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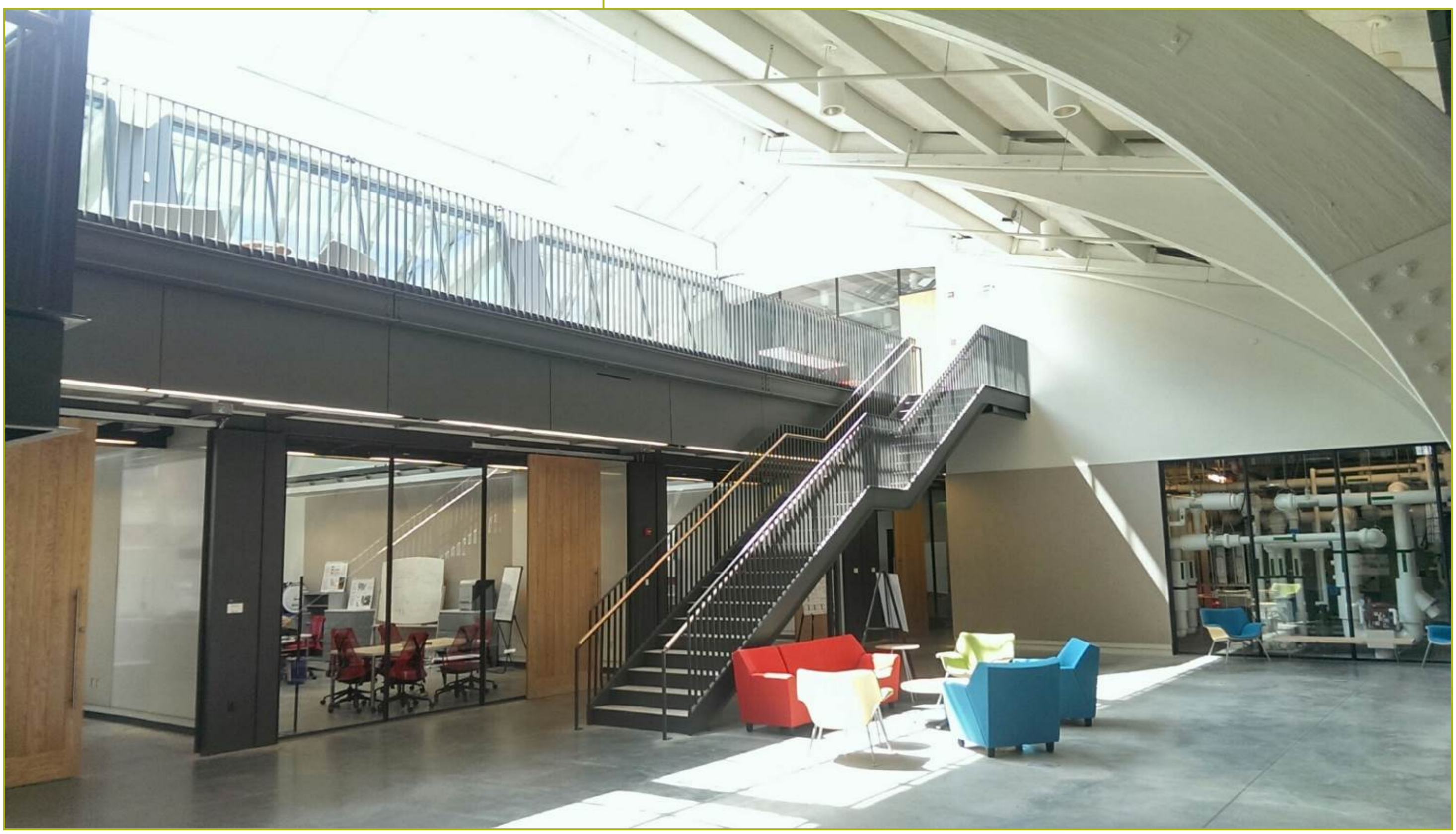

CBEI was referred to as the Energy Efficiency Buildings HUB at the time this report was developed.

REPORT

Report Abstract

CBEI conducted an analysis of the interconnectedness of investment, technology, behavior, and governance to the energy system for the Alliance Commission on National Energy Efficiency Policy

Contact Information for Lead Researcher

Name: Mark Alan Hughes
Institution: University of Pennsylvania

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SYSTEMS INTEGRATION REPORT

Work group members:

Mark Alan Hughes, EEB Hub
Austin Brown, NREL
Stefan Buettner, Scottish Parliament
Dick DeBlasio, NREL
Elizabeth Noll, AGA
Jim Presswood
Barbara Tyran, EPRI
Nicole Steele, Alliance to Save Energy

Preamble

The Alliance Commission on National Energy Efficiency Policy (the Commission) was organized to study energy-efficiency policies, programs, and opportunities, and to make consensus recommendations on the next generation of domestic policies, programs, and practices to ensure that the U.S. can double its energy productivity (twice as much gross domestic product (GDP) from each unit of energy) from 2011 to 2030.

The work of the Commission will include an assessment of the current state of energy efficiency in the U.S. economy; a review and assessment of the best local, state, and national practices; and the development of a set of recommendations on policies and programs for the next administration and the 113th Congress to achieve the stated goal of doubling U.S. energy productivity by 2030.

This report, Systems Integration, is one of seven research reports that assess the current state of efficiency within the economy and review the best local, state, and national practices. These assessments will be used to support and provide the technical basis for the Commission's efforts to develop a set of recommendations for doubling the nation's energy productivity. The other reports will address the following areas: history and business case of energy efficiency; energy productivity in American manufacturing; transportation, land use and accessibility; residential and commercial buildings; power generation and smart grid; and natural gas infrastructure.

To provide a comprehensive assessment to the Commission, the "systems integration" report will be a comprehensive analysis of the other research reports to identify common areas of consideration and areas of interdependency. It will also identify opportunities for the various sectors of the economy to work together.

All the reports referenced above are included in the Commission's final report.

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Introduction: Why an Integration Chapter?

The Alliance Commission recognized at its first meeting that any format used to describe the energy system in the United States, such as the sectors that define the preceding reports, would necessarily fail to convey fully the interconnectedness of the energy system. The sectoral chapters are organized using a common set of cross-cutting topics: investment, technology, behavior, and governance. This organization helps identify some of the interconnectedness across sectors. This chapter seeks to integrate those points of connection and highlight their importance both to understanding the current energy system and to improving future energy productivity.

Power, industry, mobility, and buildings are four economic sectors identified as critical to energy productivity in the United States. In each of these four sectors, the research of the Alliance Commission identified the importance of technology, investment, behavior, and governance in determining the energy productivity of the sector. The Commission found that, indeed, these cross-cutting themes emerged as significant elements of the challenges and opportunities for energy productivity in the four sectors of the economy we studied. These cross-cutting elements may be thought of as infrastructure: common platforms of technology and behavior and so on that support multiple sectors of the economy. Modernizing this infrastructure is critical to the productivity of the sectors.

In the preceding chapters of this report, the Alliance Commission presented research on energy generation efficiencies and power delivery efficiencies, as well as end-use application efficiencies in the three sectors of the U.S. economy with the largest energy consumption: buildings, transportation, and industrial. In this chapter, the Commission draws on all of these sources of efficiency and connects them in pursuit of our goal of doubling U.S. energy productivity by 2030. Each of the sections below presents key insights from this systems integration. Everything is indeed connected to everything else. In this chapter, the Commission offers some of the more significant connections. A fuller understanding of the interconnectedness of the energy system may transform a set of barriers to improved energy productivity into a framework for achieving it.

Technology

The four sectoral papers agree that the technological potential for advancing energy productivity while enhancing economic productivity and competitiveness, employment opportunity, quality of life, and energy reliability and security is very large. The opportunities arise from both new, innovative technologies and accelerating the adoption of existing good and best practices, techniques, and technologies.

Further, the rapid advance of information and communication technologies (ICT) is providing the technological tools for a wide array of "smart" and "intelligent" technologies for more efficiently and productively managing energy across all sectors of the economy, including building energy management systems, intelligent manufacturing and industrial controls, smart grid, precision agriculture, intelligent transportation systems, and smart appliances, among others. Success will be assured in real world applications through research and development which identifies and provides improvements through technology validation in the laboratory and in the field. Technology validation should then lead to standardization of interoperability design, products, and requirements for interconnection interfaces and outcomes. Technology barrier removal must be removed initially through validation R&D before anyone entity will make large investments in infrastructural change of the power grid operation.

The electricity industry faces growing demand for power and the imperative to maintain reliable, affordable service that is environmentally responsible. Utilities and policymakers in the United States and abroad are increasingly turning to energy efficiency as a resource to help address these challenges. Many U.S. states have enacted legislation that mandates specific energy efficiency savings goals, and some explicitly require utilities to place energy efficiency atop the loading order in resource planning. Key to the realization of these goals is research and development that enables the adoption of emerging energy-efficient technologies and best practices. Research that focuses on the assessment, testing, and demonstration of energy-efficient and smart end-use devices can accelerate their adoption into utility programs, which can influence the progress of codes and standards and ultimately lead to market transformation. R&D can also establish analytical frameworks essential to utility application of energy efficiency, including assessment of resource potential, characterization of end-use load profiles, calculation of environmental impacts, and integration into utility resource planning.

From Systems Integration to Integrating Systems of Systems

The advanced electricity infrastructure system increases the potential for greater energy productivity by integrating power, communications, end use, and information technologies. It offers the promise for consumers of greater insight about and control over their own energy use and costs, as well as more efficient dispatch of power plants, reduced blackouts, and reduced energy losses in the grid due to greater situational awareness and control by grid operators. As the power and end use systems are upgraded with more flexibility, integrated communications, and advanced controls, it will enable large-scale integration and interoperability of a greater diversity of technologies and result in a smarter and more efficient energy system.

For many years the natural gas infrastructure has met the needs of the consumer. However, it must evolve further to support the level of operations necessary to achieve the vision and associated benefits of a smart energy future. The gas infrastructure can enhance the value of investments made in the electric smart grid, can expand the goals of the current smart grid proposition and can enable new capabilities to enhance safety and reduce the environmental impact of gas distribution. There are also opportunities to support emerging technologies and new markets such as alternative fuel vehicles and hydrogen for fuel cells and to develop even broader holistic energy grids to the benefit of customers.

Technological solutions such as smart grid power system interoperability can provide organizations with the ability to communicate effectively and to transfer meaningful data using a variety of different information systems over widely different infrastructures, sometimes across different geographic regions. The diversity of evolving smart grid technologies intended for use across the entire power grid—from transmission to distribution and, ultimately, to enabled devices used at homes and businesses —presents significant challenges to achieving efficient interoperability. The utility-There are energy savings opportunities that are enabled by customer options at the distribution level, the adoption of which can only be accomplished when elements of more holistic systems fully consider the costs and benefits of end-use technologies and potential benefits to customers in the near term. Customer-driven demand for options may be a future tool to enable policy makers to pursue a variety of methods to encourage customers to balance the goals of efficiency and cost-effective networks. The utility/customer relationship and the regulatory business model need to also consider the importance of interoperability, enabling data management to be secure, reliable, and efficient, as well as to provide beneficial value.

From Flow of Electrons to Flow of Information

The reliability required for a given data flow is a basic requirement and challenge that needs to be set by power systems. The process for developing specific criteria for a data flow should be iterative in nature based on management systems and methods that assure continual improvement. The energy, information, appliance, and communication industries will need to work together to determine the optimum implementation of interfaces and data links to support the data flows needed to be able to translate between individual system requirements and the requirements of the full energy system. These optimal solutions should evolve over time to increase energy productivity and other metrics of success.

At its most fundamental level, data management must be based on assurances that the data is securely and effectively transferred. Each integration interface will typically contain a wide variety of data. Each data has its own set of characteristics, and each characteristic is independent of any other. These sets of characteristics are determined by usage; therefore the data-use categories could consist of control data, protection data, and/or monitoring data as well as other relevant categories.

Information reliability is sometimes characterized as the ability of a component or system to perform required functions under stated conditions for a stated period of time. Often, qualitative reliability indices are established, such as: 1) Informative: data that is informative in nature but not necessarily important for operations; 2) Important: the failure of information transfer may result in loss of revenue); and 3) Critical: the failure of information transfer may result in compromised safety or damage to equipment. This function needs to be addressed by new management data systems such as cloud technology or other organized systems.

The distribution system is designed to provide electrical energy to each customer in an efficient, reliable, secure, and affordable way. Power flow on typical legacy distribution systems are uni-directional with the flow being from the substation to the customer. Many distribution systems have or will have bi-directional power flow due to the topology of their design or the fact that customer-owned generation in excess of the customer's load is located on the distribution system. The use of communications and sophisticated control devices must take into account, through digital control and coordination, this inherent communication of information present in grid operations to avoid unintended consequences due to control interactions. Full evaluation and an understanding of all interfaces and impacts on the power system's operation are critical.

The natural gas transmission and distribution systems also benefit from advances in communications and safety. The integration of natural gas infrastructure into a smart energy grid has the potential to enable grid managers to more quickly identify, locate and assess damage to the natural gas distribution system and to allow for quicker and more cost-effective repairs and safe return to service. As well energy decisions are increasingly moving closer to the point of use which reduces the energy losses associated with transmission and distribution. Distributed energy technologies generate electricity more efficiently than large scale generation plants and allow for significant energy productivity gains to be realized.

From Powering the Economy to Empowering the Economy

Advanced technologies have dramatically increased the resolution of data available about customer energy usage. Information- and behavior-based products and programs, such as web portals, home energy reports, in-home displays, and information access protocols enable utilities and third-party providers to offer their customers more insight into how to save energy. Ensuring the availability of detailed usage data via smart meters and smart equipment is a critical first step. To optimize the use of natural gas, electricity and other energy resources, accurate and comparable information must be available to consumers. This information must enable direct and fair comparisons of cost, reliability, efficiency and other attributes of importance to consumers. Improving sensing and communications technologies coupled with advanced metering options for residential, commercial and industrial consumers can provide tremendous insight on how individual appliances and equipment can be managed cost effectively. Armed with this information, consumers will be able to make choices about their energy usage and reduce their energy cost.

The data provided by these technological advances may motivate customers to take action to reduce energy waste and help teach them what actions would be most effective. Availability of this level of detailed information, which has become status quo in other industries such as banking and telecommunications, will permit consumers to both understand and better control their energy choices. However, because customers may not have a comprehensive understanding of this type of granular energy data we must both educate consumers and present the information in useful ways so that they can successfully manage their energy and optimize energy productivity.

The Impact of Risk and Adoption of Technology and Practice

Technology investment decisions are also shaped by incomplete, uncertain, and potentially untrustworthy information on the performance of energy productivity performance improvement options. Consumers may be unwilling to trust an equipment vendor who wants to make a sale or the technical assistance advice of an outsider. They may also have doubts about whether the new or modified technology, equipment, or practice is reliable and cost-effective. Some technologies may not be immediately compatible with current operations and could cause disruptions or affect product quality. These factors can slow adoption, but can be addressed with strong quality control and informational practices.

Everett Rogers described variables that affect the rate of adoption of innovations.[1] Among these are perceived advantage, compatibility, complexity, trialability, and observability. Potential adopters of a novel practice or technology may be concerned about compatibility with existing processes, products, skill sets, and business relationships and practices. The person will be influenced by whether or not the alternative is (or appears to be) complex (do they understand it, see how it works?). Whether they can try/test is at a modest scale to reduce risk (trialability) and whether the results of others' experience can be easily discerned (observability) are important for resolving questions of relative advantage and compatibility of the proposed technology or practice. Being able to try the new approach on a portion of a production line or facility allows the potential user to mitigate risks of disrupting large parts of its operations for something that may not deliver the expected benefits. Observability is also important for diffusing techniques; seeing a technology or practice work at one plant or in a demonstration facility may give confidence that it will work at one's own facility. In a corporate or organizational setting there's also the question of motivations—will an employee or manager be rewarded or not for trying something new; will they be (or think they will be) punished if the idea does not work as well as expected.

These factors have implications for disseminating energy productivity improvements in all sectors of the economy and among buyers, sellers, and intermediaries throughout the marketplace. Federal and state agencies and vendors provide various fact sheets, case studies, "tool kits," decision software, and other products to help promote energy-efficient technologies, but these may do little to address the perception of risk and associated barriers described here.[2] Information exchanges, mentoring, on-site energy assessments, technology demonstration and validation activities, and on-site technology trials are approaches available to reduce the uncertainty and risk of trying new technologies and techniques, whether related to energy productivity improvements or technological and operational improvements generally.

Awareness versus Validation

A case study from the field of waste reduction illustrates the relative effectiveness of different approaches toward technology diffusion. The Illinois Waste Management and Resource Center (WMRC), now the Illinois Sustainable Technology Center) examined impacts of several forms of outreach it employed in the 1990s to further the use of available but poorly deployed technologies for reducing wastes in the metal finishing industry.[3] The study noted that such technologies as conductivity controls, evaporators, ion exchange, and reverse osmosis had been commercially available for years and shown to be technically and economically beneficial in numerous contexts but had a market penetration rate at the time of around 10%.

WMRC found that "awareness" information (e.g., discussions, literature) alone had little effect on technology adoption. Potential users tended to require deeper "how to" assistance (on-site demonstrations and trials of technologies) before deciding to adopt new technology. The "how to"

[1] Rogers, "Attributes of Innovation and Their Rate of Adoption," Ch. 6.
[2] U.S. Department of Energy "Energy Resource Center."
[3] Lindsey, "Key Factors for Promoting P2 Technology Adoption."

assistance allowed companies to become more familiar and comfortable with technologies, particularly when trials were done with their own parts and chemical baths. This addressed both the "trialability" and "observability" traits identified by Rogers. The WMRC study observed the importance of vendors. In one case a chemical vendor worked with WMRC to resolve compatibility questions, leading that vendor to identify a market opportunity and become an advocate for the pollution preventing technology. Yet in another case, a vendor saw the technology as a threat to its sales and actively discouraged adoption by falsely claiming incompatibilities. Independent third party demonstration and validation of new practices and technologies that provide credible performance data can enhance potential users' confidence that new techniques and technologies will deliver benefits.[4] The general finding is that "awareness" information (brochures, discussions, etc.) has less impact than "how to" information (trials, demonstrations—preferably with the users' own parts and equipment). While this study was in the manufacturing context, the issue applies to residential technologies.

The Technology Bottom Line

These lessons drawn about technology are applicable to sectors throughout the economy. The links between technologies that constitute our energy system are complex, and benefit from a broad understanding that includes the myriad system effects.
Bottom line I think is—

- Very large potential for new tech.
- Very large potential for better diffusion of existing tech.
- Need to think about and manage systems and systems of systems.
- ICT provides tremendous tools to more productively manage energy, from individual device to systems level.
- Potential users/adopters/consumers face uncertainties and risks that can be mitigated through demonstration, validation, tech assistance and other ways; these interact with investment and behavior (and governance).

Investment

The Bottom Line

The dramatic possible improvements in energy intensity cataloged in this report across the fundamental sectors of the U.S. economy of the energy systems and infrastructure, the industrial sector, mobility, and buildings will each require significant capital investment. Achieving a portfolio of these various

[4] The Environmental Protection Agency (EPA) operates the Environmental Technology Verification (ETV) program to provide third party validation services in a number of environmental technology categories. The Department of Defense operates the Environmental Security Technology Certification Program (ESTCP) that demonstrates and validates environmental (and energy) technologies that address defense environmental needs. Some of the technologies verified by the programs are pertinent to manufacturing. Several other verification programs have operated at federal and state levels and abroad, some of which are focused on particular environmental technology categories.

opportunities simultaneously may require investment on a scale unprecedented in the energy efficiency world. The recent economic crisis involved many factors, but also revealed how much capital can flow to investments perceived as safe with acceptable rates of return – in that case real estate financial instruments. The collapse of U.S. real estate and related derivatives means that future savings will need new safe havens with better fundamental value propositions. Energy productivity as an investment has many characteristics that are common to all of the economic sectors examined in the preceding chapters: such as high rate of return and low uncertainty. These characteristics could make energy productivity a compelling haven for these funds, building wealth while simultaneously catalyzing the efficient vision diagrammed in the various chapters.

In addition, energy productivity can be treated as a quantified aspect of other investment vehicles. If energy and locational productivity are incorporated into lending criteria for buildings and industrial plants, this additional data can increase the security of the loans and investments in the real estate sector, resulting in more investment in energy productivity and lower interest rates for projects. It can also alter the tradeoffs faced by facility owners that cause them to forego productive investments with relatively long paybacks.

Productivity improvements are a function of human as well as physical capital. Energy productivity advances will depend on the knowledge, skills, and training of management, technical (including specialist energy managers), and production personnel to discern, evaluate, develop, and implement improvements and operate existing processes efficiently. There is a need for energy and process expertise both in-house at companies and facilities as well as for outside consultants and technical assistance providers.

There is also a need for expertise among the facilitators and intermediaries of energy productivity improvements, such as financiers and appraisers. There is considerable potential to stimulate growth of energy efficiency in buildings through greater use of emerging financial models. Despite ample evidence of energy efficiency measures producing reliable energy cost savings, the mainstream financial community lacks experience and familiarity in this area and encounters difficulties in finding and gaining access to relevant and reliable data sets.

The Opportunity

Historically, investment in energy has largely been focused on the supply side. Oil, coal, and natural gas production are big business in the United States and worldwide, and have no trouble attracting investment through public or private ownership (Large Company Stocks annual return across all sectors: 9.8% and Small Company Stocks annual return across all sectors: 11.9% over the period 1926-2009.)[5] Electric utilities are generally more regulated, but returns a rate acceptable to investors looking for a safe investment in many markets where utilities are investor owned. (10.17% approved utility annual rate of return over past 33 years.)[6] Historically, energy supply has been able to attract far larger

[5] Morningstar Inc. "Morningstar Financial Communication 2010 Image Library," 13.
[6] "2010 Financial Highlights,"2.

amounts of capital than energy use efficiency, and conventional forecasts implicitly assume that it will continue to be this way.

For a variety of reasons, investment in energy productivity has not been directly financed by private capital extensively. Private sector energy productivity investments made routinely such as higher mpg and hybrid cars, more efficient turbines, appliances, building materials, motors, logistics software, and building management systems are challenging to define and estimate, but these investments appear to be increasing and there is a potential to increase investment going forward. In 2009, US administrators spent about $4.6 billion on natural gas and electric efficiency programs. Spending for these programs then increased by over $1 billion in 2010, amounting to $5.7 billion in energy efficiency investments. The budget for natural gas and electric energy efficiency continued to grow, reaching over $8 billion in 2011, around 2.5 times the 2007 budget for these programs[7]. In addition, government programs such as DOE's weatherization program and U.S. Department of Health and Human Services' (HHS) Low Income Home Energy Assistance Program, and a variety of local and state programs, have contributed to national energy productivity. Many investments have come by the user of the energy service-providing items: more efficient appliances are paid for by the purchaser, more efficient trucks by freight companies, more productive buildings are paid for by the building owner, all without being separately accounted.

Despite this investment by the private sector, numerous detailed and credible studies have identified enormous possible financial opportunities in energy productivity. The 2009 McKinsey report "Unlocking Energy Efficiency in the U.S. Economy[8]" report identified more than 7 quadrillion British thermal units (Btus) of savings available (in just the residential, industrial, and commercial sectors) with a 20% effective rate of return, and 10 quadrillion Btus at 4% effective rate of return *after inflation*[9]. Even this lower rate is consistent with or better than rates demanded for safe investments, especially in this era of low interest rates. An independent review by the National Academies[10] similarly found that "4.9–7.7 quads could be saved through cost-effective energy productivity improvements (those with an internal rate of return of at least 10% or that exceeds a company's cost of capital by a risk premium)". These savings equate to billions of dollars of annual savings, portions of which could be passed to the investor. Energy productivity therefore represents one of the great economic opportunities of our time.

Unlocking New Sources of Investment

To achieve this vision for energy productivity improvements, we must bring the power of private markets to bear. Many specific instruments offer the potential to open various productivity opportunities. A recent report by Capital-E[11] identified 11 distinct models and 7 strategies to scale

[7] Wallace and Forster, "State of Efficiency Program Industry," 14.
[8] Granade et al. ," Unlocking Energy Efficiency in the U.S. Economy,"8.
[9] For comparison to this 4% value, the interest rate on inflation-adjusted government bonds is actually negative.
[10] National Research Council, *Real Prospects for Energy Efficiency*, 15.
[11] Kats, Menkin, Dommu and DeBold, "Energy Efficiency Financing – Models and Strategies," 2, 4-5.

investment up to $150 billion annually, up from only $20 billion[12] today. Several key barriers remain between where we are today and must be addressed investment through these financial instruments. But most of these barriers are common across all sectors of the economy and efforts to address them will unlock potential value far beyond a single energy productivity investment in, say, buildings or manufacturing processes. These barriers include:

- **Confidence in investment returns.** The rate of return demanded by investors depends dramatically on the perceived risk of the project. Building up credible data on the effectiveness of energy interventions will lower uncertainty going forward.
- **Aggregation.** Secretary of Energy Dr. Steven Chu described the productivity opportunity as "$20 bills lying on the ground all around us." [13]While the money is indeed there to be picked up, it may be more accurate to describe it as 2000 pennies than $20 bills. The opportunities are cost effective, but each individually too small to attract major investor interest. Securitization or other bundling of the opportunities can aggregate financial opportunities so they are appealing for mass investment.
- **Address split agency.** In many cases, the agent who would receive returns from investing in productivity is not the agent who can decide to make the investment. For mass scale, all decision makers involved need to see a positive outcome and a share of the returns.
- **Certainty in policy.** In many cases, the opportunities for energy productivity are influenced by federal, state, and local policies. Stable markets are much more likely to develop in a world of policy certainty because investment decisions require a reasonable degree of predictability. For example, the "Property Assessed Clean Energy" model received significant interest and was on its way to being implemented in many states before objections shut it down.
- **Oversight.** The collapse of the housing derivatives market and subsequent economic effects serves as a warning for proper oversight of complex financial instruments. In mortgage bundling, the instruments concealed the risk of the actual underlying loans. If energy productivity investments can be securitized to access larger scale capital, as has been done with mortgages, student loans, auto loans, and other debt categories, then there must be proper oversight built in.
- **Changing the market's perception of risk.** When energy projects are evaluated on their own, they can be seen as adding risk. Yet when they are evaluated in the context of the entire facility they have the potential to decrease risk. For example, a more productive building will be easier to lease and will be less vulnerable to spikes in energy costs. But the market does not evaluate this risk factor at present: it implicitly assumes that higher energy prices affect all facilities equally.
- **Correctly integrating energy costs into the credit and risk ratings of the underlying investment.** Many of the market failures discussed in the sectoral reports are direct consequences of failing

[12] No single definition for efficiency investment exists. This definition of the investment is inclusive of EE projects and services that involve a third party and/or a separate financing mechanism (internal fund, third party financing) (including the ~$8 billion annual ESCO market.)
[13] Chu, "Energy Efficiency: Achieving the Potential, Realizing the Savings."

to account for energy service costs when evaluating a larger investment. Thus, industries, often fail to invest in two year paybacks because of capital rationing: but capital is rationed because the credit rating of the corporation is compromised when debt gets beyond a certain threshold regardless of whether the efficiency project that fails to make the cut improves or degrades the financial security of the plant. For commercial buildings, a more efficient building is not appraised as more valuable despite its higher likely return on investment (ROI) due to lower operating costs. For homes, incorporating the value of improving energy productivity in mortgage calculations has the potential to reduce risk[14].

- **Coordination.** Investments in energy productivity will be optimized by looking at all energy sectors and developing a coordinated network will help system operators utilize energy resources more effectively and efficiently, while enhancing the value of the investment made.

Behavior

Behavior is the ultimate "cross-cutting" theme in that even the most automated technologies—from financial transactions to power transmission, from building control systems to traffic control systems—eventually require human decisions and actions. Behavior is pervasive and decisive in the productivity of energy systems, including:

- Decisions to invest in the development of new goods, services, technologies.
- Decisions to buy, adopt, or change practices and technologies by users and consumers.
- Feedback on energy use, price signals, and operational performance can improve decision making.
- Predictable patterns of assessing future costs and benefits, dealing with uncertainty, and overcoming inertia that affect decision making.

The Alliance Commission found evidence of this in all our research theme chapters and this section integrates that evidence into a few key findings demonstrating the importance of behavior in improving energy productivity. Research into behavioral factors helps to (1) estimate the potential impact of behavior on improving energy productivity and (2) design ways to leverage behavior to achieve those improvements.

The Energy Productivity Impact of Behavior

- A study by the American Council for an Energy-Efficient Economy (ACEEE) estimates the potential savings for households (home and vehicle energy use) to be 22%, equal to 8.6 quadrillion Btu (quads) per year, or about 9% of the nation's annual consumption.[15]
- A study by Lawrence Berkley National Laboratory (LBNL) that measured differences in implementation of energy efficient technologies by principals and agents (e.g., owners and

[14] EPA Energy Star "Energy Efficient Mortgages"
[15] Laitner, Ehrhardt-Martinez, and McKinney. "Examinging the Scale of the Behavior Energy Efficiency Continuum," 200.

users) found that residential energy use associated with the principal-agent problem (for refrigerators, water heating, space heating and lighting) amounted to over 3.4 quads in 2003, equal to 35 percent of site energy consumption.[16]

- Another study by ACEEE estimates that behavioral changes may provide as much as 25% efficiency gain above normal energy productivity improvements in the economy.[17]
- A study at the Massachusetts Institute of Technology (MIT) concludes that gains between 1.37% and 3.32% were achieved from the behavioral programs, with a mean savings rate of 2.03%. The programs provided savings at an average cost of 3.31 cents per kilowatt hour (kWh). [18]
- A study by the Environmental Defense Fund (EDF) estimates that behavioral programs, if applied nationwide across the United States, could save 26 Terawatt hours (TWh) of electricity per year in the residential market alone. Such savings would save American households over $3 billion annually.[19]

Behavior as a Tool for Improving Energy Productivity

Many behavioral factors affect energy productivity. One useful distinction is between:

- those behavioral factors that focus on the formal structures of information sharing and tangible incentives , and
- those behavioral factors that focus on the predictable ways in which humans process information and incentives, for example, the impact of competition.

The first group of behavioral factors is analyzed as a market barrier, as exemplified by Akerlof's discussion of how information asymmetries can create a "market for lemons"[20] and many other discussions of split and perverse incentives, uncertainty about information, and so on.

- Misaligned incentives in the market affect behavior across all sectors. In the building sector, if the tenant pays the utility bill the owner may have little incentive to make energy productivity capital investments. In manufacturing, department managers whose performance criteria do not include energy costs are less likely to pursue energy-saving innovations on the shop floor or in the boardroom. In the power sector, utilities must be able to recoup the returns to their investments in productivity realized by end users. In the mobility sector, the marginal cost implications of infrastructure investments on the metropolitan periphery should be considered in the public financing of transportation and utilities.
- Incomplete information in the market impacts behavior across all sectors. Policies and innovations are underway to provide decision makers with accurate information about energy productivity. In the mobility sector, consumers too rarely receive driver/rider feedback tools that facilitate efficient driving and custom route guidance. In the building sector, potential buyers and lessees in a small number of cities and states have access to information about the

[16] Murtishaw and Sathaye."Quantifying the Effect of the Principal-Agent Problem on US Residential Energy Use,"v.
[17] Laitner and Martinez "People-Centered Initiatives for Increasing Energy Savings," iii.
[18] Ibid.
[19]Davis, "Behavior and Energy Savings: Evidence from a Series of Experimental Interventions," 2.
[20] Akerlof, "The Market for 'Lemons': Quality Uncertainty and the Market Mechanism."

energy performance of a building to allow such performance to impact prices. In the power sector, customers sometimes receive information about how their choices can impact the cost of their consumption. In the industrial sector, manufacturers too rarely have available a validated basis for evaluating the productivity claims of vendors of new products or systems. As these information mechanisms diffuse throughout the sectors, the emerging challenge is to make this information salient and meaningful to consumers. To optimize the use of energy resources, accurate and comparable information must be available to consumers. Armed with this information, consumers will be able to understand the implications of their energy decisions and associated costs.

The second group of behavioral factors is analyzed from the vantage point of cognitive psychology and behavioral economics, as developed by the Nobel Prize-winner Daniel Kahneman and his colleagues and students.[21] These are deeper failures of markets, because they are based on the psychology of human thinking and decision making, and are hard to change.

- How information and incentives are presented impacts behavior across all sectors. Web portals, energy reports and displays, and information access protocols enable utilities, building owners, and product vendors to offer their customers more insight into how to achieve more from energy use. But both the sourcing and the framing matters. Trusted sources of information and meaningful frames that place information in context will vary by sector and segment. Producers, regulators, and technical assistance providers (such as manufacturing and agricultural extension agents) should recognize this variation and accommodate it.
- Motivation beyond incentives and information affects behavior across all sectors. Information and financial incentives can change attitudes but are insufficient. Leveraging motivations like competition and cooperation are powerful complements to tangible incentives. Association with role models, providing tokens of gratitude, and stewarding resources for future generations, are all effective motivators that can accelerate the influence of information and incentives.

Improving energy productivity also requires a robust, skilled workforce. Many buildings are sophisticated systems; even when designed well, they must be tuned and maintained to function properly. Commissioning is the process of ensuring a new building works as designed and that the operations staff is trained to manage it. Re-commissioning is necessary to keep a building operating well. Expert building operations and maintenance is as important as capital retrofits in reducing energy use. These needs also apply to other sectors as well. For instance, well trained operators and maintenance staff are needed to optimize energy productivity in industrial operations, and transportation systems, and for electric, natural gas, water, and other. For many years, natural gas distribution systems and electric distribution systems have been planned and built separately to meet the forecast peak demands of each infrastructure typically based on a 30-year planning horizon. Improving energy productivity includes implementing broad ways to be more efficient. One of the

[21] Kahneman, *Thinking, Fast and Slow*.

largest opportunities is to leverage the non-concurrent nature of the two US energy grid serving customers. Better demand information, new end-use technologies and demand management strategies can be employed to flatten demand curves for both utilities and reduce the units cost of both infrastructures.

Enhancing Expertise to Improve U.S. Energy Productivity

That lack of standard measures impedes the development of expertise. Consumers (whether homeowners or corporate buyers) as well as lenders as well as operators all seek efficiency information. To take buildings and equipment as an example, actors in the market must understand different rating systems with scales ranging from 0 (bad) to 10 (good), to 0 (bad) to 100 (good), to less than zero (good) to over 100 (bad), to, for example $57 (good) to $74 (bad).[22] This adds a level of complexity for both consumers and for training curricula.

In the industrial sector, while commercially available training, credentials, and service-providers may be available for some energy systems (e.g., boiler tune-ups and steam system maintenance), they are not readily available for others. The limited pool of expertise impedes opportunities for energy service companies (ESCOs) to provide to manufacturing industry the types of energy efficiency services that they provide in the commercial and institutional buildings sector. It also means that manufacturing extension, utility technical assistance staff, and similar assistance providers often lack in-depth understanding of client processes, thus constraining the advice they can effectively provide their clients.

The Behavioral Bottom Line

- No proposals for improving U.S. energy productivity are self-implementing. Ambitious goals must be translated into aligned incentives that are mutually reinforcing. People must be able to act on those incentives and other motivations through carefully constructed mechanisms.
- Significant changes to the workforce development system are needed to modernize curricula and certifications to fill the competencies required of new jobs in energy efficiency across all sectors of the economy.
- Awareness and understanding of energy productivity must be improved throughout the decision chain: among intermediate and final consumers as well as those who facilitate these transactions, including the final consumer’s understanding on how he has to act to achieve the highest possible energy productivity once solutions are in place.

Standardizing the measures used to rate and compares both capital investments and operating performance supports both of these challenges.

Government

[22] These scales are respectively for DOE’s new Home Energy Score, Energy Star commercial building energy performance rating system, RESNET’s Home Energy Rating System (HERS), and Energy Guide for refrigerators. See: U.S. Department of Energy. "Home Energy Score," and U.S. Environmental Protection Agency. "How the Rating System Works."

Government influences the nation's energy profile, usage trends and patterns, and productivity in many ways. All levels of government, from national to local, have critical roles to play in pursuit of the Commission's goal of doubling U.S. energy productivity by 2030. There are a large number of policies that enhance energy productivity. In addition, governments are large consumers of energy and of many goods and services, so they can achieve energy productivity gains on their own, lead by example, and directly influence markets through procurement.

The federal government has the benefit of scale. Its policies can address and influence entire national and even international markets. It also is the largest energy-consuming entity in the country. State, regional, and local governments (including public bodies such as public schools, regional and local authorities, and publically supported hospitals and colleges) are closer to their constituencies than the federal government, so they are in a better position to know how to address regional and local needs. They can design policies and programs that are tailored to their own contexts.

These various levels of government provide "laboratories of democracy" where different policies and programs are developed and tried. While this multiplicity enables creative solutions to problems, it can also lead to challenges, from exchanging ideas and solutions between governments (including other nations) to complying with non-uniform standards across jurisdictions. At the federal level, responsibility for energy productivity issues is scattered across a number of agencies and committees, which inhibits a coordinated federal strategy to increase energy productivity.

Government Policy

Government policies and investments will play a critical role in meeting the goal of doubling U.S. energy productivity. The key types of government policies and investments that are already being used to enhance energy productivity include building codes, appliance and equipment standards, state utility regulation, land use planning, financing, research and development, and tax policies.

Codes and standards are responsible for much of the energy productivity gains that have been achieved in the United States. The federal government first established energy efficiency standards for appliance and equipment products in the 1980s, and they have been remarkably successful. Refrigerators now use much less energy than they did in the 1970s even though they are larger, have more features, and cost less.[23] The federal government finalized rules that will roughly double fuel economy standards for passenger vehicles by 2025, after the initial standards doubled fuel economy compared to levels in the early 1970s.[24] The standards will provide families an estimated $8,200 in fuel savings over the lifetime of a new vehicle compared to a similar vehicle in 2010 as well as save 12 billion barrels of oil over the life of the standards.[25] Building energy codes are adopted and enforced at the state and local levels. According to Alliance to Save Energy analysis, the potential benefits of more aggressive codes are

[23] Appliance Standard Awareness Project, "Refrigerators and Freezers." In 1972 the typical refrigerator used 1,800 kilowatt-hours (kWh) per year, whereas today's refrigerators use about 500 kWh per year.
[24] White House, "Obama Administration Finalizes."
[25] White House, "President Obama Announces."

substantial. The Alliance found that if all new residential and commercial buildings and alterations in all states complied with the new 2012 International Energy Conservation Code (IECC) starting in 2013 consumers and businesses could save about $40 billion on their energy bills each year by 2030. The code would reduce covered energy consumption by 30 percent compared to the 2006 IECC, resulting in over 3.5 quads of annual source energy savings by 2030.[26]

State utility regulatory policies play a major role in increasing energy productivity. According to a July 2012 Institute for Electric Efficiency (IEE) report, electric utility company (and utility customer-funded state) efficiency program budgets in 2011 totaled $6.8 billion, and IEE projects this amount will increase to over $12 billion by 2020.[27] The report found that supportive regulatory frameworks are key to these expanded investments, enabling utilities to treat efficiency programs as equivalent to supply-side investments from a financial perspective. The report states that three regulatory mechanisms are key to providing a supportive framework –

- Direct cost recovery (regulator-approved mechanisms for the recovery of costs related to the programs).
- Fixed cost recovery (mechanisms that assist the utility in recovering the marginal revenue associated with fixed operating costs lost due to decreased demand).
- Performance incentives (mechanisms that reward utilities for achieving certain efficiency program goals).

Widespread adoption by states of performance targets for energy savings from utility efficiency programs (Energy Efficiency Resource Standards) and, in some cases, of requirements to use all cost-effective energy efficiency before increasing electricity production has also been critical to the rapid growth of the programs. Another important set of state utility regulatory policies for increasing energy productivity are time-variant rates, which provide customers actionable price signals that reflect the cost of electricity production.

All levels of government have an ability to increase energy productivity in land use planning, ranging from local zoning to regional grant programs. From 2000 to 2025, the U.S. is expected to convert 18.8 million acres of land to build 26.5 million homes and 26.5 billion square feet of nonresidential space.[28] Just as energy efficiency was added as a core objective of building codes and utility regulation in many states, reducing fuel use needs to be a key goal of land use policies. The opportunities to help ensure this growth is resource-efficient include –

- Redirecting growth into urban centers by creating an urban growth boundary, and/or limiting external growth to a small area or county while protecting other suburban areas.
- Providing incentives for urban infill and/or ensure that development properly covers its full costs including externality costs.
- Including efficiency metrics in regional performance based planning activities.

[26] Alliance to Save Energy, "Potential Nationwide Savings."
[27] Institute for Electric Efficiency, "State Electric Efficiency Regulatory Frameworks,"1.
[28] Burchell and Mukherji, "Conventional Development," 1536.

- Providing regions greater control and flexibility to fund transportation systems that offer choices including transit, biking and walking.

A number of financing policies have emerged to address barriers that are holding back larger investments in energy efficiency. These include loan guarantees, on-bill finance, on-bill repayment (OBR), Property Assessed Clean Energy Financing (PACE), and state and municipal loan programs. While there is not a one-size-fits-all solution, a high degree of standardization, predictability, and scale would greatly contribute to a greater penetration of energy efficiency financing.

Government-supported research and development (R&D) is needed to provide the technologies and measures that enable greater energy productivity gains in the future. Energy sector companies tend to under-invest in R&D because of market barriers. One of the most prominent barriers is knowledge spillover, which occurs when a company faces the prospect of its R&D investment benefiting its competitors without them compensating the company for this benefit. Federal R&D has helped compensate for the lack of private sector R&D investment. Tax measures, public-private collaboration and research consortia, innovation-friendly design of regulations and standards, and other tools can encourage further private sector energy productivity R&D. A systematic review by the National Academies of Science of the U.S. Department of Energy's Office of Energy Efficiency and Renewable R&D found strong linkages between this investment and accelerating dozens of advanced technologies to market.[29] Only about ten percent of federal R&D support for energy technologies, however, has gone towards energy efficiency technologies from 1945 to 2012.[30]

Federal, state, and local agencies, in partnership with utilities, other private companies, and non-profit bodies, can also accelerate the deployment and diffusion of improved energy productivity practices. The United States has had a long history of extension bodies serving the agricultural sector to advance productivity, economic development, and resource stewardship. The National Institute for Standards and Technology (NIST) operates the Manufacturing Extension Partnership (MEP) in partnership with state and local bodies and the private sector as the main U.S. technical assistance service for small and medium sized manufacturers, though it does not necessarily focus on energy. There are also separate Department of Energy (DOE) and Environmental Protection Agency (EPA) supported programs as well as some state, local, and utility programs that provide energy productivity related technical assistance and resources for industry. It is not clear what, if any, cooperation or collaboration exist among the various programs to integrate energy productivity with manufacturing modernization. Furthermore, U.S. support for manufacturing extension services is, on a per gross domestic product (GDP) basis, much smaller than that provided in a number of other industrial countries, such as Japan, Canada, Germany,

[29] National Research Council. *Energy Research at DOE: Was It Worth It? Energy Efficiency and Fossil Energy Research 1978 to 2000*. Washington, DC: The National Academies Press, 2001.

[30] Sissine, F. 2012. Renewable Energy R&D Funding History: A Comparison with Funding for Nuclear Energy, Fossil Energy, and Energy Efficiency R&D. Congressional Research Service. http://www.fas.org/sgp/crs/misc/RS22858.pdf

and the United Kingdom.[31] Enhanced support and coordination of technical assistance services can serve American economic and energy objectives simultaneously.

Demonstration and validation of emerging energy productivity technologies and practices is one of the tools needed to help bridge the "valley of death" between R&D and commercial deployment and fill the gap between government support of R&D and of technical assistance. There are initiatives within the U.S. Department of Defense (DOD) and the General Services Administration to use federal facilities as test beds to demonstrate and validate new and emerging facility energy technologies to meet government mission needs. State and local governments as well as federal agencies were early adopters of plug-in electric vehicles. These and other efforts can provide valuable performance data and experience to accelerate the application of energy productivity technologies across the broader economy.

Tax policy can be a major driver of energy productivity improvements. In the industrial and commercial buildings sectors, making depreciation schedules and other tax policies more favorable to new capital investment would enhance energy productivity while increasing overall competitiveness. Federal tax incentives have also been used to promote public transit use, high-efficiency homes and commercial buildings, electric-drive vehicles, and more efficient appliances.

Governments also play a key role in ensuring consumers have reliable and accessible information on energy efficiency and energy use to facilitate market adoption of energy efficiency. The EPA and DOE Energy Star program has been especially successful, with high consumer familiarity with its voluntary "premium" label for efficient products, typically aiming for the most efficient 25 percent of products in 60 categories. EPA and the Department of Transportation issue labels for passenger cars and light trucks that provide comprehensive fuel economy information to consumers including five-year fuel costs or savings compared to the average vehicle and environmental impact information. Consumers, however, do not have comparable information for energy use in buildings, which use more energy than the vehicles covered by federal labels. There are two non-governmental labels based on building characteristics with significant penetration for new buildings: the comparative Home Energy Rating System (HERS) is increasingly used by large production builders, and the broader LEED premium ratings for green commercial buildings are often required by governments and large private owners. Energy Star also has a comparative benchmarking system (Portfolio Manager) for actual energy use of existing commercial buildings and a premium designation for the top 25 percent of those buildings. DOE is also developing a voluntary Home Energy Score based on building characteristics for existing homes. Each of these has a different scope, rating scale or threshold, and methodology, which could lead to consumer confusion.

Government as an Energy Consumer

[31] Ezell and Atkinson, *"National Manufacturing Strategy."* Ezell, *"Revitalizing U.S. Manufacturing."*

The federal government is the largest consumer of energy in the U.S. According to the DOE, the federal government consumed 1.6 quads of primary energy in Fiscal Year 2011, which was equivalent to 1.7 percent of total national energy consumption in that fiscal year.[32] The federal government is making progress towards increasing its energy productivity. The administration recently adopted Executive Order 13514, which requires agencies to meet a number of energy-related targets, including a 30 percent reduction in vehicle fleet petroleum use by 2020.[33] Following this executive order, the president also directed federal agencies to enter into at least $2 billion in performance-based contracts to improve the energy efficiency of buildings.[34] DOD released in 2011 its first-ever strategy to reform energy consumption by reducing demand for energy in military operations, expanding and securing the supply of energy to military operations, and building energy security into the future force[35].

States and municipalities have taken similar actions to reduce energy use in government buildings, demonstrating their commitment and leadership. For example, more than half of the states now integrate one or more green building rating systems into state building policies, with the majority emerging just in the past four years.

Beyond buildings, vehicles and geographic allocation, Governments can further improve operational and cost-effectiveness by considering the energy productivity opportunities embedded in all internal day-to-day activities of public bodies, but also external engagement of these, that involve resource or energy consumption, such as supply chain efficiency, procurement of office equipment, organizational and administrative processes and energy aware behavior of staff.

Government Bottom Line

Governments will play a vital role in the United States doubling its energy productivity by 2030. Policies at all levels of government create market frameworks needed to encourage energy productivity. Targeted government investments help break through market barriers to innovation and can facilitate deployment. Governments also lead by example as a market actor in how they consume energy and operate more cost-effectively.

Conclusion: Leveraging Integration with a National Indicator

In conclusion, important determinants of energy productivity cut across the major sectors of the economy. In this chapter, the Commission offers some of the more significant interconnections. Technology, investment, behavior, and governance create an infrastructure that can impacts the energy productivity of the power generation, industrial, buildings, and mobility sectors of the U.S. economy.

[32] Derived from US EIA, *Annual Energy Review*, Tables 1.1 and 1.12 (with site energy converted to primary energy).
[33] White House, "President Obama Signs."
[34] White House, "Presidential Memorandum."
[35] U.S.Department of Defense, "Energy for the Warfighter: Operational Energy Strategy."

Energy productivity is the common currency of all this interconnectedness and we conclude with the opportunity that presents.

The unemployment rate and the Dow Jones Industrial Average are imperfect measures of underlying realities. But they fix public attention and inform decision making and thereby make collective action possible. To a lesser extent, vehicle miles per gallon (MPG), average mortgage interest rates, and many other indicators function in a similar way.[36] The pervasive quality of energy productivity and the leverage it potential exerts across all sectors of our economy suggests the value of constructing an indicator to benchmark and facilitate a national commitment to improved energy performance. In many specific and partial ways, this is already happening within sectors and spheres of decision making such as building energy performance benchmarks and public mandates for disclosing that performance.

Corporate and organizational management policies and procedures are critical to providing motivation for energy productivity advances. Companies that engage and incentivize employees and managers as well as customers, suppliers, and other stakeholders can identify profitable opportunities to reduce costs, improve quality, and enhance product offerings. The International Organization for Standardization (ISO) series of management standards for quality, environmental and, now, energy management (such as ISO 50001) promote incorporation of those factors into core corporate decision making, commitment by top management, employee and stakeholder engagement, clear and quantified metrics and goals, favorable management and accountability structures, and a culture of continuous improvement. Also, Identification of interoperability design criteria and reference models are needed, as described in IEEE Standard 2030 published in September 2011 that brings together power generation, communications, and computer technologies in defining interface and design criteria needed in designing a smart grid infrastructure. Further, energy management standards (EnMSs) can be encouraged through supply chain relationships. Quality and environmental management system adoption grew as major firms and governments started to prefer or even require appropriate certifications from their suppliers. Government procurement preferences could strengthen incentives for EnMS adoption.

An opportunity exists to accelerate our nation's improvement in energy productivity. A generally accepted measure of energy productivity is economic output, measured in GDP, divided by the total energy use, measured in British thermal units (Btu) per year. Over the 30-year period 1980-2009 energy productivity increased from $75 per million Btu to $133 per million Btu, as illustrated in Figure 1. This improvement represents a 1.9% annual improvement resulting in cumulative 78% improvement over the 31 year period.

[36] Kingdon, *Agendas, Alternatives, and Public Policies.*

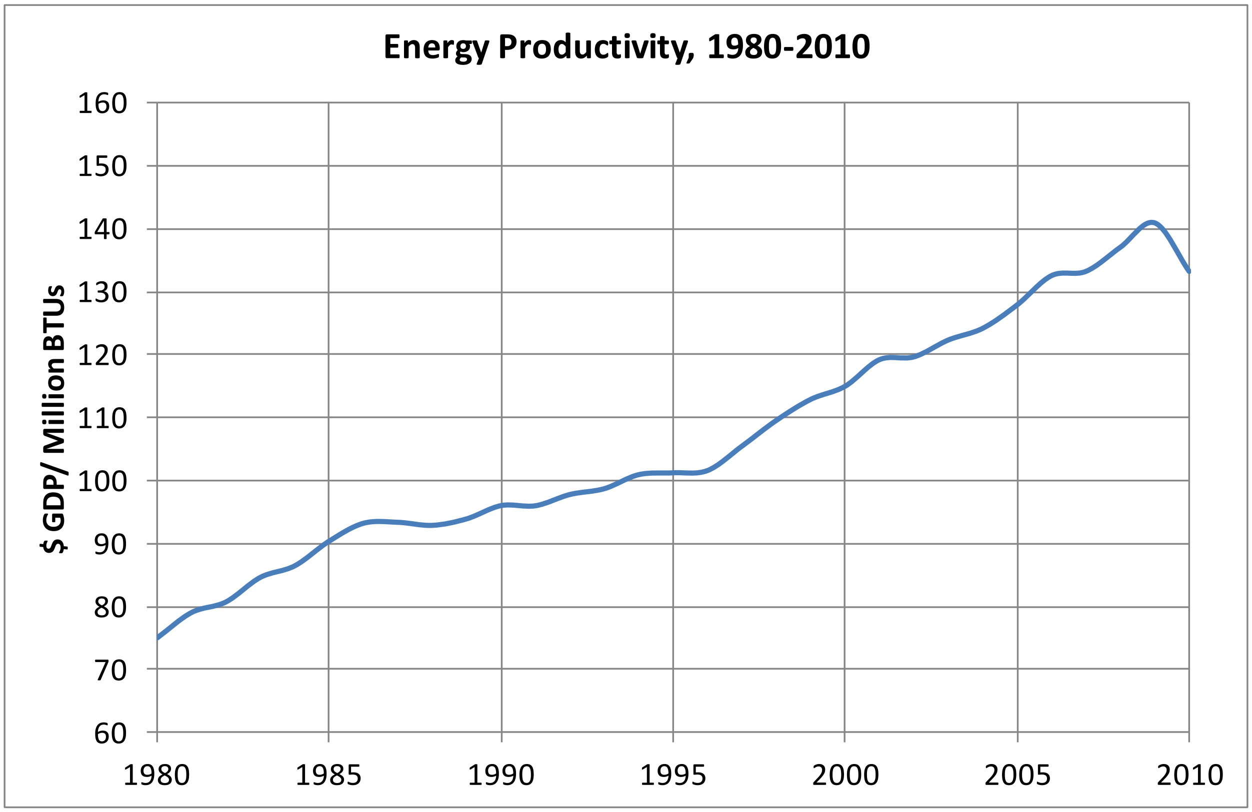

Figure 1: Energy Intensity improvement from 1980-2009 has averaged 2.2% with five-year average rates ranging from 0.6%/year to 3.8% per year.
Sources: Energy Information Agency, Bureau of Economic Analysis, Department of Energy, Energy Efficiency and Renewable Energy, Planning, Budget, and Analysis.

The adoption of and persistent attention to a measure of national energy productivity could foster accelerated improvements in that productivity and leverage the inter-connections discussed here. Rewards and requirements based on the energy productivity measure and attached to Federal programs could incentive the search for and use of the integration identified here. The Commission report demonstrates a total savings of 26.3 quads is achievable with known and emerging technologies and is expected to be cost effective. Thus we are confident that the Alliance goal of doubling energy productivity is achievable. An accepted national indicator reported as regularly and followed as closely as the unemployment rate could rally crucial support.

Appendix A: List of Acronyms

ACEEE – American Council for an Energy-Efficient Economy
Btu – British thermal unit
DOE – US Department of Energy
EDF – Environmental Defense Fund
EPA – Environmental Protection Agency
ESCO – Energy Service Company
ESTCP – Environmental Security Technology Certification Program
ETV – Environmental Technology Verification
GDP – Gross Domestic Product
HHS – US Department of Health and Human Services
ICT – Information and Communication Technologies
IEE – Institute for Electric Efficiency
ISO – International Organization for Standardization
kWh – Kilowatt Hours
LBNL – Lawrence Berkley National Laboratory
MEP – Manufacturing Extension Partnership
MPG – Miles Per Gallon
MIT – Massachusetts Institute of Technology
NIST – National Institute for Standards and Technology
OBR – On-Bill Repayment
PACE – Property Assessed Clean Energy
Quad – Quadrillion (10^{15}) British thermal units
R&D – Research and Development
ROI – Return on Investment
TWh – Terawatt Hours
WMRC – Waste Management and Resource Center

Appendix B: List of Figures

Appendix C: unit conversions

1 Btu = 1.055 kilo joule
1 Quad = 10^{15} Btu = 1,055 056 000 000 000 kilo joule = 293 TWh = 8,007,000,000 Gallons gasoline
= 970,434,000,000 Cubic feet of natural gas = 36,000,000 Tonnes of coal
1 kWh = 10^{3} Watt = 3,600 kilo joule = 3,412.14 Btu = 0.02732 Gallons gasoline

= 3,312 Cubic feet of natural gas = 0,12287 kg of coal

1 TWh = 10^{12} Watt = 3,600 000 000 000 joule = 0,003412,14 Quad

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