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Measuring the Efficacy of Low-Income Residential Sustainability Interventions

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Measuring the Efficacy of Low-Income Residential Sustainability Interventions

by

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Dedication

Dedicated to the hard working women and men of the Louisiana Green Corps.

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Abstract

Measuring the Efficacy of Low-Income Residential Sustainability Interventions

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The University of Texas at Austin, 2011

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Volatile and rising global fuel prices present a tremendous challenge to our energy-dependent economy, and the ramifications are especially great for low-income households. Residential weatherization programs represent a tremendous opportunity to shield vulnerable populations, but the allocation of funding and assessment of efficacy has historically been fraught with political and procedural hurdles. This report examines the methods of assessing the efficacy of low-income weatherization and proposes a set of best practices.

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CHAPTER 1. INTRODUCTION

The issue of sustainability for low income households is at the nexus of two of my personal and professional passions. I spent several years in nonprofit program development in New Orleans between 2004 and 2008, designing and supporting programs that addressed issues of educational equity, workforce development, and environmental justice. In that role I was able to see both the potential for these programs to do tremendous good in the community juxtaposed against what as often a gross ismanagement of public resources and massive missed opportunities.

New Orleans is an old American city blessed with an incredible architectural heritage, and residents of all backgrounds can be found living in historic, handcrafted houses dating from the turn of 20th century. An unfortunate downside to this is that while these houses were built to provide the best cooling techniques available at the time, an air tunnel through a sequence of rooms facilitated by high ceilings and transoms, they are not at all equipped to act as the airtight heat envelops assumed by the manufacturers of modern air conditioning systems. As a consequence the utility bills of residents tend to be extremely high, especially in times of high natural gas prices when fuel costs were passed on to ratepayers.

At such times our community centers would see a large influx of clients applying for assistance on their bills. Our case managers would triage these families' financial problems and negotiate bill forbearance or forgiveness with Entergy, the local utility, but we were only treating the symptom of a problem that was guaranteed to continue to surface. In my experience in most rental houses the transoms and large windows had long since been painted shut, and in the sweltering, humid Gulf Coast summers air conditioning is a necessity rather than a luxury, especially for the elderly or those with small children.

In the summer of 2005 New Orleans proved to be a microcosm representing the challenges of an inefficient consumption of fossil fuels to the poor and the consequences of anthropogenic climate change. Prices for natural gas, a baseload power fuel source in New Orleans, were steadily climbing as temperatures reached record highs. In the community center where I was working as a GED math tutor, St. Mary of the Angels in New Orleans 9th Ward neighborhood, staff was working overtime and bringing in volunteers to handle the case load of clients seeking mediation with Entergy. At the time it seemed that the best we could do was pray for cooler weather and cheaper gas prices.

In late August of 2005 the 9th Ward was completely submerged in the floodwaters following Katrina, and in the Lower-9th Ward hundreds of houses were literally torn from their foundations when the floodwall of the Industrial Canal broke under the pressure of the storm surge. Obviously no single climactic event can be attributed to anthropogenic climate change, but there is an undeniably ominous undercurrent in the image of an historic American city, particularly one whose 20th century prosperity was driven by oil and gas, as the scene of unprecedented destruction of the sort experts warn will be exacerbated by global climate change. The ill-fated industrial canal that bisected the 9th Ward was overwhelmed by a storm surge that coursed through the erstwhile Mississippi Rive-Gulf Outlet (MR-GO), a shipping channel connecting the heart of the area's refining operating to offshore rigs in the Gulf.

I am fascinated by New Orleans and the Louisiana Gulf Coast as a symbol of the paradox of prosperity and instability in our modern energy systems. The boom-bust nature of the commodities capitalism that has dominated the American Deep South for centuries has always been a double edged sword for its people. From the brutally labor-intensive King Cotton and sugarcane to the often ecologically devastating petroleum extraction and production the brunt of the consequences has always been borne by the poorest people.

Nowhere was this paradox more evident than in St. Bernard Parish, a suburban and rural community wedged between the MR-GO and the Mississippi River. When the storm surge swept over the refineries the Chalmette Vista neighborhood was covered in a six-inch thick coating of crude oil. I was present at Our Lady of Prompt Succor Catholic Church after mass one Sunday when the Louisiana Bucket Brigade, an environmental justice organizing group partially funded through my office with funds from the Catholic Campaign for Human Development, presented the results of soil testing that they performed in backyards, playgrounds and other public spaces after the clean-up was completed. The expert presenting the information tried to remain objective about the risks accompanying the high levels of heavy metals and refining compounds found in the soil, but upon persistent and pointed questioning from a mother he conceded that he personally would not live in the community if he had young children. The mood in the crowded church gym was subdued, even resigned. The refineries and offshore rigs were the livelihood of the working class families of this community, and as one pastor put it in a private conversation, “I can’t browbeat people on Sunday about how they feed their children the rest of the week.”

For New Orleans and the rest of the world our modern energy systems are not sustainable. We use too much non-replenishable fuels in ways that fray the ecological and climactic fabric into which our lives and economies are inextricably interwoven. In the years of rebuilding following the storm many members of the community sought to address the problems of inefficient residential energy consumption along with reconstruction and job training. Louisiana Green Corps, an organization largely funded through the Weatherization Assistance Program (WAP), trained young women and men in light carpentry and energy auditing skills by weatherizing low-income homes, the very issue that I had been introduced to in the months prior to Katrina.

I helped the organization with their fundraising and operations planning and helped them conceptualize a marketing strategy to eventually bring in higher-end residential customers. The synergy of this program, providing job training, addressing the root of the symptom of high utility bills, and reducing the natural resource consumption of New Orleans home, greatly appealed to me. I was somewhat surprised and frustrated, however, that we did not attempt to measure the impact of the program on clients' households in a meaningful way. It seemed to me a critical measure of the positive impact of our work, and furthermore a relatively straightforward metric to estimate. Like many nonprofit programs the Green Corps was understaffed and overworked, so I did not take issue with their inability to perform the analysis in-house, but I was very surprised that there were no apparent data-gathering systems aimed at collecting the information necessary to determine offset energy usage as a result of their intervention.

The focus of my work in graduate school has been the economics of sustainability, and I had the privilege in the Spring of 2010 to take a practicum course in Sustainable Housing with Professor Peter Ward of the LBJ School of Public Affairs. Through this course was able to explore the case for sustainable housing interventions in depth, as well as develop a framework for the microeconomic analysis of the decision making regarding such interventions. While our team was examining the best practices for sustainable housing interventions, bureaucratic gridlock on the national level was throwing into high relief the issues of inefficiency and missed opportunities that has plagued their implementation for decades. The funding allocated for the Weatherization

Assistance Program as part of the American Recovery and Reinvestment Act (ARRA), or 'stimulus act,' was trickling slowly through the federal and state systems, with only a small fraction of funds having been put to work a year after its passage.

The roadblocks on the national level were mostly procedural and administrative, but what they exposed was a lack of focus regarding the policy goals of low-income weatherization, and an inconsistent understanding as to how to judge their efficacy of implementation. The clarity I developed regarding the merits of sustainability interventions explored by our practicum team combined with my frustration with the national-level policy failure inspired me to research the issue at length for my capstone professional report. In this professional report I set out to determine how policies and program supporting low income residential sustainability interventions ought to be evaluated an implemented.

Scope of the Report

To begin with, I would like to review several important topics that this paper does not cover. This report is not an engineering or architectural report. I do not review specific interventions and weigh their benefits and limitations under different conditions. I do not claim expertise in this topic, and would not presume to prescribe weatherization techniques for given housing types and climates. I do, however, cover in some detail methods through which policymakers may infer which techniques are most appropriate.

Furthermore, this is not a program management manual. There are many high quality 'best practices' guides for performance management and quality control of low-income weatherization programs, covering topics such as personnel training, budgeting, and community outreach. These are worthy topics that were explored in the practicum, however the focus of this report is on issues that would concern policy managers at a higher level of decision making.

The problem that I noted in working with the Louisiana Green Corps, a lack of sufficient data collection to properly estimate energy savings, was only scratching the surface. Until very recently there has not been a nationwide attempt to quantify the benefits of public money spent on weatherization, and it is a stretch to say that many of the methods used in reporting have been good-faith attempts. In this report I will examine and critique the methods used to estimate energy savings from program such as WAP and identify appropriate frameworks for incorporating the data into decisions regarding the allocation of public money. Ultimately, this report is an attempt to clarify the role that rigorous, objective performance measurement in techniques can play in the assessment of NGOs with multiple, difficult to measure objectives. Using the Louisiana Green Corps as an example, few would assert that the short-term provision of green-collar job training is not a worthy enterprise, but the fact that no information exists as to the impact of weatherization on clients' homes means that success of the program in completing two facets of its mission, affordable energy usage and reduced resource consumption, is entirely speculative.

As a both a former administrator of a grant program and a former grant-writer I am highly attenuated to the missed opportunities and misallocation of resources that are the result of insufficient performance measurement. Organizations that do great work but are unable to verify their impact are not competitive for large-scale funding, and what I would consider to be less worthy causes are often able to win support based solely on the persuasiveness of charismatic advocates. The affordability of the American lifestyle and efficient, sustainable use of natural resources are two of the most pressing challenges facing policymakers today, and we cannot gain any traction in addressing these issues if without separating the wheat from the chafe in terms of community-based sustainability programs.

I consider low-income residential energy efficiency and weatherization as a low-hanging fruit and focus this report on it for several reasons. The first is that private sector energy efficiency and weatherization services are thriving with customers in the industrial and commercial sectors, and thus there is a significant existing literature on best practices for analyzing their efficacy. Second, of course, is my personal experience with the importance of finding long-term solutions for low-income families facing volatile utility bills. Finally, with the push to move the generation mix towards lower-carbon, alternative energy and growing global demand for fuel commodities it may be reasonably estimated that the cost of energy will increase in the future, meaning that the burden of affordable energy consumption is likely to grow.

In summary, the two main policy questions addressed in this paper are how to analyze the efficacy of residential energy efficiency programs and how to appropriately incorporate that data into a decision-making framework. The recommendations of this report will help policymakers create a framework to determine regional allocation of weatherization funds rather than local management of programs.

Organization of the Report

This report will review the policy logic of low income weatherization programs and review existing methods for measuring the benefits of these programs. Chapter 2 explores the definition of sustainability, establishes the logic for narrow focus of benefits that may be monetized, and reviews the recent history of low-income sustainability policy. Chapter 3 is an overview of the cost-benefit analysis (CBA) framework and explores the special case of using CBA in a policy context. Chapter 4 is a technical overview and critique of the most prominent evaluation methods for residential weatherization programs, as well as an exploration of how the methods may be adapted for simple use by policymakers to establish a measure of benefits. Chapter 5 draws on the methodology established in the previous chapter to make more recommendations for the creation of an economically efficient low-income residential weatherization policy-making paradigm.

CHAPTER 2. SUSTAINABILITY IN THE CONTEXT OF LOW-INCOME HOUSING

Sustainability is a holistic term that may encompass financial, social, and environmental considerations. Its interpretation is highly sensitive to initial assumptions regarding the value of particular resources and the relevant time scale for the agent under consideration. Financial sustainability is by definition uniquely germane to the context of low-income housing, and housing interventions that stand on their economic benefits are the easiest to analyze and justify. Monetizing the benefits of efforts to improve social, environmental and health sustainability is a largely subjective task sensitive to biases and priors, and thus housing interventions that purport to produce these benefits are much more difficult to compellingly integrate into policy.

Conceptualizing Benefits of Sustainability Interventions

Given scarce resources policymakers must manage the tradeoff between making a significant impact for each household served and making an impact for the greatest number of households; the methods for measuring benefits will be the main driver as to how this balance is achieved. It is useful to utilize a taxonomy of sustainability intervention options that distinguishes between those which may be justified on their economic benefits alone, those which have no immediately apparent economic justification, and those which have a combination of an obvious economic benefit and a set of non-monetized and quality of life benefits.

The first step in analyzing sustainability options is to separate the types of benefits which may be feasibly monetized and those which may not. The former lend themselves to a well-established set of analytical methods with near universal consensus as to their application and interpretation, whereas the latter are difficult to generalize and may be subject to widely varying contextual interpretation. Quality of life improvements to households or neighborhoods, such as greenspace and parks, may lead to increased community interaction and undoubtedly have aesthetic value, but the monetary value of these benefits to individual households is very difficult to establish.

Given that many sustainability interventions have significant quality of life impacts that are difficult to monetize a careful use of terms ought to be employed in order to avoid unduly disregarding viable options. Rather than refer to the 'net present value' of an option, common parlance in the financial sector, this policy report will instead, where applicable, use the term 'net expenditure' and define it as positive or negative. In practice this changes nothing but the sign of the value, but the conceptual difference is the expectation that the monetized benefits will most often fall short of the initial outlay. An agent making a decision about investing in housing interventions may consider the net expenditure the 'true cost' rather than the initial outlay and adjust their decision based on their own personal willingness to pay for the expected quality of life or environmental benefits. This distinction is non-trivial, because in conventional CBA a negative net benefit automatically disqualifies a project from consideration, whereas individual consumers often make consumption decisions where the cost is known and the benefit is not quantitatively defined.

Policies Affecting Low-Income Households

TYPES OF POLICY INTERVENTIONS

Low-income household service policies have historically been administered by local utilities, which have considered broader values than economic sustainability. Such policies historically have taken the form of energy assistance, weatherization, and consumer protection policies. Energy assistance policies are direct subsidies for energy consumption for low-income ratepayers. Customers may pay a lower rate per kWh, receive a lump-sum grant, or take advantage of a special payment plan for abnormally large bills as might result from spikes in fuels costs or extreme weather events. In some cases utilities will pardon the debts of customers who demonstrate significant hardship. Consumer protection policies include delayed termination of services, non-termination covenants for certain seasons of the year, or even universal service policies[1].

Weatherization services most commonly entail direct investments in homes to increase the efficiency of energy consumption, but they also may include education regarding efficient energy usage and professional audits to determine what simple investments and behavioral changes might easily generate energy savings [2]. Weatherization services are distinct from the other types of low-income residential sustainability polices in that they may be performed by any government agency or nonprofit, whereas energy assistance and consumer protection must be done in conjunction with the retail utility in order to be effective.

A COMMENT ON POLICIES FOR POWER MARKET STRUCTURE

There are a myriad of market structures for electric power in the United States, ranging from full vertical integration of a monopoly utility and power producer to a fully restructured market with both retail and wholesale deregulation. In a fully regulated market structure the monopoly utility negotiates with regulators to set a price per unit of electricity that covers capital and operating costs and provides a set return on equity. This fixed rate assumes a certain price level for fuel, and when fuel prices deviate from this

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[1] Houthhakker, H.S., Phillip K Verleger, Jr., and Dennis P. Sheehan."Dynamic Demand Analysis for Gasoline and Residential Electricity."*American Journal of Agricultural Economics*, vol. 56, no. 2 (May, 1974) . p. 250.

[2] *Ibid*. p. 250.

assumed level the balance is obtained from customers through a variable surcharge. In a fully restructured market competing power retailers offer service to end-use customers and purchase power from independent producers. Retail contracts are shorter term than the period of time between rate cases for monopoly producers, so the prices more directly reflect the state of power markets. Although price discovery follows different dynamics based on the market structures, in all cases prices are fundamentally driven by the marginal cost of producing a unit of electricity, and that cost is eventually borne by consumers of that electricity. [3]

The effects of restructuring on retail residential energy consumers is a controversial topic, so it is useful to review some of the concerns from the perspective of low-income ratepayers. Low-income customers are uniquely concerned with adequacy of service and the cost of power. [4] With regards to the former, restructuring at its most basic level will introduce more uncertainty into the financial planning of power retailers and will tend to put downward pressure their margins, affecting their ability to set aside funds for consumer protection policies. Regarding the latter, several dynamics introduced by restructuring have the potential to be especially problematic for low-income ratepayers. Since restructuring causes price-discovery to occur more quickly it is also more volatile, and low-income consumers will have less flexibility in absorbing this volatility. Furthermore, they may lack the market power or the savvy of commercial, industrial, or higher-income power customers and may at least fail to reap the benefits of restructuring, and perhaps bear a disproportionate share of power prices.[5]

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[3] Shively, Bob and John Ferrare. *Understanding Today's Electricity Business*. (San Francisco: EnergyDynamics, 2008). p.126.

[4] Department of Health and Human Services. *Monitoring the Impact of Electric Restructuring on Low-Income Consumers: The What, How and Why of Data Collection*. June 1999. Online. Available: http://www.ornl.gov/~webworks/weather/Documents/WX00312.pdf. p. 40.

[5] Houthhakker, "Dynamic Demand Analysis." p.250.

A Focus on Low-Income Households: Here and Now

VULNERABILITY OF LOW-INCOME HOUSEHOLDS TO PRICE VOLATILITY

The observed response of low-income households to changes in energy prices further contributes to a sense of urgency regarding the formulation of policy interventions. Poor households are much more likely to respond to changes in energy prices with proportional changes in energy consumption, with reductions in response to higher prices representing a much higher proportion of baseline energy use than higher-income households.[6] The public health and quality of life implications of this are drastic in areas of the country prone to extreme weather, because the baseline energy use for low-income households is already disproportionately dedicated to climate control. The inability to make large capital purchases of more efficient appliances or climate control systems often leaves non-use of energy as the only option available to low-income households. [7]

IMPENDING RELEVANCE OF LOW-INCOME ENERGY ASSISTANCE POLICIES

The question of how to effectively equip low-income households for a low-energy consumption lifestyle is increasingly relevant in the context of macroeconomic factors which are putting upward pressure on real energy costs. The fundamentals of supply and demand for residential electricity consumers are such that the burden of increased costs will be borne by ratepayers, and as energy prices increase a larger and larger share of the disposable income of households will be dedicated to the electricity bill. Whereas middle-income households typically spend less than 5% of their income on residential fuel costs, low income consumers spends 10-20% of their income on home utility bills. [8]

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[6] Frieden, Bernard, and Kermit Baker. "Market Needs Help: The Disappointing Record of Home Energy Conservation." *Journal of Policy Analysis and Management*, vol. 2. no. 3. (1983). p. 437.
[7] *Ibid.* p. 442.
[8] Houthhakker, "Dynamic Demand Analysis." p.249.

A full analysis of forecasted energy prices is far beyond the scope of this report, but a review of important trends is in order to underscore the importance of energy efficiency investments. Natural gas is the marginal price setting fuel source for most of the country's power markets, and it is by far the most volatile fuel source. [9] While there is rarely a consensus on price forecasts in commodity markets, prominent analysts are bullish on power prices due to a likely increase in natural gas prices and the forced retirement of a significant portion of the country's low-cost baseload coal plants. There is a healthy debate about the feasibility and affordability of alternative sources of energy, such as renewable and nuclear power, but the investment cycle of the power sector is long-term and even in the most optimistic scenarios the supply-side response to these developments will only mitigate a cost increase. [10]

A leading indicator of the effect of electricity price increases on low-income consumers is the example of heating oil price increases in the winter of 2011. The EIA updated its winter fuels outlook February to adjust to higher than expected prices, and consumers are expected to spend a record amount on heating by the end of the 6 month season[11]. Heating oil is derived from crude oil, which unlike power and natural gas is a commodity whose prices are driven by global supply and demand fundamentals. Increasing demand from the developing world has moved marginal supply to more

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[9]Energy Charter Secretariat. *International Pricing Mechanisms for Oil and Gas*. (Belgium: 2007). pp. 121-122.

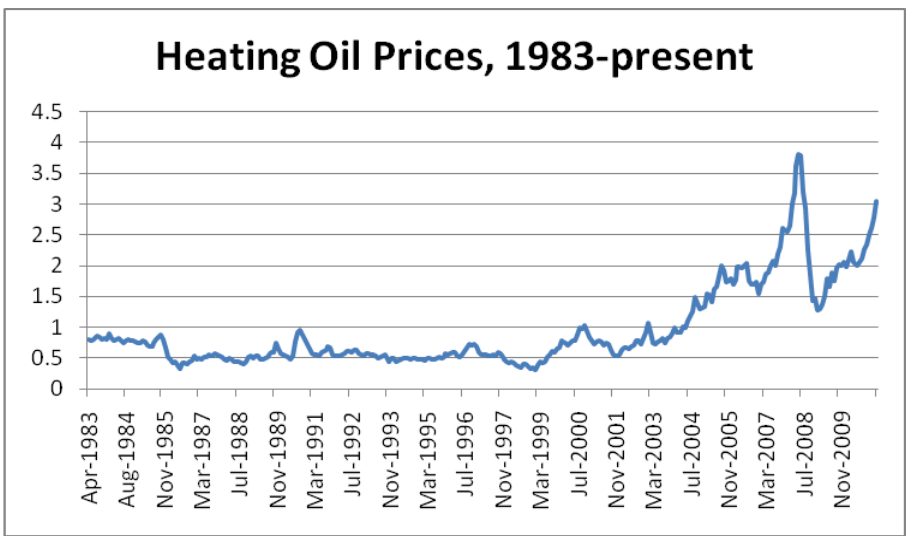
[10] Dizard, John. *Coal Plants to be Snuffed Out Faster than Expected*. Financial Times (June 26, 2010)

[11] Doggett, Tom. "Heating Oil Bills about $500 more than Last Winter." *Reuters*, (Feb. 2011). Online. Available: http://af.reuters.com/article/energyOilNews/idAFN164584620110216. Accessed: February 20, 2011

expensive sources of oil than ever before, which has directly impacted the costs of residential heating oil. [12]

As can be seen in Figure 1, there has been a definite increase in both the average price and volatility of heating oil prices over time. A common method to forecast fuel prices for less liquid commodities is to establish cointegration with a commodity that has strong trading volumes. [13] Crude oil is the most heavily traded energy commodity in the world, and the future price of heating oil can be interpolated from its futures prices. [14] Crude and heating oil prices have maintained an equilibrium ratio of approximately 35:1 over three decades, and a cursory glance at Figure 2 Demonstrates that the move strongly in tandem.

Figure 1: Historical Heating Oil Prices[15]



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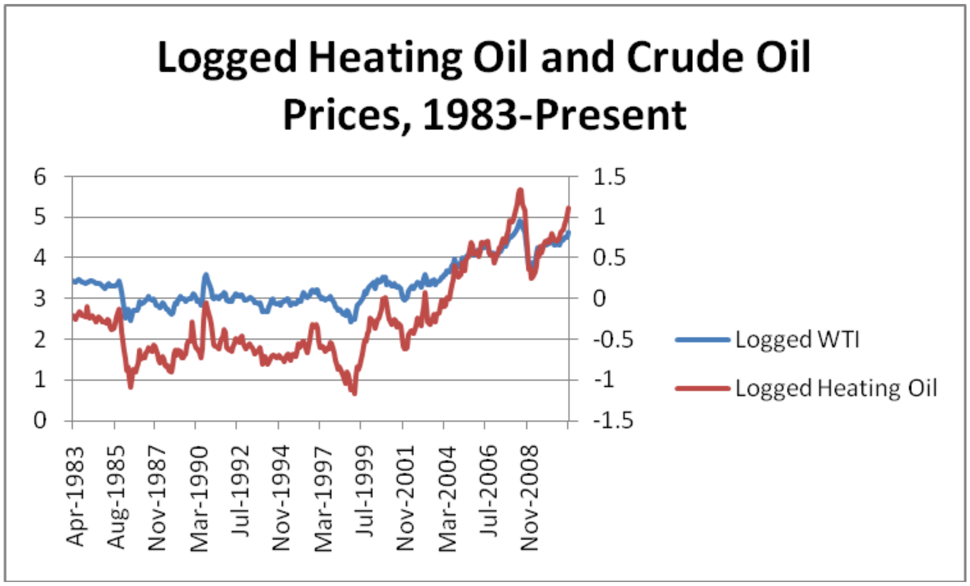
[12] Energy Information Administration. *Residential Heating Oil Prices: What Consumers Should Know.* Online. Available: http://www.eia.doe.gov/pub/oil_gas/petroleum/analysis_publications/heating_brochure/heatbro.htm. Accessed: February 2011

[13] Serletis, Apostolos and Ricardo Rangel-Ruiz. "Testing for Common Features in North American Energy Markets." *Energy Economics* ,vol. 26, (2004), pp. 401-414

[14] Energy Charter Secretariat 2007, p. 99

[15] Energy Information Administration. Available online: http://eia.gov/petroleum/data.cfm

Figure 2: Logged Heating Oil and Crude Oil Prices, 1983-Present[16]



Note that the prices have been logged in order to normalize their volatility in periods of extreme prices and to more appropriately demonstrate their equilibrium relationship. [17] Recent turmoil in oil-producing regions of the world and increasing demand from developing economies has been pushing the global price of oil ever higher, and as of late April NYMEX petroleum commodity futures are sitting much higher for winter of 2011-2012 than they did for winter of 2010-2011.

There is not a strong consensus regarding the future of North American gas prices, with analysts divided on the impact of new shale gas on the depth of supply of low-cost reserves. [18] Natural gas prices have been extremely volatile in recent years, as

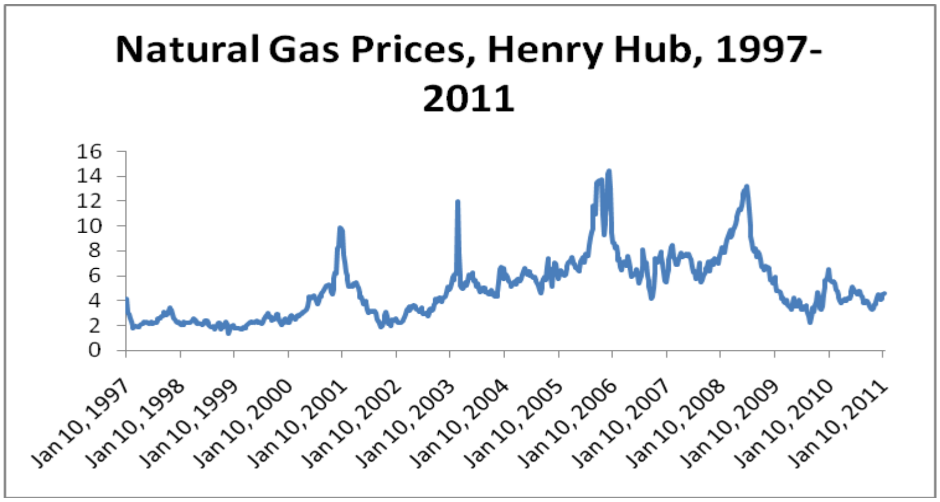
16 Source: Energy Information Administration. Available online: http://eia.gov/petroleum/data.cfm

17 Nelson, Charles I. and Charles R. Plosser. "Trends and Random Walks in Macroeconomic Time Series." *Journal of Monetary Economics*. vol. 10, (1982), pp. 139-162

18 Financial Times, June 26, 2010

can be seen in Figure 3, and their most immediate impact in the lives of most residential customers is felt in the price of electric power.

Figure 3: NYMEX Natural Gas Prices, Henry Hub[19]



The fundamentals of the supply and demand of energy are highly complex and prices are difficult to forecast, but it may generally be said that conventional sources of energy are much more likely to become more rather than less expensive in coming years. In this context, the observed dynamic of low-income persons being particularly vulnerable to increases in energy prices lends an air of urgency to the effective implementation of residential sustainability and weatherization services.

19 Source: Energy Information Administration. Available online: http://eia.gov/naturalgas/data.cfm

CHAPTER 3. ANALYZING BENEFITS FROM A POLICY PERSPECTIVE

Complex social problems cannot be effectively tackled without a strategy grounded in a rigorous analytical framework. Raw data alone does not suggest a solution; performance metrics and benchmarks for success arise from a comprehensive theoretical context for optimizing the use of scarce resources. The traditional economic model whose entity of interest is the profit-seeking firm is parsimonious in its assumptions and lends itself to elegant formulations of equilibrium states and maximum value scenarios. In the context of policymaking, however, there are confounding factors which complicate the analysis. Competing objectives and difficult to define outcomes are the natural consequence of a broader definition of value and more expansive scope of interest, and this chapter is dedicated to reviewing how to appropriately apply cost-benefit analysis in a residential sustainability context.

The Special Cases of CBA

Cost benefit analysis for a government or nonprofit with a mission-driven focus on maximizing positive externalities is necessarily different from the case of a private firm. Opportunity cost and time preference, the core assumptions of CBA, are not as self-evidently valid for the case of a benevolent public planner as opposed to a self-interested rational firm. Competitive equilibrium models are fashioned by logically positing the optimal choices of a representative agent maximizing present utility, whereas a benevolent, detached social planner is able to consider time varying preferences and will give weight to future consumption, and thus in every case will operate with a lower discount rate than the representative agent. [20]

The classical efficient outcomes of competitive equilibrium encompass a much narrower set of possible resource deployments than is possible under a detached planning model, and theory would suggest that government and planning entities ought to enact policies with a bias towards future consumption in order to counteract the 'tyranny of the present.' This sensitivity to time varying preference generally means that in comparison to private entities rational policy makers are more likely to favor resource conservation and savings than current consumption. [21]

DETERMINING AN APPROPRIATE DISCOUNT RATE

In defining the rate that a detached planner would use, the 'social discount rate,' it is important to examine the factors that are encompassed in a discount rate and consider the elements that are unique to a public planning perspective. First, the concept of risk is different for a public investment, when risk is spread amongst a large and diverse group of taxpayers [22]. Expectations about the future are very different on a public planning scale than they are for individuals. Assumptions that future generations will be wealthy will tend to raise the discount rate, weighting current consumption more heavily, whereas expectations of stagnant or negative economic growth for an economy will encourage delayed consumption in the form of savings and investment. [23]

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[20] Federal Reserve Bank of Minneapolis. *The Social Discount Rate*. January 2001. Online. Available: http://www.minneapolisfed.org/research/dp/dp137.pdf. p. 3.
[21] *Ibid.* pp. 14-15.
[22] New Zealand Treasury. *Determining the Discount Rate for Government Projects*. September 2002. Online. Available: https://www.treasury.govt.nz/publications/research-policy/wp/2002/02-21/twp02-21.pdf. p. 4.
[23] *Ibid.* p. 5.

At its core, the operational use of the social discount rate is a representation the opportunity cost to society of spending. This is most appropriate for the analysis of public investments, and also the most straightforward to infer from other indicators in the economy. [24] The social discount rate in this case may be considered a function of time preference, which is the marginal rate of substitution of current and future consumption. [25] This can be calculated in the same way that private firms calculate their weighted average cost of capital (WACC):

$$WACC=(k_b\ D/(D+E)\ +K_e\ E/(D+E)$$

In this specification k_b is the return on debt calculated based off of its yield in the market in order to demonstrate the cost of borrowing with debt, D is bonds outstanding and K_e is return on equity, calculated using CAPM, without taxation and E is equity outstanding. Note that this differs from the standard WACC specification in that it has been adjusted to reflect that governments do not pay corporate taxes. [26] This is a straightforward cost-based calculation of the discount rate, and given that the government does not conventionally issue equity the WACC model will logically be reduced to $k_{b,}$ the cost of government borrowing.

The benefit of the WACC method is that it is most directly observable in the market, but given then 'dictatorship of the present' concerns raised in the discussion of competitive equilibrium models it may be appropriate to use a more nuanced calculation of a social discount rate. The shadow price of capital, the offset consumption based on

[24] *Ibid.* pp. 4-5.
[25] *Ibid.* p. 4.
[26] *Ibid.* pp. 8-9.

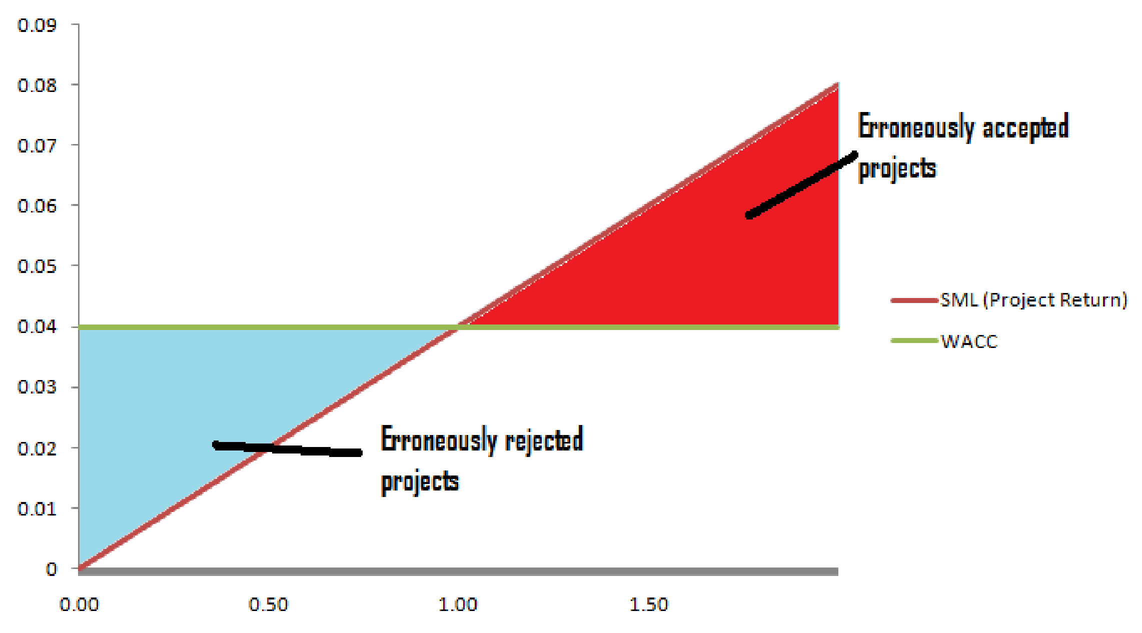
the allocation of capital to a particular project, is perhaps more appropriate, especially for a taxing entity. Unfortunately, the lack of a counterfactual for the allocation of resources in the absence of taxes means that the calculation of the social discount rate using this method will be fraught with uncertainty and political disputation. [27]

Another common critique of the WACC model is that it tends to exacerbate systemic risk when a firm applies it uniformly across all available projects. While WACC is calculated as above, the expected rate of return for a given project is based on its own inherent risk. [28] For the sake of simplicity, this can be illustrated by the example of a firm fully financed by debt with a borrowing cost of 4%, a reasonable analog to the United States government. Using the simple equation above for a tax-free firm the WACC of the government would be 4%, so a project with an expected rate of return in excess of 4% would be approved. The expected cash flows from an individual project should ideally be judged against the project's risk relative to the performance of the overall market, generally expressed as the correlation coefficient relative to the overall returns available in the market, β. Figure 4 plots the security market line of the expected rate of return over the β values for projects available to the government, using the risk-free rate of 4% as the market return. As a general principle, a project should be accepted if the net present value of its discounted cash flows are positive; that is, if the expected rate of return is positive given the risk of the project. As can be seen in Figure 4, there are projects with a positive internal rate of return that would be erroneously rejected by the firm and projects with negative rates of return that would be erroneously accepted. When an organization calculates a discount rate for the entire firm and applies it to all projects without rigorous

[27] *Ibid.* pp. 6-7.
[28] Ross, Stephen A., Randolph W. Westerfield, Bradford D. Jordan. *Essentials of Corporate Finance.* New York: McGraw Hill, 2003

analysis of the specific risks of the cash flows associated with it then over time the organization will not be expected to optimally benefit from the risks that it takes.

Figure 4: Inefficiencies of Risk Management with Broad Application of WACC



CBA AS USED BY THE FEDERAL GOVERNMENT

In Circular A-94 he Office of Management and Budget periodically offers guidance for Federal programs in performing CBA that is useful for conceptualizing the inclusion of externalities and considering issues such as opportunity costs and the social discount rate. The guidance for public investments is that benefits and costs should always start with the 'willingness to pay' metric of the competitive equilibrium model, and only incorporate other values with solid theoretical justification.

OMB directs policymakers to consider 'distributional' effects of any public investment decision based on the principle that a positive NPV economic event will result in a scenario whereby those who benefit the most would be able to compensate those who lose value and still be better off than their initial condition. This assumption of non-zero-sum creation of value is difficult to implement on the project-level for governments because the 'losers' are millions of taxpayers who more likely than not are not direct beneficiaries of the created value. The purpose of taking distributional effects into account is to help ensure that the net value created by government activities is accrued by taxpayers across the economy is such as way that it exceeds the losses from taxation for the greatest number of taxpayers possible. Again, the absence of a counterfactual economic scenario obstructs the rigorous corroboration of the success or failure distributional efficiency. This policy goal presents the greatest challenge to social welfare spending that directly benefits those who do not generate significant tax revenue for the government, as is the case with subsidized low-income residential weatherization.

The discount rate that the OMB currently mandates for public investments is 7%, which it claims is based on the opportunity cost of alternatively allocating funds in the private capital markets. It is interesting to note that this rate is significantly higher than that which would be implied by the WACC model, considering that the government's cost of debt is considerably lower, and by conventional risk-free based valuation procedures is at any point in time the lowest cost of borrowing in the market. [29]

Relevant to the assessment of the net benefits of weatherization and other sustainability investments is the guidance to especially consider the variability of assumed figures in cost-benefit calculations. OMB directs policymakers to primarily consult market data for volatility estimates and compose sensitivity analyses that take the

[29] Office of Management and Budget. *Circular A-094*. Online. Available: http://www.whitehouse.gov/omb/circulars_a094/. Accessed: February 12, 2011

underlying volatility into account. The net benefits of weatherization investments are highly sensitive to the price of energy, which is notoriously volatile.

While CBA is a useful paradigm for policymakers, empirical evidence suggests that there are significant difficulties applying a rational actor model to predict the behavior of the residential energy consumer. Complete and accessible relevant information is a critical assumption of the rational actor model, but in the case of residential energy efficiency there are concerns both about the way that consumers perceive price and the way that this affects their choices. [30]

Limitations to the Representative Agent Assumption

The fact that residential consumers do not generally know how to assess the costs and benefits of energy efficiency interventions is borne out in their observed behaviors[31]. In the absence of guidance or policy interventions residents will invest in efficiency interventions in order of increasing costs with inconsistent regard to the cost-benefit ratio of the intervention. [32] Furthermore, the time preference implicit in the discount rate suggested in the observed replacement of appliances with more efficient models is highly inconsistent, likely due to the fact that the largest consideration of personal utility in an appliance has more to do with its function than its energy use. [33]

RECONCILING OBSERVED BEHAVIOR WITH ECONOMIC THEORY

In the parlance of microeconomics, the fact that consumers remain largely ignorant of the mechanics of the pricing of their energy would conventionally be attributed to high 'search cost,' wherein the cost in time and resources of accessing

[30] Stern. "Blind Spots." p. 203.
[31] Frieden. "The Market Needs Help." p. 442.
[32] *Ibid.* p. 445.
[33] Stern. "Blind Spots." p. 209.

information about energy consumption would render the entire prospective efficiency project uneconomical. This concern would seem to be obviated in that total consumption and pricing information is provided to most consumers by the utility on a monthly basis. This suggests that the culprit is behavioral in nature, and has more to do with a subjective prior orientation regarding the amount of agency that a resident has over the cost of their energy use [34]. This hypothesis is corroborated by observed behavior in the decision to purchase an energy audit. Even when the existence of a service is generally known amongst the ratepaying public the extent to which this service is pursued is driven more by outreach and promotion efforts of the sponsoring agency than by pricing or efficacy in producing real savings. [35]

The concerns raised in this chapter address both the application and the theory of cost benefit analysis, especially in the context of affecting residential energy consumption. In practical terms, the basic intuitive question that must be addressed is whether the resources allocated to a weatherization investment on behalf of a resident could be better spent on that resident's behalf. On this level the question is endemic to all government actions that are not directly involved in the creation of a tangible public good. In the absence of a strong justification more expansive that simple cost savings a government that invests in energy efficiency for a household is in effect purchasing an annuity on that households behalf. An investment judged solely on its cash flows is most appropriately discounted at a rate determined by the preference of the recipient of those cash flows, and in many cases it would make more sense to simply grant the principal of the investment to the resident.

[34] *Ibid.* p. 204.
[35] *Ibid.* p. 211.

The two countervailing threads of reasoning to this argument are the critique of the time preference assumption of CBA in a policy context and the simple argument in favor of incorporating non-monetary benefits into an assessment of a project. The latter begs the question of program evaluation in general and exposes policymakers to a slew of subjective weighing mechanisms that cannot be assessed objectively or consistently. The former is technically elegant and consistent with the core definitions of value used in CBA, but practically is difficult to employ because it assumes knowledge by policymakers of a field of opportunities over time that in practice are speculative at best. The exception would be the case where policymakers had special knowledge of the field of relevant costs and benefits at certain points in the future that individual, self-interested economic actors either lack the knowledge to incorporate into their decision-making or are unable to asses within their constrained time horizon.

Pursuing the latter thread of argument, the case for intervention by policymakers can be built either on establishing that they have access to a broader array of information than is generally available to the population of low-income residents and are thus justified in taking license to invest on their behalf, or that they are able to make investments that are erroneously rejected by the residents due to their inappropriately high time preference for consumption, as is outlined in Figure 4. The distinction may seem academic, but the policy implications of each view are starkly different. The case of policymakers having better information could be solved through education outreach initiatives, and the market for weatherization services would automatically achieve efficient outcomes through newly-informed consumers deciding to invest in efficiency interventions appropriate to their level of consumption. Utilities that offer rebates for efficient appliances are essentially operating under this framework of facilitating market equilibrium. The Weatherization Assistance Program targets low-income individuals, however, and is acting under the framework that a project that cannot be justified by the implicit time preference for consumption of the client can still be justified by decoupling the analysis of value from the 'tyranny of the present.'

The final issue to consider is whether the systemic destabilization dynamic accompanying a universally applied discount rate could affect governments as well as private firms. The first, most important distinction in this analysis is that a government generally does not rely on cash flow generated directly from its operating activities to remain solvent, so the threat of eventual bankruptcy due to an inappropriate risk management strategy is somewhat more remote. Whereas the cost of borrowing for a firm that continuously makes poor decisions would increase as it loses favor with investors, leading to a vicious cycle of both increased costs and a diminished field of profitable investment opportunities as the WACC line climbs higher, the credit standing of a government is not driven by the profitability of its activities and as such the cost of borrowing is relatively more stable.

If inefficient allocation of public resources does not pose the same sort of existential threat to governments as it does to private firms it still represents an opportunity cost to beneficiaries of those resources. Given OMB's dictum to apply a 7% discount rate to the benefits of government spending without specific guidance as to how to account for the project-specific risks of those benefits it can be hypothesized that policymakers are erroneously implementing programs whose expected returns exceed 7% but whose level of uncertainty exceeds that return.

The tools of risk management are highly developed in the energy sector, and it is simple to find a market proxy for the risk of an investment whose cash flows are driven by the cost of energy fuel commodities. Forecasted volatility in natural gas markets, for example, could be used to set project-specific risk for a residential weatherization project that would save power, and volatility in oil markets could be used to determine the discount rate for a project that saves on heating oil. Rather than accepting the 7% one-size-fits-all rate or speculating on the time preference of the average low-income consumer a weatherization project should be discounted based on the unique risk of its benefits.

CHAPTER 4. EXISTING EVALUATIVE METHODS

Having addressed how to analyze information regarding the impact of weatherization services in a decision-making framework like CBA, we will now more closely examine methods used for generating the data on prospective benefits that may be included in the model. No matter how thorough a financial model, its outputs are only as good as the quality of its inputs, so creating strong estimates with well defined variances is critical to forecasting benefits and choosing between investment options.

Establishing evaluative measures is the prerogative of the funding agency, and a variety of program evaluation regimes to assess sustainability investments have developed over the years. While there is much common ground between the regimes, there are key contrasts driven by the assumed size and sophistication of the implementing organization and the varying policy goals of the funding group.

The Weatherization Assistance Program

EFFICACY VS. POLITICS IN ALLOCATING FUNDS

The largest sustainability investment program in the United States is the Weatherization Assistance program, a Federal program administered by the Department of Energy whereby states receive grants to invest in low-income residential weatherization. Initially created in 1976 with the goal of helping low income families reduce expenditures on energy and to reduce reliance on foreign sources of oil, its early funding allocations were seen to favor cold-weather states where home climate control expenses were primarily on residential heating oil. The disproportionate spending was challenged by Southern states, where residential indoor climate control expenditures are primarily on electric power for cooling, and in 1995 a new formulae was developed that more equitably distributed funding based on a broader definition of residential energy expenditures. In order to not pull funding from states that had benefited from the previous formula, however, the new formula was not to be set in place until triggered by an annual budget exceeding $209.724M, a threshold that was not surpassed until the American Recovery and Reinvestment Act (ARRA) allocated $5B to the program in 2009. [36]

RECENT STEPS TO TIGHTEN EVALUATIVE MEASURES

In 2006 the Department of Energy initiated the first full-scale evaluation of the Weatherization Assistance Program in approximately fifteen years[37], and contracted with several independent agencies to collaborate with Oakridge National Laboratories to conduct a formal evaluation under the evaluative framework established by the W.K. Kellogg Foundation. The Kellogg Foundation's evaluation model seeks to balance the rigorous hypothesis testing of academic research and the empirical social sciences with planning and communication techniques that facilitate the continuous improvement of the program throughout the evaluation process. [38] A critical step in this process is the building of a 'logic model' to conceptualize the operations of a program. [39] The components of this model are as follows:

- *Inputs*- the human, capital, and material resources available to a program

[36] Department of Energy. *Weatherization Program Notice 09-1B.* Online. Available: http://www.waptac.org/datas/files/wap_basics/wpn09-1bwapfinal031209.pdf. Accessed: February 2011. p. 4.

[37] Oak Ridge National Laboratory. *National Evaluation of the Weatherization Assistance Program: Preliminary Evaluation Plan for Program Year 2006.* February 2007. Online. Available: http://weatherization.ornl.gov/pdfs/ORNL_CON-498.pdf. p.1.

[38] W. Kellogg Foundation. *Evaluation Handbook*. January 1998. Online. Available: http://ww2.wkkf.org/DesktopModules/WKF.00_DmaSupport/ViewDoc.aspx?fld=PDFFile&CID=281&ListID=28&ItemID=2810770&LanguageID=0. pp. 5-7.

[39] *Ibid. p. 11.*

- *Activities*-the specific interactions of inputs that comprise the operations of the program being evaluated
- *Outputs*-the immediate and direct results of the activities
- *Outcomes*-the consequences of the outputs to the targeted groups on a granular level
- *Impact*-an aggregate description of the outcomes that defines the overall mission of the program [40]

The exercise of building a logic model internally or with the collaboration of a funder allows both for the development of relevant criteria by which to assess an organization as well as clarify goals within the staff of the organization so as to improve performance. [41]

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[40] W. Kellogg Foundation. *Logic Model Development Guide.* January 2004. Online. Available: http://ww2.wkkf.org/DesktopModules/WKF.00_DmaSupport/ViewDoc.aspx?fld=PDFFile&CID=281&ListID=28&ItemID=2813669&LanguageID=0. p. 8.

[41] W. Kellogg Foundation. *Evaluation Handbook*. pp. 35-36.

Figure 5:Logic Model of the Weatherization Assistance Program [42]

Table 1.1. Logic model for the Weatherization Assistance Program

Resources/ Inputs	Roles/Activities	Outputs	Outcomes		
			Short-Term	Medium-Term	Long-Term
Federal authorizing legislation Direct funding from DOE, LIHEAP, PVE, and leveraged sources DOE Program staff State grant administration agencies and related national organizations Local service network of 900 agencies and related national organizations Support network in national laboratories, training centers, and support contractors with special technical skills Utilities and national and state energy organizations	<u>DOE</u> - Establish and explain national policy direction - Formulate annual budgets and grant guidance, and make grants - Formulate Program rules and regulations - Initiate and coordinate strategic planning with network - Approve and monitor state plans and their implementation - Create, coordinate, and conduct technical training and assistance to state and local agencies - Develop and maintain core capabilities of the Program including audit tools and standards, evaluations, and assessments - Coordinate Program relations with other Federal agencies, programs, and institutions <u>States</u> - Set eligibility requirements and priorities for participants - Contract with local agencies and allocate funding - Establish production goals (number of units weatherized) and schedule - Specify diagnostic, audit, and inspection procedures and allowable measures for local agencies - Determine extent of allowable repair, health, and safety work - Provide training and assistance to local agencies - Establish leveraging programs and expand resources and partnerships - Monitor local agency work <u>Local Agencies</u> - Solicit and process applications and select low-income residents to receive weatherization services - Train crew members - Perform home energy diagnostics, audits, and inspections - Determine most cost-effective weatherization measures and other work needed for each home - Purchase, store, and maintain equipment, materials, and supplies - Install measures and perform other specified work - Perform quality assurance work - Meet with clients to review improvements and provide educational materials - Support advocacy and leveraging - Link clients to other programs and services - Track and report client status, expenditures, and funding	Number of low-income homes weatherized Number of priority households weatherized Cost-effective measures installed in weatherized homes Health and safety deficiencies mitigated in weatherized houses Clients receive education on energy savings Number of weatherization staff trained Number of clients referred to social programs Guidance and regulations published Audits developed, improved, and approved Partnerships established	Weatherized homes, particularly those of priority populations, have increased energy efficiency Health and safety of those living in weatherized homes improved Indoor comfort of those living in weatherized homes improved Clients have increased knowledge of energy savings strategies	Reduced energy consumption in weatherized houses Reduced energy bills and burdens for clients Reduced emissions of pollutants and greenhouse gases involved in energy production and consumption Other non-energy benefits for clients, utility rate payers, and society Robust weatherization network Increased Program leveraging	Reduced gap between low-income energy needs and actual consumption of energy services Reduced impact of energy price inflation and market disruptions on low-income communities Improved health and safety for communities Improved local housing stock Workforce enhancement in local communities Creation of sustainable weatherization services market Increased non-energy purchases in low-income communities Transform market for weatherization products

The logic model of WAP distinguishes between the short-term, intermediate-term, and long-term outcomes of the organization's weatherization efforts. Short-term goals are largely related to the household-level benefits, intermediate-term goals expand the scope to include the development of the professional weatherization sector and reducing

[42] Source: Oak Ridge National Laboratory. *National Evaluation of the Weatherization Assistance Program: Preliminary Evaluation Plan for Program Year 2006.* February 2007. Online. Available: http://weatherization.ornl.gov/pdfs/ORNL_CON-498.pdf. p.19.

emissions, and the long-term goals include the reduction in volatility of energy prices, a permanent weatherization industry, and community-level health impacts. [43]

MEASURING BENEFITS OF SUB-GRANTEES: THE 'WAP ALGORITHM'

These high-level goals are implemented through the granting of funds to state-level agencies, which in turn have been given wide latitude to institute oversight procedures over their sub-grantees. Grantees are tasked with allocating funds to sub-grantee service providers and giving guidance on the allowable expenditures, which are designed using the criteria of maximizing the energy savings per dollar invested in terms of 'energy savings' in British Thermal Units. [44] The method used to calculate these funds is referred to as the 'WAP Algorithm', a proxy estimator with significant limitations.

A review of publically available WAP Program Filing submissions, the annual update that state grantees submit to the Department of Energy, found that most states chose to use the 'WAP Algorithm' rather than perform an original analysis. This is understandable, given the amount of labor hours required to collect and analyze data from utilities to test actual impacts on weatherized houses, or alternatively the amount of technical sophistication required for inferential methods of estimation.

The development of the most recent iteration of the 'WAP Algorithm' was based on a meta-analysis of studies of the efficacy of WAP-funded energy efficiency programs in 17 states and the District of Columbia and used ordinary least squares regression to

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[43] Oak Ridge National Laboratory. *National Evaluation of the Weatherization Assistance Program: Preliminary Evaluation Plan for Program Year 2006.* February 2007. Online. Available: http://weatherization.ornl.gov/pdfs/ORNL_CON-498.pdf. p. 13.

[44] National Energy Technology Laboratory. *Weatherization Formula Grants American Recovery and Reinvestment Act (ARRA) Funding Opportunity Number: DE-FOA-0000051.* Online. Available: http://www1.eere.energy.gov/wip/pdfs/wap_recovery_act_foa.pdf. Accessed February 2011. p. 40.

determine the drivers for energy savings. [45] It was intended to replace an earlier formulation that was based on the weighted average savings of two state studies that specified an energy savings of approximately 31.7 mmBtu per household. The assumptions of this regression technique are that the covariates are linear in their relationship to the independent variable, the variance of the discrepancy between the estimated and observed values is constant over the range of the covariates, and that these discrepancies are normally distributed. [46] The initial model specifies natural gas energy savings as the dependent variable, and pre-weatherization energy usage, square footage of the home, heating degree days, and per-household weatherization expenditures as the explanatory variables. [47]

TECHNICAL PROBLEMS WITH THE 'WAP ALGORITHM'

The difficulty in using a small sample for this sort of regression is that the estimated parameters, while unbiased, are not of minimum variance[48]. This creates an issue for hypothesis testing, which relies on demonstrating that a specified area of the estimated range for a parameter does include zero, and the likelihood of generating a type II error, or 'false negative', is increased. [49]

In this case, the limitations of regression are compounded by the attempt to use several covariates to explain the energy savings as a result of WAP. The classical multivariate OLS model assumes no covariance between the explanatory covariates,

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[45] Oak Ridge National Laboratory. *Estimating the National Effects of the U.S. Department of Energy's Weatherization Assistance Program with State-Level Data: A Metaevaluation Using Studies from 1993 to 2005*. September 2005. Online. Available: http://weatherization.ornl.gov/pdfs/ORNL_CON-493.pdf. pp. 5-6.
[46] Gujarait, Damodar, and Dawn C. Porter. *Basic Econometrics: Fifth Edition*. (Singapore: McGraw Hill, 2009). pp. 97-102)
[47] Oak Ridge National Laboratory. *Estimating the National Effects*. p. 5.
[48] Gujarati, p. 828.
[49] *Ibid.* p. 121.

otherwise the ability to estimate the minimum-variance parameters in confounded and the variance of parameter estimates is inflated. [50] Intuitively, however, one would see that there is a direct relationship between the explanatory variables specified in the above model. The annual amount of natural gas used to warm a home is directly related to the size of the home as well as the number of days of the year where the climate requires the home to be heated. Furthermore, the amount of money spent on weatherization would be directly related to the size of the home.

The implementers of the study were seeking a general algorithm by which to estimate the impact of weatherization across the United States, and thus made the decision to drop any covariates whose parameters were not deemed to be statistically significant from zero. As a consequence, after several iterations of regression and re-specification of the model the final algorithm specified that the only explanatory covariate for energy savings was the pre-weatherization energy savings:

Annual Natural Gas Savings (mmBtu)= -10.833+(0.311*pre-weatherization Natural Gas Usage)

R^2=0.41(V6)

This model may be interpreted to say that the energy savings for a weatherized home are a direct linear function of the energy used prior to weatherization, with a marginal annual savings of .0311 mmBtu per mmBtu of usage pre-weatherization.

The authors did not include diagnostics to test assumptions of normality and constant variance of the error terms, but such diagnostics are difficult with a small sample. The important consequence of this is the inability to test for systematic patterns

[50] *Ibid.* p. 181.

in the error terms that would provide clues as to the important omitted variables. The sum of squared error comprises 61% of the total variance of the variance of energy savings in this model; the implicit assumption that this is white noise is not corroborated and highly suspect.

In order to generalize the model the authors use the assumption of 133 mmBtu as the baseline natural gas consumption for a US household, and thus the estimated savings provided by the algorithm is 30.5 mmBtu per year per household. [51] Having a constant, nationwide estimate for the savings generated by weatherization funded by WAP is politically safe and administratively simple, however the implicit assumption that the only systematic driving factor of energy savings is initial energy usage, and that all other factors are randomly geographically distributed defies logic. The most apparent example of bias inherent in this specification is the distribution of 'heating degree days', the number of days per year below 65^{o} F. This is directly related to geography, with many fewer heating degree days in southern states, and energy usage in southern states is consequently much lower during the winter.

Another problem with this specification is the adequacy of the definition of 'energy savings'; it does not take into account the energy benefits for cooling, which would be measured in kWh or mmBtu-equivalents of electricity rather than mmBtu of natural gas. In areas with more cooling degree days than heating degree days the principal savings would be measured in terms of electric power, whereas this algorithm is derived exclusively from pre- and post-weatherization natural gas usage. As a proxy for energy savings from states with large number of cooling degree days and significant electric power expenditures during the summer, as is the case in southern states, this

[51] Oak Ridge National Laboratory. *Estimating the National Effects*. p. 7.

algorithm is entirely inadequate. Other assumptions, such as the random distribution of households with regards to size and non-systematic geographic distributions of labor and materials costs would likewise not be expected to withstand rigorous scrutiny.

In spite of these shortcomings, this algorithm is used by many states to report their energy savings to WAP. For example, Texas, Virginia, and Michigan all reported energy savings of 30.5 mmBtu per household, and Hawaii and New Hampshire both used the 31.7 mmBtu per household of the earlier formulation. [52] [53] [54] [55] [56] [57] [58] [59] [60]

The development of a new algorithm is expected as a result of the aforementioned study being performed by a consortium of groups lead by Oak Ridge National Laboratory, the source of the existing algorithm. As part of the national evaluation of

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52 Texas Department of Housing and Community Affairs. *Draft-2011 DOE WAP State Plan*. February 2011. Online. Available: http://www.tdhca.state.tx.us/ea/docs/11-DOE-WAP-Plan-Draft.pdf. Accessed: February 2011

53 State of South Carolina. *(Draft) PY 2011 Weatherization Assistance Program State Plan.* February 2011. Online. Available: http://www.oepp.sc.gov/oeo/forms/PY%202011%20WAP%20State%20Plan%20(draft).pdf. Accessed: February 2011

54 Commonwealth of Puerto Rico Energy Affairs Administration. *American Recovery and Reinvestment Act Weatherization Assistance Program State Plan.* May 2009. Online. Avaialble:http://www.pr.gov/NR/rdonlyres/71AF1CB4-397B-4CB6-9206-FFBF2094A373/35455/StatePlan20195500.pdf. Accessed: February 2011

55 Department of Energy. *Weatherization Annual File Worksheet: Hawaii 2009.* Online. Available:http://hawaii.gov/labor/ocs/pdf/HI%20ARRA%20WAP%20Annual%20File%20WinSAGA-Revised%207-15-09.pdf. Accessed: February 2011

56 Department of Energy. *Weatherization Annual File Worksheet: New Hampshire 2009.* Online. Available: http://www.nh.gov/oep/recovery/documents/wx_annual_file_worksheet.pdf. Accessed: February 2011

57 Department of Energy. *Weatherization Annual File Worksheet: Virginia 2010.* Online. Available: http://www.dhcd.virginia.gov/HousingPreservationRehabilitation/Word/DOE_WAP_State_Plan_Annual_File_Worksheet.docx. Accessed: February 2011

58 Department of Energy. *Weatherization Annual File Worksheet: Kentucky 2010.* Online. Available: http://www.kyhousing.org/uploadedFiles/Resources/Home_Repairs/DRAFT_2010WeatherizationAnnualFile.pdf. Accessed: February 2011

59 Department of Energy. *Weatherization Annual File Worksheet: North Carolina 2009.* Online. Available: http://blog.news-record.com/staff/green/NCweatherizationapplicationMay2009.pdf. Accessed: February 2011

60 Department of Energy. *Weatherization Annual File Worksheet: Missouri 2009.* Online. Available: http://www.dnr.mo.gov/energy/docs/wx-arra-py09-annual-file-rev1110.pdf. Accessed: February 2011

WAP a sampling is currently underway that will use billing data from 2009-2011 in order to infer the direct impacts of weatherization on household energy expenditures. [61]

The monitoring requirements for grantees include the inspection of at least 5% of the residences which have been weatherized using WAP funds and ensuring that expenditures are within the allowable range per serviced home as outlined by their approved budgeting procedures. [62] The principal accountability responsibilities of the sub-grantees are quarterly reports that include information such as the number of households and persons helped by demographic characteristics, fuel and energy type usage by household, outlays and hours worked. [63]

THE FUTURE OF THE ALGORITHM

With the ARRA in 2009, colloquially referred to as the 'Stimulus Act', the reporting requirements for grantees were notably expanded. The unprecedented increase in funding for the program was accompanied by a perceptible shift in the emphasis of its goals. New reporting requirements included capital expenditures in excess of $5000 and the number and type of jobs created or retained. [64] The notable emphasis of WAP oversight from the Department of Energy is fiscal management, and with the ARRA expansion the priority has expanded to include training and employment.

Monetization of benefits such as energy savings is not expected of sub-grantees, nor is the collection of empirical data on home energy usage. Certainly this information is difficult to collect and interpret; even amongst professional energy analysts the

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[61] Oak Ridge National Laboratory. *National Evaluation*. pp. 25-28.
[62] Department of Energy. *Weatherization Program Notice 10-9.* Online. Available: http://www.waptac.com/data/files/technical_tools/wpn10-09.pdf. Accessed: February 2011. p. 2.
[63] Department of Energy. *Weatherization Program Notice 10-13A.* Online. Available: http://www1.eere.energy.gov/wip/pdfs/wap_arra_reporting_requirements.pdf. Accessed: February 2011. p. 7.
[64] Department of Energy. *Weatherization Program Notice 09-1B.* Online. Available: http://www1.eere.energy.gov/wip/pdfs/wpn_09-1B.pdf. Accessed: February 2011. p. 14.

methods are disputed. Regardless, the attempt to use a universal algorithm with only one parameter to report energy usage across the country is highly problematic and cannot be taken seriously as representative of the actual benefits of WAP.

PRISM: Princeton Scorekeeping Model

The gold standard for energy-savings calculations in analyzing the efficacy of weatherization is the Princeton Scorekeeping Model, commonly referred to as PRISM. It is a statistical method for determining the fuel savings for a particular intervention or a sampling of interventions, and is able to demonstrate actual consumption changes over time by directly controlling for the relationship between fuel consumption and ambient temperature. [65]

The specific advantages of PRISM over other methods, such as the WAP algorithm, is that it is directly derived from empirical observations of a building or set of buildings, has been deemed to be reliable through demonstrated validations of the model, and generates a standardized score that facilitates meaningful cost-benefit-analyses or efficacy comparisons. [66]

SPECIFICATION OF PRISM

The inputs for PRISM are a vector of billing data for a house or for samples of houses and corresponding ambient temperatures for certain intervals of time, and the dependent variable is the fuel consumption. Its simplest form is for a heating-only weatherization project, and is formally specified as follows. [67]

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[65] *Fels, Margaret F.* "PRISM: An Indroduction." *Energy and Buildings*, vol. 9, no. 5. (1986). PRISM (http://www.princeton.edu/~marean/publications/prism_intro.pdf). p. 6.

[66] *Ibid.* p. 2.
[67] *Ibid.* p. 1.

$$f=\alpha+\beta(\tau-T)_+$$

Where f is fuel consumption, α is the baseline energy consumption for a household, τ is the desired target temperature within the household, T is the ambient temperature, and '+' indicates that the difference term is non-negative, bounded by zero. The value of interest for users of the model is the normalized annual consumption (NAC), which is a function of heating-degree days in a given year. F_i is the average fuel consumption for a given period, and $H_i(\tau)$ is the average heating degree days for a given period. Heating degree days for a given period is calculated as follows:

$$H_i(\tau)=\sum_{i=1}^{Ni}=(\tau-T_{ij})_+/N_\mathrm{i}$$

Where N is the number of days in the given period. Given these inputs the model for a given building is specified using ordinary least squares linear regression:

$$F_i=\alpha+\beta\, H_i(\tau)+\epsilon$$

Where ϵ is the normal error term with constant variance. One year of data is sufficient to calculate this model, after which the parameters may be applied to forecast the NAC:

$$\mathrm{NAC}=365\alpha+\beta\, H_i(\tau)$$

Once derived it may be used to project the efficacy of specific interventions with any scenario of forecasted temperature values and heating base for a given year. [68] The value of the PRISM model is that the statistical techniques are fairly straightforward and subject to the conventional diagnostics of linear models. It is important to note that the interpretation of these parameters is sensitive to the accuracy of τ , the indoor temperature target, a value which in fact may have a significant degree of variance, especially in homes where thermostats are controlled by human decisions rather than in large,

[68] *Ibid.* p. 10.

automated buildings [69]. It is also possible that for individual residences the different usage of heating infrastructure at different times, such as weekdays versus weekends or vacation periods, will skew the parameter estimates if not managed in the data gathering period.

EXPANDING FOR MORE THAN ONE FUEL TYPE

While the creators of PRISM do not elaborate on the topic, they do suggest that a significant advantage of the NAC index is that it given that it may be expanded to include cooling as well as heating. Given that building cooling is done electrically and heating is generally done through gas or heating oil combustion the NAC will need to be specified in terms of heat-content equivalents of whatever unit the energy consumed is measured in, such as converting kWh to equivalent mmBtu. [70] A proposed specification of the model for both heating and cooling savings is as follows:

$$f=\alpha+\beta_1(\tau_1-T)_+ + \beta_2(T-\tau_2)_+$$

Wherein the initial terms are specified as above in the heating-only model, but the second covariate term is representative of cooling-degree days. The relationship between the outdoor temperature and the target temperature for cooling degree days is opposite of what it is for heating degree days, and remains a non-negative term bounded by zero. It should be noted that the values for τ, the targeted indoor temperature, do not necessarily need to be equivalent for the calculation of heating-degree and cooling-degree terms. It is reasonable to assume, however, that τ_2 is greater than τ_1 in a rational climate control system, such that the heating and cooling units are never simultaneously deployed.

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[69] *Ibid.* p. 8.

[70] *Ibid.* p. 14.

Technical Issues with Interpreting and Using PRISM

A new concern raised by this multivariate specification is that the explanatory covariates are directly negatively correlated, raising the dreaded statistical specter of multicollinearity. This need not be an issue of concern for the reliability of the calculation of NAC, however, although it even further confounds the ability to meaningfully interpret the component parameters of the model. Multicollinearity in ordinary least squares models will not bias the coefficients, but it will not allow for their efficient estimate and tend to report higher standard errors. The consequence of this is that baseline energy usage (α) and the exact marginal fuel usage for heating and cooling (β_1, β_2) cannot be reliably estimated, although overall standardized energy consumption over a period of time may be modeled.

The two possible uses of the PRISM model are to attempt to determine the exact change in energy consumption patterns before and after an intervention in a single structure or to calculate a change in the overall NAC in the pre-weatherization versus the post-weatherization periods.

In the first case, the parameters may be subject to the standard diagnostic and hypothesis testing procedures for ordinary least squares regression. The example given by PRISM is to compare the α value, or the baseline, non-climate control energy usage of a building, for models run before and after the installation of a water heater jacket. Such a test may be specified as

$$H_0: \alpha_{pre} = \alpha_{post}$$

$$H_0: \alpha_{pre} > \alpha_{post}$$

The creators of the model caution against this, however. First, the assumption that the parameters of energy use are constant over time does not hold true in reality. [71] For

[71] *Ibid. p. 11.*

example, plugging in a new appliance would significantly affect α, and standard wear and in a heating system will tend to increase the value of β. Furthermore, the assumed constant value of τ confounds the methods of ordinary least squares to generate parameters that are physically interpretable as actual proxies for energy use, although the overall estimate of NAC remains robust. [72]

Another issue to consider in hypothesis testing is that temperature data is highly autocorrelated, such that there tend to be significant runs in the data and a high degree of seasonality in energy use. The problem with using ordinary least squares regression with autocorrelated data is that the standard error of parameter estimates is artificially underestimated, leading to a risk of type-I error. [73] If autocorrelation is not accounted for then the parameter estimates for α and β would be unbiased but erroneously sharp, and tighter variances would exaggerate the differences between pre and post weatherization models. However, because the parameter estimates remain unbiased the estimate for NAC still remains reliable, although forecasting becomes a technically more complex endeavor.

For both of these reasons PRISM should not be used for testing hypothesis related to the specific components of physical energy usage of the household, but it is still a very useful tool for understanding the overall changes in energy consumption. The recommended metrics for savings are the absolute or percent change in the NAC from the pre and post intervention periods.

$$S_{raw}=NAC_{pre}-NAC_{post}$$

$$S_{raw\%}=[(NAC_{pre}-NAC_{post}\ )]/\ NAC_{pre}]*100$$

[72] *Ibid. pp. 11-12.*
[73] Gujarati. pp. 747-748

The best use of PRISM is to test a sample and control group of houses to determine the effect of weatherization. The developers recommend using the standard error of the mean to perform hypothesis test on NAC for groups of buildings. [74] This formulation lends itself to standard difference-in-difference testing, wherein ordinary least squares is performed on a model specified to account both for the effects of the treatment, control for differences in initial conditions of the treatment and control groups, and also control for the secular changes in energy consumption, providing a legitimate counterfactual so as to completely isolated effects of weatherization. The data would be specified in 'long form', such that each house has two observations, and clustered by house, neighborhood, or city.

This counterfactual is particularly important for weatherization, given that the variance in energy consumption due to minor alterations in a structure, such as caulking or insulation, will be extremely small compared to the proportion of variance of energy consumption that may be attributed to climate control efforts that are driven directly by changes in weather. An easy way of conceptualizing this is to say that the energy consumption of weatherized houses in a given neighborhood will look more alike to the energy consumption of non-weatherized houses of the same type within their neighborhood that they will to weatherized houses, even of the same type, in a different part of the country.

PRE-POST TREATMENT INTERPRETATION OF PRISM PARAMETER ESTIMATES

The difference-in-difference model for a treatment group of weatherized structures and a control group of non-weatherized structures would be performed by

[74] Fels. p. 12.

estimating the NAC for each in appropriately substantial periods, preferably a year, before and after the weatherization event.

$$NAC=\beta_0+ \beta_{weatherization}+ \beta_{post}+ \beta_{weatherization*post}$$

Each explanatory covariate is a binary variable. The component variables *treatment* and *post* indicate whether the measurement is from the treatment or control or in the pre or post period, respectively, and the interaction term for the two is the difference-in-difference term that isolates the effect of weatherization. The coefficients are easily interpreted when organized into a difference-in-difference matrix:

Table 1: Difference-in-Difference Grid for NAC

	Pre- Weatherization Period	Post-Weatherization Period	Difference
Treatment	$\beta_0+ \beta_{weatherization}$	$\beta_0+\beta_{weatherization}+ \beta_{post}+ \beta_{weatherization*post}$	$\beta_{post}+\beta_{weatherization*post}$
Control	β_0	$\beta_0+ \beta_{post}$	β_{post}
Difference	$\beta_{weatherization}$	$\beta_{weatherization*post} + \beta_{weatherization}$	$\beta_{weatherization*post}$

A hypothesis test to corroborate the efficacy of weatherization would examine whether $\beta_{weatherization*post}$ is statistically significantly different from zero. The advantage of using the difference-in-difference method as opposed to a simply test of the changes in energy consumption is that the variance in the change in consumption that is driven by weather and other systematic factors is captured in the coefficient for the explanatory covariate '*post*' and not erroneously attributed to weatherization. Furthermore, the coefficient for the explanatory covariate *'weatherization*' may be used to capture any differences in initial energy consumption between the treatment and control groups. Ideally, randomization would obviate this concern, but with this specification the assumption is automatically tested in whether the coefficient is significantly different from or equal to zero.

MONETIZING THE OUTPUTS OF PRISM

The creators of PRISM stress that the NAC is best used as an index of consumption to estimate the efficacy of energy efficiency interventions and not as a forecasting tool for specific components of energy consumption[75]. Perhaps its most significant contribution to the field of low-income weatherization is that, as opposed to other evaluative models, its inputs are so simple that the model may be composed and interpreted with little formal training in analytical methods and no training in engineering or architecture.

Of course, the primary concern for those interested in low-income weatherization is the question of actual savings in terms of monetary expenditures rather than mmBtus. Incorporating pricing into any standardized index of energy savings is tricky because prices vary significantly over a given. Additionally, pricing per unit of energy is extremely variable given the type of fuel, and price volatility is much higher for certain forms of energy, such as electricity in areas with natural gas as the marginal price setting fuel, and relatively stable in a given period for other forms, such as coal and residential heating oil.

[75] *Ibid.* p.14.

For these reasons determining pricing for the multivariate NAC model is more problematic than for the bivariate NAC model. In the latter case the average price per mmBtu over the given period multiplied by the NAC may give the best standardized expenditure indicator, and for the former an average price weighted by energy consumption would be appropriate. The biggest shortfall of this method is that it does not capture the important microeconomic dynamic that energy consumption correlates directly with energy prices, so weighting prices by consumption over the period in which NAC is estimated would be necessary to generate the relevant expenditure metric.

Consideration of Cost Estimates for CBA

The issue of labor costs for weatherization program have been a significant source of controversy, weighing issues of workforce development and fair wages against maximizing the impact of service delivery to low-income households. Weatherization services vary widely in their complexity, ranging from a large amount of low-skilled light carpentry sealing tasks to services such as energy auditing that require formal training and certification from the Building Performance Institute. This is further complicated by the fact that sub-grantees of WAP are often nonprofit human service agencies as opposed to professional construction firms, and thus lack internalized core competencies for construction personnel management [76].

Historically, the Weatherization Assistance Program has been exempt from Davis-Bacon Act requirements that federally-funded positions pay the prevailing wage for whatever services are procured. This changed with the expansion of funding under ARRA, which required that all stimulus-related programs adhere to Davis-Bacon

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[76] Oak Ridge National Laboratory. *Nonenergy Benefits from the Weatherization Assistance Program: A Summary of Findings from the Recent Literature.* April 2002. Available: http://www.ornl.gov/~webworks/cppr/y2001/rpt/113893.pdf. pp. 2-3.

standards [77]. A complication of this was that the lack of a vibrant private residential weatherization sector outside of previously exempt WAP programs made finding comparable wages on a county-level difficult for many regions, and in most cases the prevailing wages for professional construction work was initially used to set the Davis-Bacon wage [78]. While the expansion to WAP under ARRA was passed in February of 2009 the Davis-Bacon revisions for weatherization worker wages were not issued until December of that year, to which many delays in state implementations of the program have been attributed. [79]

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[77] Department of Labor. *FA-TC-0050: Davis-Bacon Act Requirements*. Online. Available: http://www1.eere.energy.gov/wip/pdfs/dba_clauses_weatherization.pdf. Accessed: February 2011. p. 2.
[78] *Ibid.* pp. 2-3.
[79] Department of Energy. *Energy Efficiency and Weatherization Block Grants Program Notice 10-012.* Online. Available: http://www1.eere.energy.gov/wip/pdfs/eecbg_guidance_not_using_wap_rates_05062010.pdf. pp. 2-3.

CHAPTER 5. POLICY RECOMMENDATIONS

Final Thoughts on Using CBA Methods

UNCERTAIN ACCRUAL OF BENEFITS DUE TO INTERVENTIONS

Having established methods to effectively estimate the benefits of intervention packages, we must consider who the targeted recipient of these benefits may be. The application of CBA assumes a single representative agent to whom the benefits of a program will accrue, presumably a single low-income household. In the case of home-owning families the assumption is warranted; realistically, however, property ownership and housing patterns of our target constituency may affect our ability to definitively support this assumption. There are two major concerns that arise from the possibility of transient housing behavior in our target population.

First off, policymakers must determine whether the goal of a program is to benefit a particular low-income family, or generally to benefit families that are low-income at a given point in time. Energy efficiency investments in a residential unit designated for low-income tenants will serve the latter goal, and may be sufficient to justify public expenditures.

The second concern is not so easily allayed, however. It is possible, especially in an environment of increasing energy costs, that the housing market will place a premium on housing that includes weatherized and efficient amenities, in which case spillover benefits of increased asset values with accrue to the owner of the property. This is generally a secondary policy concern, however if the property owner is then able to extract higher rents due to this market premium weatherization for rental units may have the perverse effect of subsidizing the income of property owners and reducing the available affordable stock of housing for low-income families. For this reason it is reasonable for weatherization funds to be allocated exclusively to housing designated for low-income residents.

DEFINING AN APPROPRIATE DISCOUNT RATE

In practice, low-income families operate as economic agents with very high discount rates, such that present consumption is highly favored over future consumption. As discussed previously, policymakers have the prerogative to overcome this ‘tyranny of the present’ by taking a non-time varying view of benefits, however the problem still remains as to how a benefit allocated over time ought to be compared to a benefit today.

Using the framework of ‘net cost’ defined in the introduction, I would suggest that policymakers develop a discount rate based first on a risk-free rate stet by the alternative view of a hurdle rate defined by the offset cost of living to a household were the cash allocated for the weatherization intervention instead given as a direct subsidy over the expected lifetime of the intervention. If the net cost of living for a household were to be higher under the direct cash transfer scenario, then the intervention is justified. This view of cash flow analysis avoids the issue of time preference altogether and is more directly based in the conceivable alternatives available to policymakers than cost-of-capital methods of discount-rate determination. As suggested in Chapter 3, this rate should be adjusted by the relative risk of a project based on the volatility of the relevant fuel commodity.

Low-Hanging Fruit: Nationwide Regional Benefit Estimate

USING EXISTING DATA TO SPECIFY PRISM

A model for the estimation of benefits to low-income households of weatherization programs is entirely possible using existing data. The Weatherization Assistance Program has information on the types of houses and specific interventions used by their subgrantees for decades, and the amount of data has increased significantly in the past several years due to ARRA-funded expansion. This information may be segmented by housing type and intervention type to create a set of scenarios for each climactic region of the country.

The final piece of the puzzle that heretofore has not been available is the data on consumption, but the challenge here is more administrative than technical. Every utility has comprehensive consumption data for every customer for the lifetime of the account, and they already use this data to determine load forecasts and schedule power capacity. By taking relatively small samples for each housing and intervention scenario in question and matching them with two years of utility data, one prior to weatherization and one post-weatherization, the Department of Energy can fully run the PRISM model and create specific NAC estimates for every array of housing type and intervention option in each state.

As outlined in Chapter 4, the NAC differentials can be paired with energy pricing assumptions to forecast the monetary value of an intervention. A reliable, empirically valid CBA model can then be constructed in order to determine a regionally optimized most effective set of intervention options as well as to support the political argument for an economically efficient rather than politically equivalent allocation of public resources throughout the regions of the country.

The primary barrier so far to this sort of analysis has been a lack of interagency cooperation, such that the Department of Energy administers the Weatherization Assistance Program without necessary cooperation of local utilities. While utilities may often argue that their load data is proprietary and that the release of individual account information violates privacy, the Department of Energy is capable of ensuring anonymity both for firms and ratepayers. After initial matching the dataset can be scrubbed of all information that may be used to identify households without at all affecting the quality of the analysis, and the sample sizes in question are so small as to be useless in the determination of information sensitive to competitive concerns in power markets.

RESIDUAL CONCERN: SUBSTITUTION AND SUBJECTIVE UTILITY

The final concern to be addressed with this proposed analysis is the substitution affect that may be expected due to the high price elasticity of demand for energy observed in low-income households. Should actual consumption be increased due to the expected higher utility per rate of unit of energy with weatherization then the conventional, NAC-only specification of the PRISM model will underestimate the benefits. The developers of PRISM indicate that the use of data from one year before and one year after the intervention will minimize the measurement issues caused by this consumption adjustment affect. The only empirically valid way to measure this adjustment affect would be to use as a control group a set of households who have been mislead into believing that they have received weatherization services and measure any erroneous consumption adjustment; the ethical problems with this are obvious.

Concluding Comments

Policy economics is often besieged by the principal-agent problem, whereby sub-optimal economic scenarios are enacted because decision makers do not bear the cost of misallocation of resources, and thus a rigorous framework for verifying benefits is critical. This professional report addressed both the theoretical foundations for applying decision modeling techniques to sustainability investment decisions in the context of low-income housing as well as technical issues in empirically establishing the benefits of such investments.

As commodity prices outpace the recovery of spending power for US households the question of how to support families burdened with excessive utility costs becomes ever more relevant, and as the consequences of global climate change become more apparent the urgency of developing efficient modes of consumption is sharpened.

In the last century the world has undergone a radical transformation in terms of how we use the resources to provide for our everyday lives. Mass migration to cities, accompanied by changes in transportation and agriculture, the ubiquitous spread of energy-dependent communication technology, and tremendous advances in technology have completely altered the economic and social environment. As the availability of resources shifts and technology continues to advance it may be expected that the next century will witness similar exciting changes for the human condition. I look forward to being part of the conversation.

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GLOSSARY OF TERMS

ARRA: American Recovery and Reinvestment Act

CBA: Cost Benefit Analysis

kWh: Kilowatt Hours, a measure of electric energy quantity

mmBtu: Million British Thermal Units, measure of energy content

MR-GO: Mississippi River-Gulf Outlet

WACC: Weighted Average Cost of Capital

WAP: Weatherization Assistance Program

VITA

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