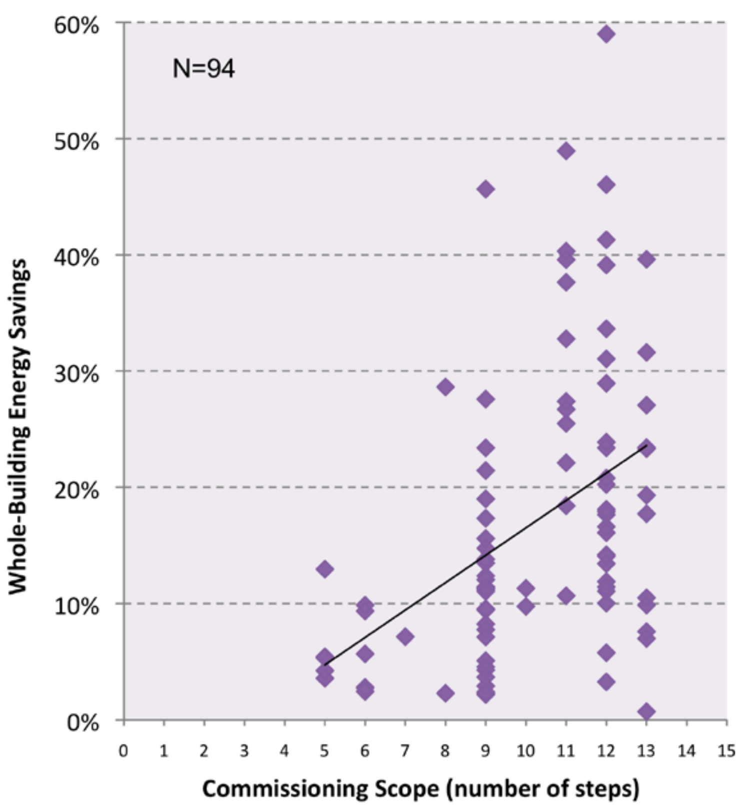
An evaluation of California utility-funded commissioning programs attributed higher savings to those that were monitoring-based (PECI and Summit Building Engineers 2007).

Best Practices

When viewed in terms of outcomes, the best practices we have observed result in zero- or negative net cost as non-energy benefits more than offset commissioning fees. The resulting payback times are in effect instantaneous, combined with energy savings surpassing 50% whole-building energy use.

Such large energy savings of course depend on thorough commissioning and the presence of serious problems at the outset, but it is clear that in more than half the cases in our database saved above our median value of 16%, and higher savings were correlated strongly with the breadth of the commissioning undertaking (Figure 20).

Figure 20. *Depth of commissioning versus savings achieved (existing buildings).*



Projects with a comprehensive approach to commissioning attained nearly twice the overall median level of savings and five-times the savings of the least-thorough projects. Comprehensiveness is measured in terms of the number of pre-defined steps/phases included in the commissioning process.[13]

In terms of application, it is critical that commissioning be well integrated with the rest of the building lifecycle and associated services. These include design and design-intent documentation at the early stages of the project cycle, through benchmarking performance to identify baseline performance and savings opportunities, and a monitoring-based paradigm for identifying and quantifying opportunities on an ongoing basis.

Within the commissioning process are a wide number of steps and documentation and training (Box A), which should be but are rarely all exercised in practice. For new and existing buildings alike, periodic recommissioning is often called for. For new construction this dictates introducing the commissioning agent at the very outset of the design and planning process and keeping them on board well through startup and into the warranty period. This is often not the case in practice, i.e., in only about one-quarter of our projects was commissioning begun during the design phase, and in only one-third of the cases did it include construction observation.

To have maximum impact, commissioning must address the whole building. Many of our case studies are selective in their focus, e.g., addressing space-conditioning systems to the exclusion of service water heating, lighting, plug loads, and envelopes.

Lastly, much better practices are needed in the documentation of commissioning projects and creation of case studies. The current literature is fraught with ambiguities and non-standard definitions. When quality control protocols are applied along with benchmarking analyses[14] that require very specific data—as is done in this report—much of the existing literature is not usable. Areas requiring clear definition include factors such as correlating floor area to commissioning cost, extent of end uses and fuels included in savings estimates, weather-normalization of pre-/post-commissioning data, specific costs included and excluded, and clarity as to whether measures and savings have been verified.

[13] Details available at http://cx.lbl.gov/documents/2009-study/supplemental-information.pdf
[14] A quality control/quality assurance checklist is provided in Mills and Mathew (2009).

The Ultimate Potential for Commissioning

Applying our median whole-building energy savings value (i.e. not best practices) to the stock of U.S. non-residential buildings corresponds to an annual energy-savings potential of $30 billion by the year 2030, which in turn corresponds to annual greenhouse gas emissions of about 340 megatons of CO_2 each year.[15] Commissioning is thus a formidable efficiency "measure" in its own right. In some cases it enables the achievement and maximizes the impact of other more traditional measures. In other cases, it provides savings independently of other measures. Like other energy-efficiency measures, it has a cost, associated savings, and a given "lifetime," or period of persistence.

Scores of studies have been conducted on the potential for energy savings. Few, if any, have rigorously included the costs and benefits of building commissioning. However, many such studies examine the "technical potential," other measures which, rather, implicitly assumes that all measures work perfectly and, typically, that they fully penetrate the targeted stock of buildings. This would require considerable commissioning effort and generate equally considerable rewards.

To put the potential for commissioning in context, Figure 21 shows the significant carbon reductions that commissioning of U.S. commercial buildings would represent in context with a prominent study of the potential for a wide range of other strategies. This exercise reveals that not only is commissioning among the very most cost-effective strategies for reducing greenhouse gas emissions, but it is also a large absolute source of savings, as indicated by the width of the step in the figure.

Thorough potential studies must also incorporate the role of commissioning in extending the persistence of other energy-efficiency measures, as well as the finite persistence of commissioning itself. Commissioning is also a delivery mechanism for operator training, which supports maintenance and extension of the savings potential of virtually all other carbon-abatement strategies in buildings.

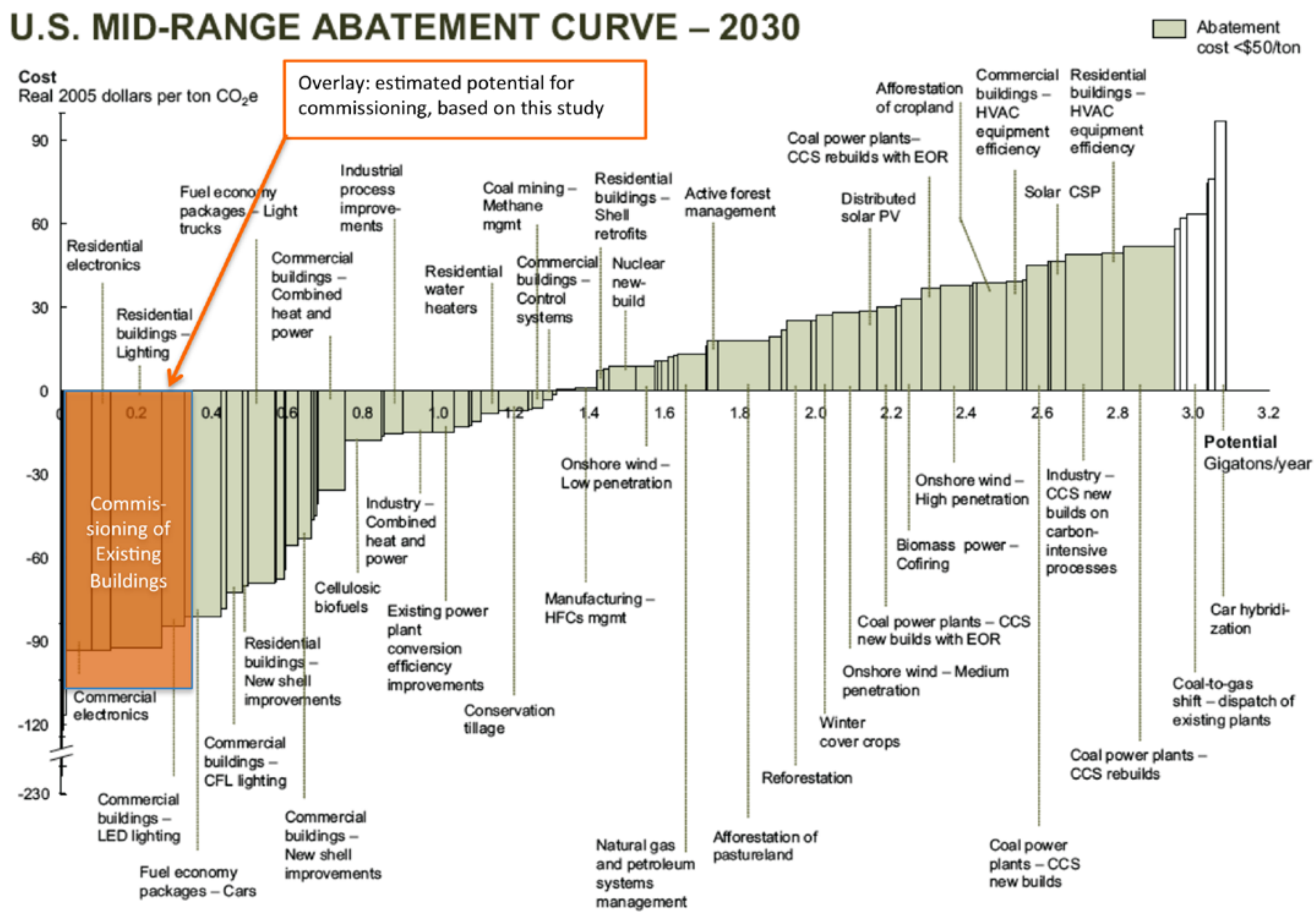
Projections of commissioning cost-benefits should also consider trends in costs and impacts. Delivery costs will be driven in large part by trends in labor prices, although as this relatively young industry moves up the learning curve, delivery will become more time-efficient. New technologies such as advanced metering, wireless sensors, and "automated commissioning" electronics stand to considerably reduce the costs. The value of energy savings will be pegged to energy prices, which will rise in the long term.

Non-energy benefits should also be incorporated in potentials studies. As borne out by the data presented in this report, they are significant and today generally not monetized;

[15] We assume energy consumption per DOE/EIA (2003), demand growth per the U.S. Energy Information Administration's *Annual Energy Outlook* (2007), median commissioning energy savings of 16% (per this study) and the energy price default values used in preparing this report.

this may change in the future. One certain example of this final point will be when a cost/value is assigned to greenhouse gas emissions.

Figure 21. *Potential U.S. carbon savings from commissioning in context with other options.*



Sources: Green curve based on Mckinsey and the Conference Board (2007), and Orange step overlay based on this study.

Notes. The overlaid orange bar is derived from the analysis in this report and superimposed for reference over the green carbon "abatement curve" published by McKinsey (McKinsey & Company and the Conference Board (2007). The full abatement curve indicates the potential emissions savings potential for a range of measures, ranked by the annualized net cost per ton of emissions reductions (y-axis), i.e., the cost of commissioning minus the value of the resulting energy savings over the measure life. The horizontal width of each step is the potential emissions reduction attributed to each measure for the particular scenario considered. The height of the orange step reflects the median cost of avoided carbon for commissioning derived in this report, and the width represents a potential 16% reduction (median value from this report) in commercial-building emissions projected for the year 2030. To estimate the baseline emissions in 2030, *commercial buildings emissions from 2005 are scaled by the projected growth in commercial floor area (EIA 2006). The mid-range scenario is described as one that "involves concerted action across the economy."*

Research Frontiers

Those who study and evaluate commissioning have a wealth of interesting technical and market-based issues to address. These include: garnering greater insight into the mechanics of savings persistence, optimal application of measurement and monitoring, decreasing the cost of delivering and reaching difficult market segments, and filling in gaps in the types of facilities for which good case-study data are available. Commissioning is becoming more specialized towards individual systems, although certain end uses (e.g., plug loads) are less well addressed than the heating, ventilating, and air-conditioning systems with which most commisisoning practitioners are most familiar. Few studies have examined the commissioning of central plants, and few have reached outside the commercial buildings sector to address industrial facilities or multifamily residential buildings.

Most of the rigorously documented commissioning projects appear to be limited to the United States. It is important to expand the practice of commissioning project data collection and evaluation to other parts of the world.

Numerous emerging technologies are entering the marketplace. Among these are solid-state lighting systems, integrated daylight-dimming and automated window shading systems, electric demand control methods and technologies, wireless controls, and a host of smart-grid strategies. Each will bring new risks along with opportunities for energy savings. In one example—a chilled-beam cooling project at a major research laboratory—about 30% of the 100 condensation sensors failed (Mantai 2009). It is critical that the practice of commissioning keep pace with the introduction of new technologies in order for their energy-savings potential to be realized.

With the new imperative of climate change, more effort must also be focused on tailoring commissioning services to the reduction of greenhouse gas emissions. As carbon savings achieve greater economic value, verifying and ensuring the persistence of reductions will become an increasingly important role for the commissioning provider. Little has yet been done on the related but broader theme of green-buildings (e.g. water use and green materials/practices) commissioning and quality assurance.

There is currently rising interest in the "softer" fields of energy research focusing on human decision-making and behavior by end users and intermediaries. These questions are central to both the uptake and practice of commissioning. While awareness of commissioning is low among building owners, it is equally low among energy policymakers (most of whom are not even familiar with the term).

Commissioning America in a Decade

Since our 2004 review of commissioning experience, the field has bourgeoned with large increases in the number of projects and the scale of coordinated deployment programs. The next tier of growth may prove more challenging, but will also be more rewarding. Given the need to reduced greenhouse-gas emissions, there is an unprecedented urgency to capture and retain energy savings wherever they can be found. With the high cost-effectiveness of commissioning, the practice will continue to be looked to as part of the solution. Reaching a more meaningful scale will require resolution of various barriers.

Leading commissioning practitioners and other stakeholders were convened at a "Town Hall" meeting in conjunction with the 2008 National Conference on Building Commissioning. The group set out to identify key issues and needs faced by the industry (PECI 2008), and it identified four high-level issues and challenges:[16]

1. **Professionalism:** inadequately trained workforce, insufficient communication within commissioning teams, and uneven quality in the practice
2. **Value Proposition:** low awareness among owners (and concern about persistence of savings), combined with split incentives where owners do not benefit from commissioning services that reduce tenants' energy bills
3. **Standardization:** need for standardization in methods and definitions, while avoiding counterproductive commoditization (where price competes with value)
4. **Fragmentation:** splintered activities and competition among a growing number of trade groups and certification programs

Addressing these issues will be no small challenge, and it will require a well-engineered mix of discipline in the training of commissioning providers and practice of the art, together with awareness-building within the broader end-user/customer community, most of whom have still never heard of commissioning, or, when they do, are skeptical as to its need or value.

The National Energy Management Institute estimated that the current market for commissioning *new* buildings grew from $121 million per year in 2001 to $788 million in 2005, and projected it would reach $1.3 billion 2008 (NEMI 2005).[17]

The vast preponderence of near-term energy savings, hare to be had in existing buildings. The NEMI study estimated that the market for commissioning *existing* buildings grew relatively slowly from $175 million in 2002 to $200 million 2005. NEMI estimates that this level of effort corresponded to 2.3 million labor-hours were spent on commissioning existing buildings, or about 1,150 full-time equivalent workers.[18] At a stipulated retrocommissioning cost of $0.30/ft^2 (based on this study) to deliver retrocommissioning,

[16] Similar findings emerged from a major survey of industry players sponsored by NEMI (2005).
[17] It is not clear whether the NEMI findings are limited to commissioning that includes an energy focus or more broadly at all forms of commissioning.
[18] NEMI states that there are 1.5 million "field-labor" hours per year, which constitute 65% of the total labor. They utilize a billing rate for the work of $65/hour.

the $200 million spent corresponds to about 660 million square feet currently treated each year and even if this is being achieved today it represents less than 1% of the U.S. non-residential building stock.

If, as a thought experiment, a goal was to commission all existing U.S. commercial building floorspace (clearly an upper limit of the need), it would take the existing workforce about 100 years to do so (assuming current practices). Thus, to achieve the goal in a decade would require a 10-fold increase in the workforce (to about 12,000 workers). While this may sound like a large number, consider that as of 2006 there were 292,000 heating, air-conditioning, and refrigeration mechanics and installers; 80,000 electrical and electronics repairers for commercial and industrial equipment; 226,000 mechanical engineers; and 511,000 engineering technicians in the United States.[19]

The corresponding industry would have a sales volume of $2 billion per year for existing buildings commissioning. In addition, there should be some degree of recommissioning to ensure persistence of savings. If done every five years, then the preceding numbers would double to 24,000 workers and a $4 billion market size.

There is clearly more potential demand for commissioning than the existing workforce can meet. One study estimates that only 20% of the existing providers have capacity to take on new projects at any one point in time (PECI and Summit Building Engineering 2007). As commissioning is a highly specialized skill, requiring keen sensibilities, it is not an overnight project to train more providers. An assessment of the record and capacity of workforce development institutions to train providers of energy services identified commissioning as one of the areas in which current programs were deficient, and concluded more generally that:

> *"Workforce development needs of the energy efficiency industry are acute. Employers are not finding sufficiently skilled job applicants in today's market and the anticipated growth of the industry will only increase the severity of the problem in the short term. Educational institutions, at all levels, are not keeping pace with the growth and needs of the energy efficiency industry. … The job creation potential in the energy efficiency industry appears to be very significant and is likely the leading sector in the clean energy field for job growth potential. The industry has need and opportunity for talented and creative thinkers, both in technical and non- technical areas, which will drive the development of a new energy economy …"* (NEEC 2008)

"Commissioning America" in a decade is an ambitious goal, but "do-able" and very consistent with this country's apirations to simultaneously address energy and environmental issues while creating jobs and stimulating sustainable economic activity.

[19] U.S. Bureau of Labor Statistics, http://www.bls.gov/oco/

References

Aldous, F. 2008. "Building Enclosure Commissioning: What's the Big Deal?" Presented at the National Conference on Building Commissioning, April 23.

Amarnani, N. , B. Roberts, N. Hernandez, and M.B. Lo. 2007. "Retrocommissioning (RCx) Sustainable Savings: Are We There Yet?" *Proceedings of the National Conference on Building Commissioning*, May 2-4.

Amarnani, N., and B. Roberts. 2006. "Value of Enterprise Energy Management Information System in retrocommissioning (RCx) Program: Los Angeles County Buildings." Presentation at the Itron Conference, Palm Springs, October.

Barr-Rague, C., and R.Wilkinson. 2005. "Success at Marlboro Memorial Middle School Makes Commissioning 'Business as Usual'." *Proceedings of the National Conference on Building Commissioning*, May 4-6, 2005.

Bell, G. 2007. "Retro-commissioning Laboratories for Energy Efficiency." Laboratories for the 21st Century, *Technical Bulletin*, March 29, 7pp.

Berner, W. H., W. A. Dunn, and D. G. Ventners. 2006. "Rolling the Dice: Using Risk Tolerance to Define Commissioning Scope." *Proceedings of the National Conference on Building Commissioning*, April 19-21.

Beyea, L. 2009. *Existing Building Cx for Energy Savings, Part 1 – How to Spot Opportunities for Fast Paybacks. Proceedings of NCBC 2009.*

Brown, K., J. Harris, and M. Anderson. 2006. "How Monitoring-Based Commissioning Contributes to Energy Efficiency for Commercial Buildings." *Proceedings of the 2006 ACEEE Summer Study of Energy Efficiency in Buildings.* 3:27-40. Washington D.C.: American Council for an Energy-Efficient Economy.

Building Operating Management. 2006. "Roadmap to Better Performance: Retocommissioning Lays out Opportunities for Improvement." March, pp. 60-62.

Chitwood, R., J. Bradford, and Chenggang Liu. 2007. "Practical M&V for Recommissioning Projects." *Proceedings of the National Conference on Building Commissioning*, May 2-4.

Criscione, P. 2008 "What's Working with Existing-Building Commissioning Programs." E Source Focus Report, EDRP-F-23.

Crowe, E. 2009. Personal communication, June 19.

Cx Journal. 2005. "One on One with Phil Welker." *Commissioning Journal*, p. 22, Fall.

Della Barba, M. P. 2005. "The Dollar Value of Commissioning." *Proceedings of the National Conference on Building Commissioning*, May 4-6.

Deringer, J. 2008. "Daylighting Systems - Commissioning (CxDL) to Avoid/Fix Problems," Presented at the National Conference on Building Commissioning, April 23, 2008.

Dorgan, C., R. Cox, and C. Dorgan. No date. "The Value of the Commissioning Process: Costs and Benefits."

EMC Engineers, Inc. No date(a). "Commissioning: GSU Information Technology Building," company fact sheet.

EMC Engineers. No date(b). "Case Study: HVAC Assessment/retrocommissioning: NOAA Weather Forecasting Office, Honolulu."

Emerson. 2004. "Case Study: Emerson Climate Technologies Shows Major Supermarket Chain Valueof E-Comissioning Project."

Franconi, E., M. Selch, J. Bradford, and B. Gruen. 2005. "Third-Year Program Results for a Utility Recommissioning Program." *Proceedings of the National Conference on Building Commissioning*, May 4-6.

Friedman, H. 2004. "A Retrocommissioning Experience." *Proceedings of the National Conference on Building Commissioning*, May 18-20, 2004.

Gowri, K. 2009. "What is new in ASHRAE 90.1-2010?" Proceedings of the National Conference on Building Commissioning, June.

Haasl, T., and K. Heinemeier. 2006a. "California Commissioning Guide: New Buildings." California Commissioning Collaborative.

Haasl, T., and K. Heinemeier. 2006b. “California Commissioning Guide: Existing Buildings.” California Commissioning Collaborative.
Hydeman, M., R. Seidl, and C. Shalley. 2005. “Staying On-Line: Data Center Commissioning.” *ASHRAE Journal*, April.
Jump, D. 2007. “Tracking the Benefits of Retro-Commissioning: M&V Results from Two Buildings.” *Proceedings of the 2007 National Conference on Building Commissioning*, May 2-4 [paper and presentation].
Kunkle, R. 2005. “Assessment of the Building Commissioning Code Provisions in the Seattle and Washington State Energy Codes.” WSUEEP05-007.
Lenihan, K. A. 2007. “Retrocommissioning for Peak Electric Demand Reduction in New York City. *Proceedings of the 2007 National Conference on Building Commissioning*, May 4.
Long, S., and E. Crowe. 2008. “Mainstreaming Retrocommissioning in a Utility Program: Lessons Learned.” *Proceedings of the National Conference on Building Commissioning*, April 22-24, 2008. [paper and presentation]
Lundstrom, C. E. 2004. "Retro-Commissioning a NOAA Weather Forecasting Office." *Proceedings of the National Conference on Building Commissioning*, May 18-20.
Mantai, M. 2009. “Case Study: Furman University Charles H Townes Center for Science.” *Proceedings of the National Conference on Building Commissioning*, June 3-5.
Marsh. 2008. “The Green Built Environment in the United States: 2008 Year-end Update of The State of the Insurance Marketplace.” Report #MA9-10017. New York, 19pp.
McIntosh, D.W. 2008. "Retro Commissioning in Connecticut,” *Proceedings of the National Conference on Building Commissioning*, April 22-24, 2008.
McKinsey & Company and the Conference Board. 2007. “Reducing U.S. Greenhouse Gas Emissions: How Much at What Cost?” December. 83pp.
Mills. 2009a. “From Risk to Opportunity 2009: Insurer Responses to Climate Change.” Ceres.
Mills. 2009b. “Sustainable Scientists.” *Environmental Science and Technology*, February, 43(4):973-1238.
Mills, E., and P. Mathew. 2009. “Monitoring-Based Commissioning: Benchmarking Analysis of 24 UC/CSU/IOU Projects.” Lawrence Berkeley National Laboratory Report number 1972E.
Mills, E., H. Friedman, T. Powell, N. Bourassa, D. Claridge, T. Haasl, and M. A. Piette. 2004. "The Cost-Effectiveness of Commercial-Buildings Commissioning: A Meta-Analysis of Energy and Non-Energy Impacts in Existing Buildings and New Construction in the United States." Lawrence Berkeley National Laboratory Report No.56637 http://cx.lbl.gov/2004-assessment.html.
Mills, E., G. Shamshoian, M. Blazek, P. Naughton, R.S. Seese, W. Tschudi, and D. Sartor. 2007. "The Business Case for Energy Management in High-Tech Industries." *Energy Efficiency*, 1(1). DOI 10.1007/s12053-007-9000-8. http://eetd.lbl.gov/emills/PUBS/PDF/Mills-JEE-HT.pdf
Mittal, V., and M. Hammond. 2008. “Evolution of Commissioning within a School District: Provider and Owner/Operator Perspectives.” *Proceedings of the National Conference on Building Commissioning*, April 22-24.
Mueller, K., T. Phillips, and E. Jeannette. 2004. “Xcel Energy’s Recommissioning Program for the Colorado Front Range: A Recommissioning Provider’s Perspective.” *Proceedings of the National Conference on Building Commissioning*, May 18-20.
NEEC. 2008. “Workforce Development Needs of the Energy Efficiency Industry Survey Results from Washington and Oregon.” Northwest Energy Efficiency Council, November, 10pp.
NEMI. 2001. “Building Commissioning Market Industry Analysis.” National Energy Management Institute, November, 73 pages.
NEMI. 2002. “Retro-commissioning Existing Building Inventory.” National Energy Management Institute. February, 65 pp. http://www.nemionline.org/downloads/hvac/2_Retro-Commissioning.pdf.
NEMI. 2005. “Building Commissioning, Testing, Adjusting, and Balancing.” National Energy Management Institute. July 15, 130 pp. http://www.nemionline.org/downloads/NEMIBuildingCommissioningTABMarketResearch2005.pdf.
Nodal, G. 2008. "Energy Conservation Auditing." *Focus Magazine*, Issue 26. DatacenterDynamics. July.
PECI. 2000. “Final Report—California Commissioning Market Characterization Study.” A Report Prepared for Pacific Gas and Electric Company. November.
PECI. 2008. “2008 NCBC Town Hall White Paper.” Listen to excerpts from the session: http://www.peci.org/ncbc/Podcast/Cx360.mp3.

PECI and Summit Building Engineering. 2007. “2007 California Retrocommissioning Market Characterization.” April, 11 pages.

Peterson, J. 2004. “Five-year Results from a Utility Commissioning Program.”

Pierce, R. A., and N. Amarnani. 2006. "A Competitively Bid Retrocommissioning Project in the County of Los Angeles - A Model Process?" *Proceedings of the National Conference on Building Commissioning*, April 19-21.

Pinnix, D. S., K. D. Hahn, J. I. Givens, and P. J. Stefancin. 2004. "University of North Carolina, Greensboro Science and Laboratory Building - A Case Study." *Proceedings of the National Conference on Building Commissioning:* May 18-20.

Pollard, P. 2009. “Prioritizing Persistence: Approaches and Technologies that Enable Lasting Savings.” *Proceedings of the National Conference on Building Commissioning:* June 3-5.

Ross. 2008. “Mission Critical Commissioning for Healthcare Facilities.” *Proceedings of the National Conference on Building Commissioning*, April 22-24, 2008.

Roth, K.W. D. Westphaler, M.Y. Feng, Patricia Llana, and L. Quartararo. 2005. "Energy Impact of Commercial Building Controls and Performance Diagnostics: Market Characterization, Energy Impact of Building Faults and Energy Savings Potential: Final Report." Prepared by TAIX LLC for the U.S. Department of Energy. November. 412 pp (Table 2-1).

Selch, M., and J. Bradford. 2005. “Recommissioning Energy Savings Persistence.” *Proceedings of the National Conference on Building Commissioning*, May 4-6, 2005.

Sellers, D. No date. "The AHU from Hell." Presentation to ASHRAE Inland Empire Chapter.

Sellers, D. 2009. “Testing a Cleanroom for Leakage.” Construction Specifying Engineering online, January 19, http://www.csemag.com/blog/1250000325/post/570039457.html.

Sellers, D., and L. Irvine. 2001. “Commissioning to Meet Space Qualification Criteria vs. Energy Consumption Optimization Focused Commissioning.” *Proceedings of the 2001 International Conference on Enhanced Building Operations.* www.peci.org/library/PECI_CxCriteria1_1002.pdf.

Sellers, D., and J. Zazzara. 2004. "Supermarket Commissioning; Designing, Operating, and Maintaining Peak Efficiency." Presentation, September 28.

Stum, K. 2008. "Underfloor Air Distribution Systems and their Commissioning." Presented at the National Conference on Building Commissioning, April 23.

Taylor, R. 2008. “Hedging Bets on the Green Gamble: Addressing Risks in the Design, Construction and Operation of Green Buildings.” AON Environmental Services Group, November 2, 25pp.

Tso, B., L. Skumatz, and J. Jennings. 2003. “The Cost-Effectiveness of Commissioning Public Buildings in the Pacific Northwest,” *Proceedings of the National Conference on Building Commissioning:* May 20-22.

U.S. Department of Energy. 2009. “Greenhouse gas abatement in the U.S. and the role of the Department of Energy’s Office of Energy Efficiency and Renewable Energy.” U.S. Department of Energy and National Renewable Energy Laboratory, January, 108pp.

U.S. Energy Information Administration. 2006. *Annual Energy Outlook 2007: With Projections to 2030.* DOE/EIA-0383(2007). February.

U.S. Energy Information Administration. Commercial Buildings Energy Consumption Survey: 2003. http://www.eia.doe.gov/emeu/cbecs/

Zazzara, J. B., and D. F. Ward. 2004. “Case Study: Supermarket Commissioning with an Emphasis on Energy Reduction.” *Proceedings of the National Conference on Building Commissioning*, May 18-20, 2004.

[redacted]

A Utility's Perspective on Retro-commissioning

Implementing Comprehensive and Effective RCx Programs

Dylan Matthews
Program Manager
Commonwealth Edison

ComEd®
An Exelon Company

AIA Quality Assurance

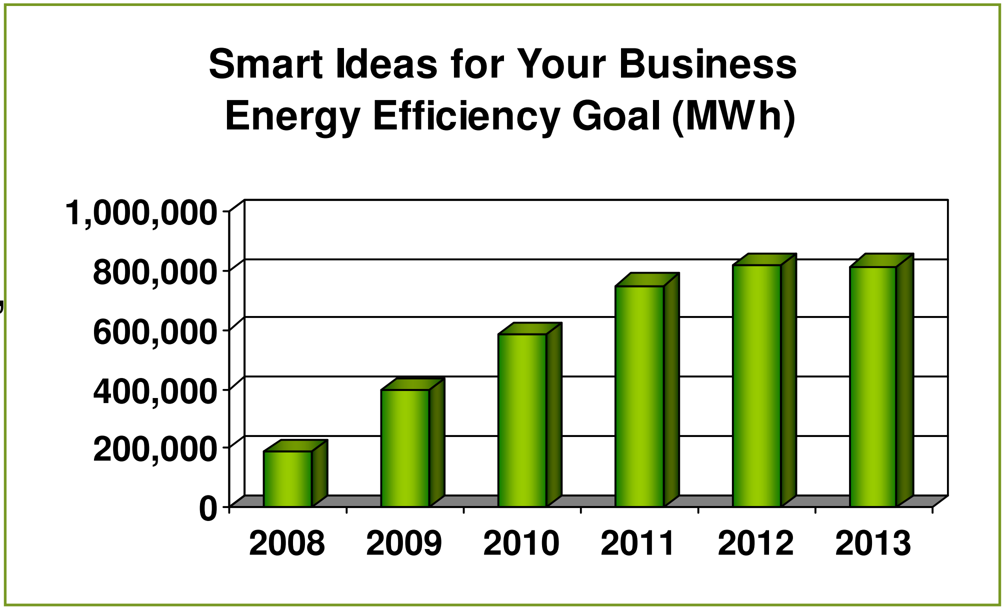
Learning Objectives

1. **Retro-commissioning Program Overview**
2. **Savings analysis breakdown by measure, customer, and building type**
3. **Program design changes and lessons learned**
4. **Vital elements for the successful scale-up of a utility sponsored RCx Program**

Smart Ideas Background

What is the Smart Ideas Program?

- Provides incentives for energy efficient upgrades and incentives
- Part of Illinois energy legislation passed in 2007
- Program implemented by ComEd, Ameren Illinois, and the Illinois Department of Commerce and Economic Opportunity
- ComEd goal: Reduce energy consumption by nearly 2 million MWh over the next 3 years



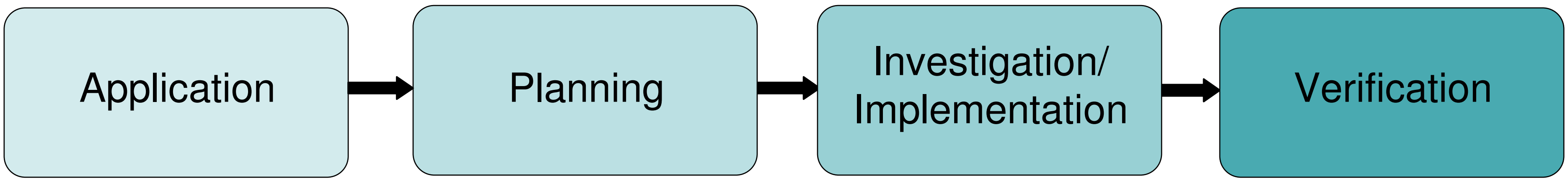
Retro-Commissioning

<u>Key Features</u>

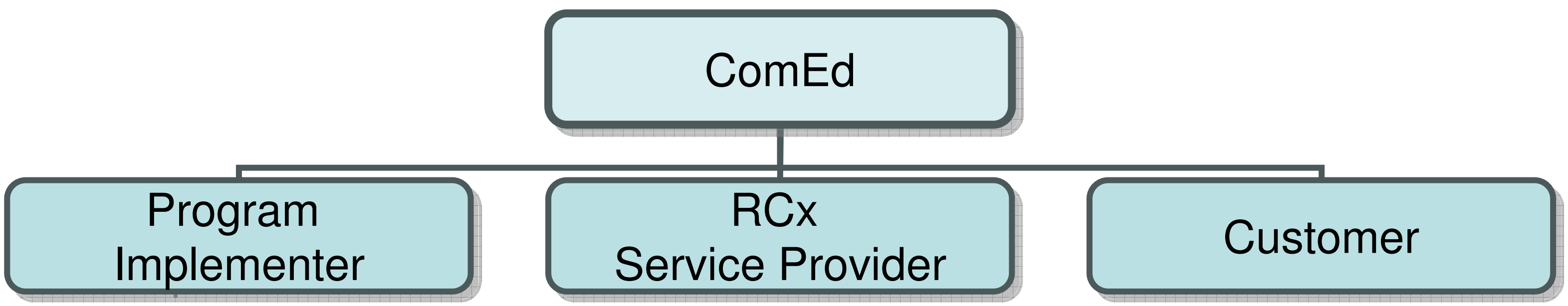
- Incentive is the cost of engineering study and M&V
- Study performed by ComEd-approved service provider
- Electric and Gas
- 500 kW and larger
- 150,000 sq ft and larger
- Measure implementation deadline
- Customer implementation requirement of $15,000 or $30,000

Program Design

Process



Players

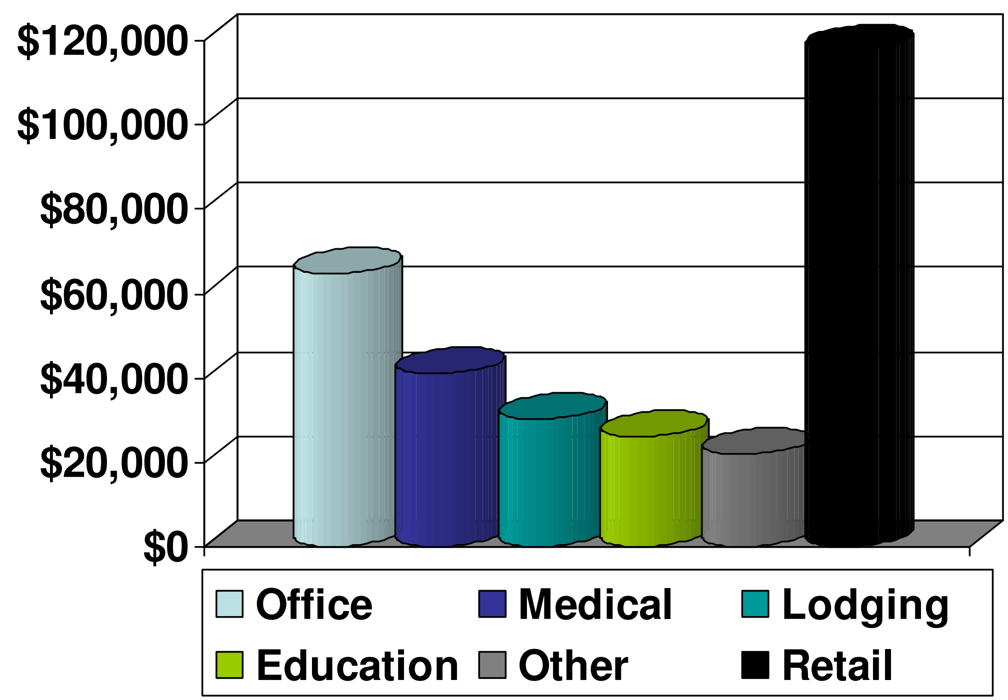


Retro-Commissioning Metrics

Program Year 3	
Target:	10,984 MWh
Verified:	22,662 MWh
Accepted Projects:	35
Acceptance Rate:	67%
Cost:	$0.139/kWh
	$0.154/ft^2

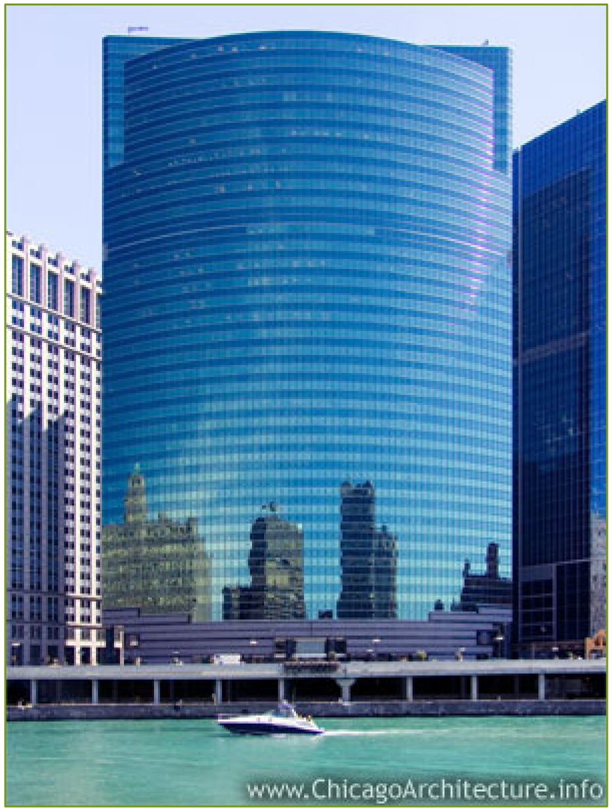
Program Year 4	
Target:	33,600 MWh
Currently:	23,453 MWh
Accepted Projects:	42

MWh Savings by Building Type



Case Study – 333 W. Wacker Dr.

- 999,480 sq ft
- Value of incentive: $104,945
- Annual energy savings: 1,664,000 kWh
- Annual cost savings: $173,000
- Total implementation cost: $43,606
- Payback period: 4 months



Case Study – 333 W. Wacker Dr.

Measures Implemented

- Minimize Simultaneous Heating and Cooling
- Fan scheduling
- Optimize Air Flow (Re-balancing VAV boxes)
- Seal Supply Ductwork

Case Study – Underperforming Project

- 371,250 sq ft
- Value of incentive: $40,425
- Annual energy savings: 288,646 kWh
- Annual cost savings: $19,269
- Total implementation cost: $5,300
- Payback period: <4 months

Case Study – Underperforming Project

1,000 MWhs targeted
522 MWhs planned

Measures Recommended

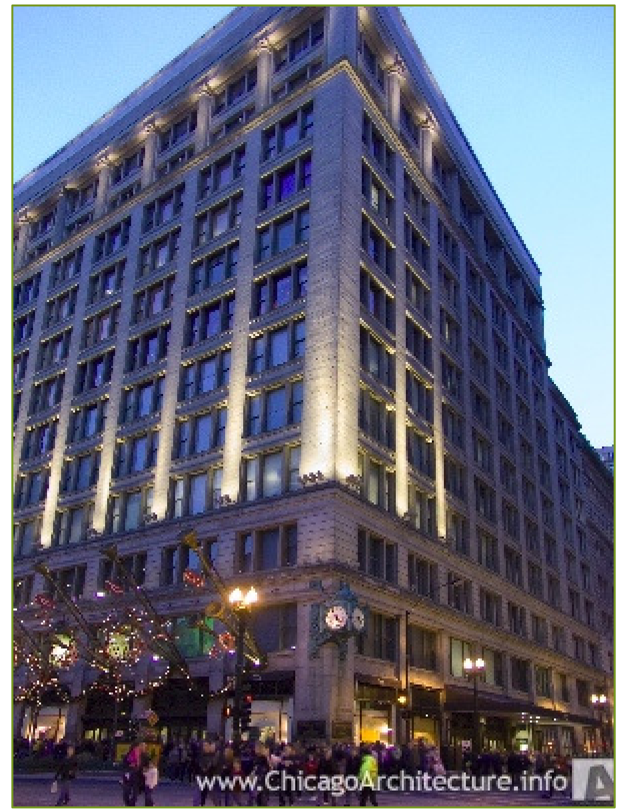
- Occupancy scheduling for air handling units
- Nighttime Setback temperatures
- Service equipment

Reasons for Underperformance

- Change in facility management
- Customer changed scope of recommendation
- Program timeline limitations
- Appropriate baseline not established per D&Cs/M&V guidelines

Case Study – Macy's

- 2,016,000 sq ft
- Value of incentive: $100,000
- Annual energy savings: 3,781,005 kWh
- Annual cost savings: $306,473
- Total implementation cost: $39,280
- Payback period: < 2 months



Case Study – Macy's

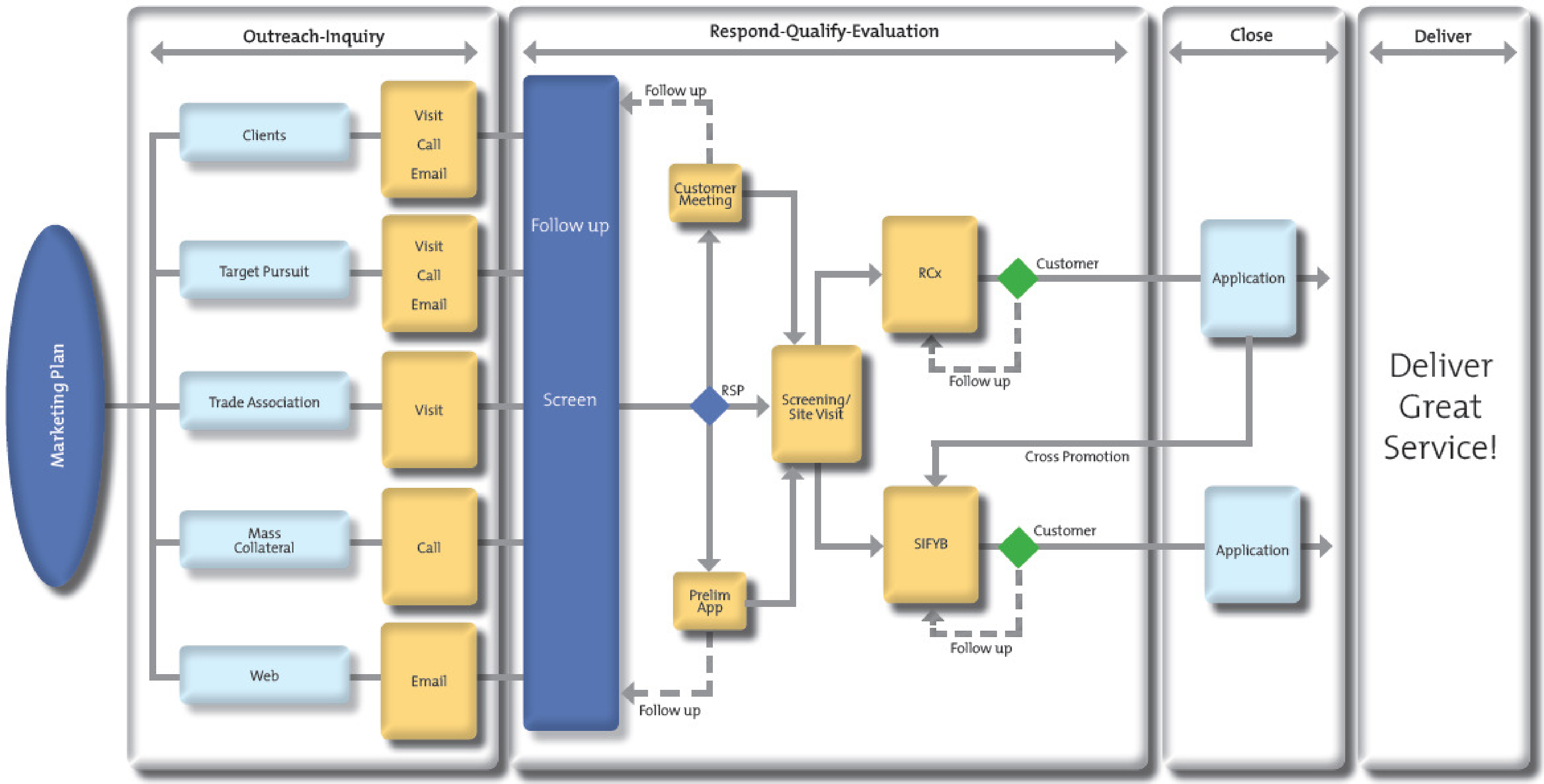
Measures Implemented

- Reduce AHU fan speeds
- Optimize chilled water pump flow
- Reduce air compressor requirements
- Shut down unused exhaust fan
- Improve exhaust systems

Program Lessons Learned

- Screen applicants carefully
- Managing timelines is a big challenge
- Incentives need to be profitable for RSPs
- Customers need accurate baselines
  - Energy usage
  - Equipment condition
- Repeat business and referrals are critical

Sales Cycle for Service Providers



Selling Points

Free study/See the recommendations before committing to the Agreement

Short paybacks

Improved tenant environment

Two clients - the customer & the utility (and we said yes already)

Verification reports

Anticipated Future Direction

- Joint utility offering
- Marketing and awareness campaign
- Monitoring based commissioning
- Integration with a commercial real estate program
- Studying viability of smaller buildings
- Cost-effectiveness

AIA Quality Assurance

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Thank You!

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