A Suite of Policies for Energy Efficiency in Buildings: Maximizing Synergies

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ABSTRACT

Policies to increase energy efficiency in buildings over the long term must combine a number of objectives: 1) acquiring all cost-effective efficiency *currently available;* 2) *continually improving* the level of efficiency that will be available in the future; and 3) *making markets function better* so that energy goals are met in the most economically efficient way possible. These broad goals are mutually reinforcing: more effective policies that make markets work will tend to promote continual improvement and make the achievement of energy efficiency easier and more straightforward.

This paper proposes a suite of policies aimed both at promoting continual improvement and also at providing the market infrastructure needed to accelerate the uptake of energy efficiency. The primary examples of the policies that promote continual improvement are: 1) codes and standards; 2) normative labels, such as LEED and Energy Star; 3) informative labels; 4) managed incentives, such as those offered by utilities; 5) market transformation, defined herein as harmonized specifications for highly-efficiency products that are incentivized; 6) tax incentives to get over the valley of death from research and development (R&D) to commercialization; and 7) targeted public R&D.

Examples of policies that provide market infrastructure include appraisal and financing standards that recognize energy efficiency, utility regulations that reward energy efficiency and define the methods for evaluating energy and cost savings appropriately, labeling and rating protocols that measure efficiency reproducibly, incentive programs that establish the business infrastructure for widespread deep retrofits, and communications strategies that encourage efficient construction.

This paper establishes a structure for analyzing these approaches, noting that no jurisdiction utilizes all of these approaches to date.

Introduction

Energy efficiency policies are often discussed, and evaluated, as if undertaken in isolation. Such consideration can allow a policy maker to create false choices, such as mandatory versus voluntary measures, or energy-price-based strategies versus regulatory strategies. But looking at jurisdictions where a number of policies have been undertaken at the same time, we find that they react synergistically: on one hand it is impossible to attribute savings to one of the policies as opposed to the other, but the total savings are larger than the amount that derive from one specific policy, particularly when the period of analysis is decades rather than years.

This paper offers a taxonomy of how a suite of policies can be established to offer the maximum level of synergy. The framework suggested here has not yet been fully implemented anywhere, so the comparison of best practices it suggests should assist the leading regions as well as those jurisdictions just getting started to increase the level of energy efficiency deployed and the economic value of those policies.

A Taxonomy of Policies

Policies are not the exclusive purview of governmental agencies, nor of a national government as opposed to a state/provincial or metropolitan/local government. Many of the policies are initiated or implemented (or both) by the private sector, or the for-profit sector.

However, there has been little structured or analytic discussion of which type of agency is best to implement a given policy: a national government, a sub-national government, a non-profit agency, or a business organization.

The policies described next may be implemented through legislation or may be adopted by delegating authority to an administrative agency. Delegation of authority is often preferable because the agency can be allowed to update the levels of efficiency demanded or encouraged by the policy as continual progress towards greater efficiency is observed, or as test standards or other processes become obsolete. Delegation of authority to a government agency is common practice, but in some cases policy development is delegated to NGOs.

For the purposes of this taxonomy, the policies fall into three generic categories:

- General economy-wide policies;
- Policies to accelerate market adoption of new technologies;
- General economic reforms focused on lending and valuing efficiency investments and on utility regulation.

General economy-wide policies

The most important policy is to set a mandatory declining greenhouse gas emissions cap. A cap is important not primarily for the fact that it puts a price on carbon (Goldstein 2015; 2016), but because it sets a goal (Goldstein 2012) that businesses, governments, non-profit organizations, and individuals will shape their actions to help meet. The importance of setting goals—in the absence of placing price pressure on consumers—should not be underestimated. Businesses commonly set goals for product introductions, sales, cost reduction, revenue growth, etc., and these goals guide organizational behavior in powerful ways. Economic models assume that businesses maximize profits, but actual business operation is based on setting goals that are not directly connected to profit maximization, particularly in the minds and job assignments of the people that are changed with meeting them, even when they tend to lead to that outcome.

This result can be seen California Air Resources Board's (CARB) Scoping Plan (CARB 2008) for meeting greenhouse gas emissions limits that relies on most of the policies discussed next for the buildings sector, along with other policies aimed at the transportation sector and the industrial sector. There are also policies to encourage renewable energy and reductions of greenhouse gases other than carbon dioxide. CARB has established a regular schedule for updates to the Scoping Plan and developing more ambitious targets for future years, as later adopted at the Paris climate negotiations in December 2015.

While it establishes a cap-and-trade system implemented at the upstream level, over 80% of planned emissions reductions are expected to occur as a result of policies rather than as a result of emissions permit trading. This is reflected both in the outcome of the auctions, in which prices are below US$15 per tonne, and in the process of the auctions, in which most of the permits must be purchased and most of the proceeds are used to fund incentive programs to reduce emissions.

Thus, the cap serves primarily as motivation for adopting the types policies described next, and to adopting target levels of energy efficiency that are ambitious enough to cause the cap to be met.

Infrastructure to Support Energy Efficiency Policies

An often overlooked policy is the provision of infrastructure such as public information, education and outreach data on energy uses and efficiency on a disaggregated basis, training for new efficiency jobs, etc.

Raising energy price is not an effective policy for promoting efficiency. Simple economic theory suggests that higher energy prices lead to lower consumption and that the reduction in consumption is a result of both higher energy efficiency and more energy-conserving behavior. Many observers in the buildings-related industries say that low energy price is a barrier to energy efficiency.

But the hypothesis *that energy price affects energy efficiency* has not often been tested empirically. Comparisons of energy efficiency between regions with high electricity prices to those with low prices consistently fail to show a difference that would corroborate an elasticity of efficiency with respect to energy price. (Goldstein 2007) And the most comprehensive tests show the hypothesis of a nontrivial price response to be false.

Note that this discussion refers to energy efficiency—defined as the provision of the same level of energy services at lower energy consumption—and not to the price responsiveness of energy-related behaviors.

Price elasticity studies are not reliable guides to use for predicting the consequences of energy price increases because they do not address the issue of causality, as opposed to correlation. There is a good reason why they do not: it is hard to imagine how one would set up an experiment designed to test a hypothesis (as opposed to a set of observations that the scientist does not set up). A good experiment would be "raise the price of electricity and hold everything else equal and see how future consumption departs from trend".

Fortunately for these analytic purposes, California inadvertently set up such an experiment, allowing us to determine how consumption changes when energy price suddenly rises by 40 percent and then stays that high.

As a consequence of its experiment with electricity deregulation, California reduced investment in both efficiency and new power plants, creating a serious energy shortage. To deal with the resulting blackouts, the state had to procure expensive new supplies, both conventional and efficiency, and thus to raise its electricity prices by 40 percent. At the same time, the shortages also prompted the state to strengthen its energy codes and promulgate new appliance and equipment standards, as well as authorizing utilities to acquire more efficiency through their incentive programs. Thus the experiment was fortuitously well-designed: to first order prices increased with no major changes in policy (the policy changes that did happen have long lead times before they save much energy), allowing us to isolate purely price effects; and to second order the policy effects would enhance the sought-after price response of lowering consumption. Thus the expected diminution of consumption would be even larger than pure elasticity would predict. And note that this experiment measured the effects of price on electricity consumption, not efficiency.

What were the results? They are so remarkable that the reader can see them in Figure 1 without the need of statistical assistance. ***It is impossible to pinpoint when the price increase happened from looking at the blue line on the figure.***

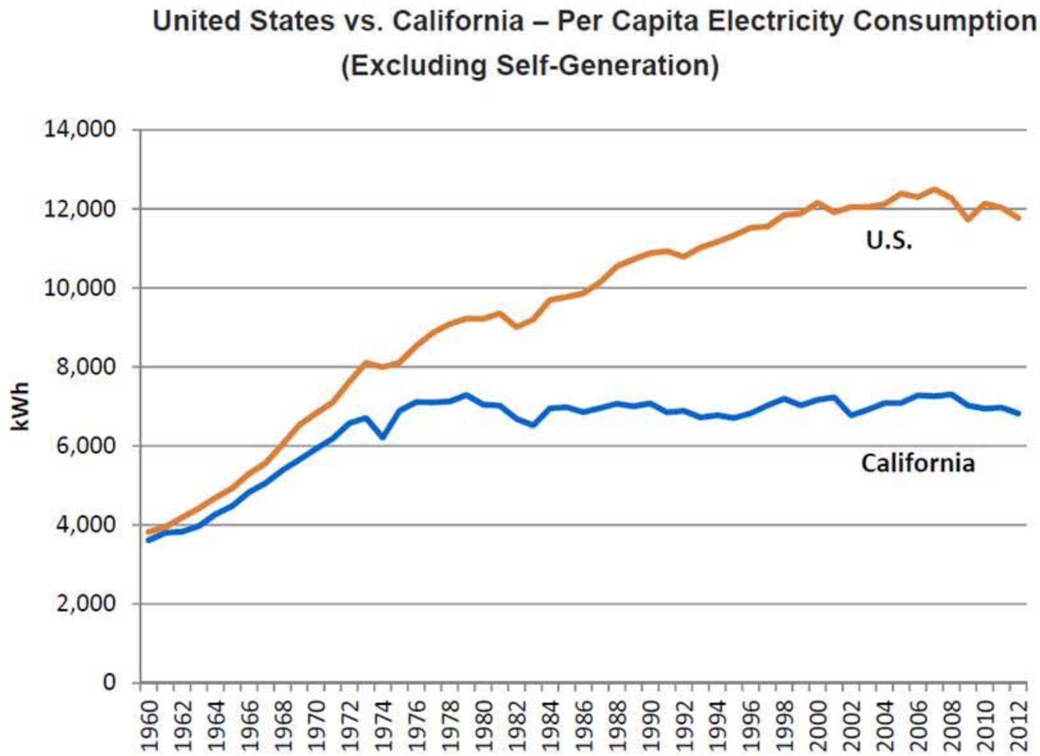

Figure 1: Electricity Consumption in California: Can you tell in which year rates went up 40 percent?

[hint: it was NOT the year that consumption dropped noticeably—that year was the one in which utility efficiency program budgets quadrupled and conservation was strongly encouraged]

[The answer is that rates went up in late summer 2001, later in the year than the summer peak during which the largest savings were recorded. The first full-year later, and during the subsequent five years, consumption went up slightly more than during the rest of the time period.]

This failure to observe a signal—in electricity *consumption* much less in electricity *efficiency*—from a 40% sudden price increase ought to be profoundly disturbing to advocates of high price elasticity. Yes, the effect of price in the first year should be muted as the conservation policies of 2000 decayed away. Yet two important factors mitigate this effect: first, the long-term price elasticity is generally found to be much greater than the short term elasticity, so we should have expected consumption *trends to drop over time*, and second, other policies adopted at the time promoted greater efficiency. Yet the next 5 years showed the highest consumption growth of the whole time period.

Is this paper trying to say that the hundreds of price elasticity studies that have been done are all (or mostly all) wrong? Not exactly: what this analysis is saying is ***that they are not correct for the purpose of predicting the consequences of a change in price caused by policy***.

Price elasticity studies look at datasets of different places or different times, each of which is associated with a price and a level of consumption, and seek statistical correlations between them. The result is a measured elasticity.

But correlation is not causality, and thus they do not provide the certainty needed to address the experimental question. There are many ways that high price is correlated with low consumption that do not allow one to predict that ***raising*** prices will ***result*** in lowered consumption.

First, the causation may go in the other direction. If you have two otherwise identical areas and one has half the electricity consumption of the other, the one with lower consumption will have higher prices because the fixed costs of service have to be amortized over lower sales, and given normal design standards and assumptions, the same level of transmission and distribution capacity will be provided for both systems.

Second, both high price and low consumption may both be consequences of something else. For example, one data point for a gasoline price elasticity study is a gas station in Manhattan. The station has some of the highest gas prices and the lowest consumption per household. But why? Gas prices are high because the land values are high in Manhattan as a consequence of high density of housing (or perhaps it goes the other way around). But in any case, high land value explains both low consumption and high price.

There are many other reasons why price and consumption correlations may not imply causality. Ironically, this figure itself shows part of the problem. Even though this figure and the data behind it refute the hypothesis that there is a causative influence of price on consumption, ***the data for years after 2001 will show both high prices and low consumption*** relative to other jurisdictions and to previous years. Thus the very data that refute nontrivial price elasticities when used in the appropriate context validate a hypothesis of large elasticities when used in the context of conventional price elasticity studies.

This analysis does not imply that energy price has NO impact on efficiency. It means that price taken alone has no impact. Most energy efficiency policies are premised on cost effectiveness. If costs are higher, more ambitious efficiency measures will pass the economic test, and will be incentivized. Even then, the hockey-stick shape of supply curves of saved energy suggest that the effect of price increases will not be large. On the other hand, if we can be more effective at the three top levels of the pyramid, we may be able to flatten (extend outward to greater savings) the efficiency supply curves.

Policies to Accelerate Market Adoption of New Technologies

Energy efficiency is confronted with a broad array of failures of the market. These are observed along the entire chain of market adoption from R&D to universal acceptance. At each step along the way, these failures can be overcome by policy. This section describes how these policies can be designed and deployed to accomplish continual improvement and to maximize reliance on functioning market forces. Perhaps a better metaphor than "chain" is a pyramid, as illustrated in Figure 2. This figure, especially the arrows on the right, exemplifies the principle of continual improvement (ISO 2011).

The pyramid structure is chosen because the lower levels of the pyramid represent broader acceptance – greater market share but lower levels of energy efficiency improvement. As we move up the pyramid, we move towards technologies and designs with increasingly larger energy savings, but declining market share.

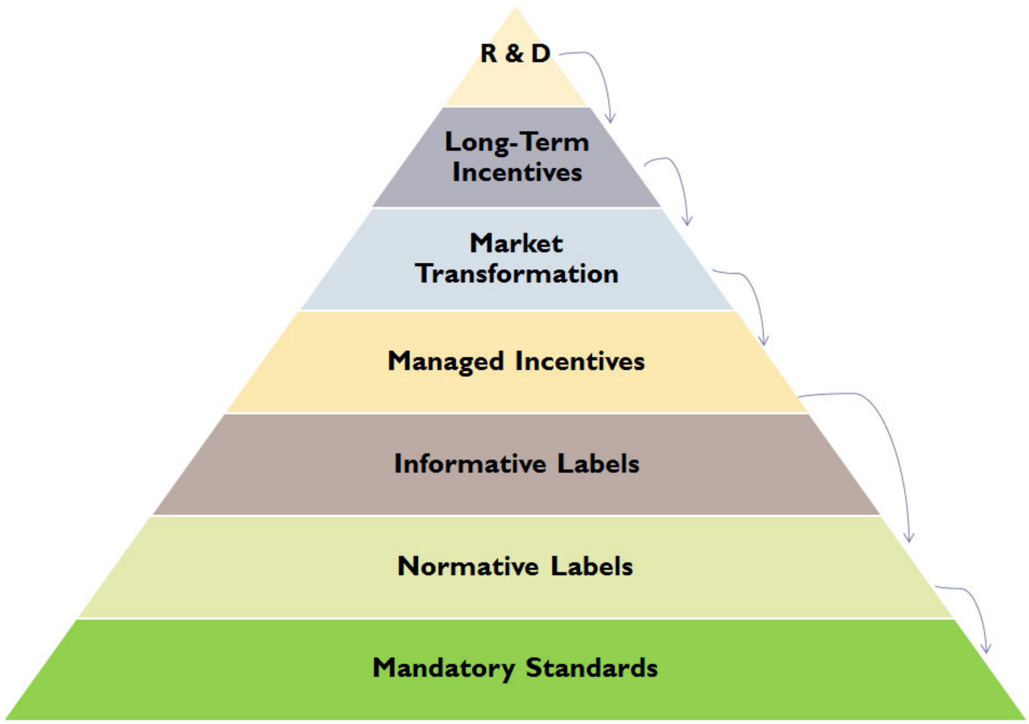

Figure 2: Accelerating Market Adoption through Continual Improvement

Before discussing the levels or structure of the pyramid, it is important to point out an element of infrastructure for it. It's hard to define a level of improvement in efficiency without a Key Performance Indicator or set of Key Performance Indicators for energy efficiency. Before we can undertake almost any step in the pyramid effectively, we need to design (and regularly update over time) test protocols to define and allow measurement of the Key Performance Indicators that are used to establish efficiency criteria for all of the levels of the pyramid. *These indicators are used for defining the targets for standards, specification, and labels described below.*

Structure of the pyramid. This structure suggests a reasoned answer to the question of how to maximize the use of carrots rather than sticks, as well as the question of how to get the most bang for the buck with financial incentives. Standards are justified when empirically we find that the almost-free normative and informational labels fall short of achieving 100% market share for efficiency, which to date has always been the case. (One can imagine cases in which labeling combined with financing and asset evaluation reforms could be sufficient to make mandates unnecessary. But such cases cannot yet be found anywhere.)

Using standards to achieve the efficiency that is possible to obtain through fair regulation and relying on labels to push purely voluntary acceptance of efficiency measures leaves the incentivized measures to limited to those where the cheaper policies don't work. This minimizes the cost of the incentives. More advanced measures acquired through market transformation and long-term incentives will require larger per-unit incentives, but will be limited in market share, again limiting the societal cost of incentives.

In addition, the policies that advance efficiency at each level of the pyramid allow smaller-scale testing, and if necessary adjustment, of the desired targets or constraints before the given level of efficiency is deployed more widely at a lower level. This allows for observations of the outcome to contribute to changes, if necessary. This structure facilitates continual improvement. This process is illustrated by the arrows on the right side of Figure 2. It also reduces costs, since the most widely adopted levels of the pyramid: labels and mandatory standards, do not require financial contributions.

Mandatory Standards. Mandatory standards for both buildings and equipment used in them are at the bottom of the pyramid because they have essentially 100% compliance, particularly if implemented effectively. Part of the paradigm of continual improvement implicit in the pyramid says that they will be regularly revised to higher levels of efficiency. Mandatory standards can be considered a market-based policy if they focus on an energy efficiency target that must be met without specifying what technologies need to be employed to meet the goal. In this case, vendors compete to meet the efficiency target and the lowest cost. Note that standards have been a part of market forces in the developed world for generations (Knopes and Goldstein 2016).

Normative Labels. These labels, such as Energy Star or LEED or the star or letter-grade system, provide a simple way of encouraging consumers to purchase or rent buildings or equipment with a reasonably high (higher than standards but still representing market shares of some 25%) level of energy efficiency. Normative labels can either provide one target level, as most Energy Star programs do, or multiple levels, as LEED and almost all normative labels in other places such as in Europe, China, Australia, etc., do. (The word “normative” is used in the sense of making a recommendation as opposed to implying that compliance is mandatory.)

Informative Labels. These labels provide information on the energy consumption of a building or a component thereof without specifying any recommended level. They often encourage higher levels of efficiency through comparison between similar products with labels.

Managed Incentives. Managed incentives are programs such as those run by utilities (in most cases), or nonprofits or state energy agencies (in other cases). They are managed in the sense that the Administrator has a fixed budget for energy efficiency, which is divided into line items for particular end uses or energy-using devices. The incentives are managed to that budget level, thus, if market uptake of a given technology exceeds expectations, the incentive may be terminated or reduced; conversely, an incentive that is not achieving its goals might be increased or changed (or simply dropped as being an assumed failure).

Market Transformation. Market transformation programs, as defined by most practitioners, are programs designed to incentivize the next level of energy efficiency beyond what can be obtained by managed incentives (Keating et. al 1998): levels that are theoretically available in the sense that products may show up in catalogs or at trade shows, but are very difficult to obtain. These programs provide targets for manufacturers that assure some level of harmonization so that they can design for these levels of efficiency. Administrators of managed incentives established the Consortium for Energy Efficiency in 1992 to address this problem of their inability to access the highest levels of efficiency without acting on a continental scale.

Long-Term Incentives. Market transformation is premised on the existence of technologies that can meet a given specification. Efficiency program administrators do not want to offer their customers incentives to buy products that turn out to be unavailable. Furthermore, program administrators sometimes can be reluctant to offer incentives for products that are only available from one or two manufacturers.

But often one can project levels of efficiency using engineering analysis that are so high that no one produces them .In this case, long-term incentives are needed. Long-term means about 5 years (as opposed to 20 years): long enough for a producer to build the capacity (such as an assembly line or the human capital to perform advanced design or construction) knowing that the first three years or five years of production from the capacity investment will receive the incentive. New technologies require extensive investment from manufacturers or from design professionals who must take additional classes or training to learn how to design to state-of-the-art levels of efficiency. They need to have some assurance that this investment will pay off. Long term incentives have seldom been used, but where they have the results have been very positive (Waltner et al. 2012).

Research and Development (and Demonstration and Deployment for New Technologies and Design Principles. R,D,D&D ought to have two different types of focus: a focus on basic technologies, similar to most of the research currently done by the U.S. Department of Energy and more market-oriented research and development currently done by California's Electric Program Investment Charge (EPIC). It should have both a national and global focus, as increasingly, the techniques and designs used for nonresidential buildings are the same everywhere in the world, or at least everywhere in the prosperous part of the world.

General Economic Reforms

Reform underwriting to account for energy and transportation costs. Owners of Energy Star homes have a 32% lower mortgage default rate than owners of conventional homes, and the likelihood of default is linearly related to the HERS rating of a home (Quercia et al. 2013). Thus, including energy costs in mortgage underwriting—specifically using the sum of energy and transportation costs along with principal, interest, taxes, and insurance (PITI) in place of just PITI in determining qualification—will increase the security of home mortgages as well as qualifying buyers to invest more heavily in energy efficiency. At current mortgage rates, a 20-year payback in energy efficiency is cost effective on a cash-flow basis and will qualify the owner for enough additional money to pay for all such efficiency improvements.

Thus the policy is likely to lead to builders employing all efficiency measures with a payback of 20 years. This outcome is in stark contrast to current custom, where efficiency measures with payback periods of less than 5 years are often overlooked due to concern over the price of the house.

This kind of reform benefits all parties: the buyer, the national need for efficiency, the lender, the investor seeking greater security for income investments, and the government and private infrastructure that responds to defaults.

It is even more important to count transportation in costs in mortgage underwriting because they are so large. The median price of a home in the U.S. is the low $200,000's, but the cost of transportation to and from the home (assuming it is built in urban sprawl, where most new housing has been built for the last half-century) at current low gasoline prices exceeds $300,000 over 30 years. This figure is some four times the cost of utility energy, and about twice the size of a median loan!

Ignoring predictable transportation and energy costs in making loans in the first decade of this millennium was a substantial contributing force to the global economic meltdown of 2007-8 (Goldstein 2010, 2013).

Reform appraisals and pro-forma's for evaluating buildings. Most commercial buildings are appraised based on the net operating income (NOI) method, where NOI is multiplied by a capitalization rate to derive the value of a building and determine how much money an owner can borrow based upon that appraisal.

But even though energy costs are some 20% of NOI on average, differences in energy costs are only rarely accounted for in the appraisal. That market failure means that while the rest of the building's characteristics are evaluated on the basis of capital investments, energy is considered a cash flow. If the cost predictions that are already a part of building energy ratings were incorporated into capital valuation, efficiency would be able to compete on a level playing field with other investments.

Incorporating building energy ratings, measured in cost, into the appraisal and lending process would complement the effect of the other policies. For example, when combined with informative labeling, the real estate markets and the lending markets would know how to value increased efficiency. Using current conditions in developed markets, for example, a dollar of energy savings would be capitalized at about $20 of asset value, since a building in 2016 typically is worth 20 times its net operating income. A builder that had the choice of adding a measure that cost $1 would gain $20 in value, and could borrow typically about 60% of this $20, or about $12. If the efficiency measure costs them $10, they would be ahead $2 and all 10-year payback measures would be included in the building. In stark contrast, today it is hard to get builders to invest in 3 year payback measures.

This reform would reduce the cost and increase the ambition of incentive programs, both managed incentives, market transformation, and long-term incentives. It is reasonable to anticipate that most or all of the clearly cost justified efficiency measures would be incorporated into buildings, and the programs would focus more narrowly on newer technologies or more ambitious levels of investment in energy efficiency.

This reform cannot be done through any of the policies previously discussed: it requires changes by appraiser and lenders, and/or their investors. For residential buildings, a suitable rating system already exists in North America. For nonresidential buildings, the U.S. Department of Energy is developing an asset rating system that would serve the purpose.

Reform utility regulation to align profit motives for utilities with those of their customers. Utilities whose revenues are tied to volumetric sales will find that a reduction in sales reduces revenues and profitability, particularly between rate cases. This regulatory principle means that they will lose profitability from operating successful managed incentive programs. A utility whose revenues are tied to volumetric sales will lose profitability from the success of any of the energy efficiency policies discussed herein. This will cause them to oppose all of the policies, resulting in unnecessary political conflict.

Reformed utility regulation can correct for this factor and also provide financial incentives for successful efficiency (and renewable energy) programs. This enables utility support of all the rest of the levels of the pyramid.

These reforms almost always have been undertaken through the regulatory system, rather than through legislation.

The reforms at issue are:

- Decoupling of revenues from sales. Under decoupling rules, utility collection of fixed costs is the same regardless of sales. If excess sales compared to forecast are recorded in a given year, the money from the fixed cost component of tariffs that is overcollected is refunded with interest the next year by lowering the revenue requirement by the amount of overcollection, and vice versa;
- Pass-through of the costs of running managed incentive programs;
- A shared-savings policy or rewards/penalties for meeting/failing to meet efficiency procurement goals.

Note that the organizational structure of utilities varies from place to place. In some countries, utilities are private companies with a government monopoly franchise and government regulation of tariffs. In others, they are owned by or part of the federal government, or by local governments. Various public/private partnerships or other management arrangements also are found. The reforms suggested herein can be implemented irrespective of what arrangement is currently in existence in a given place.

Develop markets for whole building retrofits for both homes and commercial buildings. Achieving the 1.5C global climate change goal endorsed at the Paris climate meeting will require a thorough retrofit of essentially all existing buildings. Most likely it will require two cycles of successive retrofits: The first would achieve all reasonably cost effective savings over the next ~15 years—in order to limit the near-term contribution to the buildup of atmospheric CO_2. The second cycle would build on the advancements in technology and design achieved over the first 15 years to find new cost effective measures that can be deployed in once-retrofit homes. While in principle this could be accommodated within the structure of managed incentives, in practice, all full-scale programs to date fall far short of what is needed. In part this problem is a consequence of the relatively lower cost effectiveness of home retrofits: without financing at mortgage interest rates, the projects do not pay their way from energy savings alone. Thus a more multi-dimensional approach is needed.

Home Retrofit. The Consortium for Energy Efficiency performed an analysis of retrofit programs in North America (Rosenberg 2015), noting a combined budget for managed incentives of over $400 million in the analysis year.

But this is small: to put it in perspective, a 20-year program to retrofit all of the homes in North America with an assumed 40% cost share by the efficiency program administrator would cost over $30 billion a year, or some 80 times more than the ~$400 million in recent incentives. Similar conclusions were reached in Europe, where a budget for efficiency of over €100 billion annually (Sweatman 2012), a number very consistent with the North American estimate. To put it another way, at current levels of expenditure, it would take managed incentive programs well into the fourth millennium before all existing homes were retrofit once.

Notwithstanding this paucity of large-scale successes, there are small-community-scale projects that succeeded in achieving 85% market share of deep retrofits (~40% savings) in all residential buildings over a three-year period. One was the Hood River Conservation Project (Fuller et al. 2010; Hirst and Trumble 1989), and the other the Pacific Gas and Electric "Delta

Project” (Kinert et al. 1992). Both were run by US utilities, and both required 100% payment by the utility to achieve this high share. (Note that the denominator is the total housing stock, not the eligible homes or the homes with efficiency potential. Also the retrofits were deep, consisting of all cost effective measures that the home owner would consent to have installed for free.)

The utility did all the work as well as paying all the money: they hired the auditors and the contractors, and inspected the work after completion. This allows one to speculate: what if these programs were duplicated nationwide, or globally, with the sole exception that the cost was rolled into a 30-year mortgage that the owner eventually paid off?

This suggests a three-pronged approach to retrofits:

1. Assure the availability of raters who can evaluate the efficiency upgrades that make sense and craft a scope of work for the retrofit contractor;
2. Assure the homeowner that a given contractor is qualified to do the work, in terms of expertise in building science and compliance with ethical norms;
3. Assure that the cost of the retrofit can be financed at secured loan rates for any owner who is current on their existing mortgage. Mortgages typically have interest rates of about 3% over inflation (but less in 2012-16), while non-secured loans may have rates of 8% or 11% or higher.

There is a considerable amount of chicken-and-egg required to build up these three prongs, which argues for a national incentive for retrofit savings. Several consensus proposals to do this, both for homes and for commercial buildings, are currently before the U.S. Congress. Such incentives could prime the pump for an eventually self-sustaining program.

Note the importance of energy ratings in this structure. If we want a loan that is repaid over 30 years, we need a method for transferring the value to the new buyer and his or her lender. Ratings are the way to do that.

Retrofits are not a “thing” or a good that can be traded in the marketplace. But a post-retrofit house with an energy rating in project dollars per year of utility costs is a thing that can be priced in the market, and energy efficiency becomes a defining parameter of what that thing is.

The issue of deep home retrofits has been a problem ever since programs began in the 1970s. Either we got a component-based retrofit approach that typically achieved market penetration of about 40% or lower after several years of program, or we got the 100%-subsidized demonstration projects that had near-100% market share. There was nothing in the middle.

To make it worse, the societal cost effectiveness of home retrofits was marginal, at least if non-energy benefits were not valued in dollar terms.

More recently, whole-house approaches based on new building science that recognized the value of blower-door-verified leak sealing and duct-blaster-verified duct sealing have been implemented, but cost effectiveness remains marginal.

But deep retrofits do make economic sense if they are financed as part of a mortgage, and they are clearly necessary to meet climate goals in North America and essentially every other advanced economic region.

Commercial Building Retrofit. The discussion above remains largely unchanged for commercial buildings, except that there are no community-wide deep retrofit demonstrations and the cost effectiveness is relatively much better.

Financing, appraisal, and transparency are a little more complex, as there is not yet a recognized asset rating system for commercial buildings in North America, and the rules and practices about how efficiency is recognized in lending and appraisal are less clear.

Summary

While some have suggested a dichotomy between mandatory measures or "sticks" and voluntary or market-based "carrots" on the other, this analysis points out the synergies and complementarities between different policies. Each of these policies alone, and the suite of them together, relies on and enhances market forces in an area—energy efficiency—where the evidence from around the world shows widespread and persistent failures of the market.

The suite of policies suggested herein promote economic as well as energy efficiency by enhancing market competition among vendors to meet the energy goals at the lowest cost and to develop and sell innovative technologies. Information on energy efficiency, especially when combined with economic incentives for cutting-edge designs and technologies, allows risk-taking and its consequent innovation, since the few resulting failures will affect only a small fraction of the market.

The combination of these policies drives continual improvement in energy efficiency and in the level of energy service provided.

References

CARB (California Air Resources Board). 2014. *Scoping Plan*. http://www.arb.ca.gov/cc/scopingplan/scopingplan.htm

Fuller, M., C. Kunkel, M. Zimring, I. Hoffman, K.L. Soroye, and C. Goldman. 2010. Driving Demand for Home Energy Improvements LBNL-3960E. September 2010. http://emp.lbl.gov/sites/all/files/REPORT low res bnl-3960e.pdf

Goldstein, D.B. 2007. *Saving Energy, Growing Jobs: How Environmental Protection Promotes Economic Growth, Profitability, Innovation, and Competition*. Bay Tree Publishing, Point Richmond, California.

Goldstein D. B. 2009. *Invisible Energy: Strategies to Rescue the Economy and Save the Planet.* Bay Tree Publishing, Point Richmond, California.

Goldstein, D. B. 2010. "A Root Cause of the Mortgage Crisis: The Smoking Gun" *NRDC Switchboard* (blog), January 7, 2010. http://switchboard.nrdc.org/blogs/dgoldstein/a_root_cause_of_the_mortgage_c.html

Goldstein, D. B. 2012. "Invisible Energy: Strategies for Global Economic Recovery and Climate Stabilization." European Financial Review. Feb-March 2012

Goldstein, D. B. 2013. "New Study: Mortgage Defaults Significantly Lower Among Owners of Energy-Efficient Homes" *NRDC Switchboard* (blog), March 20, 2013. http://switchboard.nrdc.org/blogs/dgoldstein/new_study_mortgage_defaults_si.html

Goldstein, D. B. 2015. "Carbon Fees are Not the Best Solution to Climate Pollution." *NRDC Switchboard* (blog), August 17, 2015. http://switchboard.nrdc.org/blogs/dgoldstein/carbon_fees_are_not_the_best_s.html

Goldstein, D. B. 2016. "How Do Low Oil Prices Affect Consumption and Climate Emissions?" *NRDC Switchboard (*blog), January 13, 2016. http://switchboard.nrdc.org/blogs/dgoldstein/how_do_low_oil_prices_affect_c.html

Hirst, E. and D. Trumble. 1989. "Effects of the Hood River Conservation Project on Electricity Use and Savings in Single-Family Homes." *Applied Economics*. Vol. 20 Issue 8, 1989. http://www.tandfonline.com/doi/abs/10.1080/758531240?journalCode=raec20.

ISO. 2011. *ISO International Standard 50001: 2011, Energy Management System*. http://www.iso.org/iso/home/standards/management-standards/iso50001.htm.

Keating, K. et. al. 1998. "Wheat, Chaff, and Conflicting Definitions in Market Transformation," Proceedings of the 1998 ACEEE Summer Study on Energy Efficiency in Buildings, American Council for an Energy-Efficient Economy, Washington, DC.

Kinert, R.C., D.C. Engel, J.P. Proctor, and R.K. Pernick. 1992. "The PG&E Model Energy Communities Program: Offsetting Localized T&D Expenditures with Targeted DSM." *In Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, 5:131-136. Washington D.C.: American Council for an Energy-Efficient Economy.

Knopes, J. and D.B. Goldstein. 2016. "Energy efficiency standards help business thrive and consumers save." The Hill, Congress Blog. http://thehill.com/blogs/congress-blog/265929-energy-efficiency-standards-help-businesses-thrive-and-consumers-save

Quercia, R., N. Kaza, C.Y. Tian, R. Sahadi, and S. Stellberg. 2013. *Home Energy Efficiency and Mortgage Risks*. University of North Carolina at Chapel Hill, USA.

Rosenberg, A. 2015. "Overview of Residential Existing Homes Programs in the United States and Canada." Consortium for Energy Efficiency, Boston, MA, USA.

Sweatman, P. "Financing Mechanisms for Europe's Building Renovation." Climate Strategy and Partners, Madrid, Spain. http://www.eurima.org/uploads/Eurima-Financing_Mechanisms.pdf

Waltner M., L. Burt, B. Howard, D. Goldstein. 2012. "A Retrospective Look at Federal Energy Efficiency Tax Incentives: How Do Cost and Performance-Based Incentives Compare in Their Ability to Transform Markets?" In *Proceedings of the ACEEE 2012 Summer Study on Energy Efficiency in Buildings,* 6:121-134. Washington D.C.: American Council for an Energy-Efficient Economy.