The Energy, Economic and Environmental Impacts Of the Nebraska Energy Office's Dollar and Energy Savings Loan Program and Weatherization Assistance Program

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Executive Summary

The Nebraska Energy Office's Energy Loan and Weatherization Assistance programs invest in projects intended to reduce consumers' energy usage. These investments have consequential economic and environmental impacts as well. We seek to quantify the energy, economic and environmental impacts that resulted from Energy Loan and Weatherization Assistance program investments made in 2009 and early 2010.

A two-phase process is used to estimate the electric and natural gas savings associated with a variety of energy efficiency investments made through the two programs. These savings are then converted into both annual dollars saved and the present discounted values of the flow of anticipated future savings.

The economic impact of program investments is estimated based on both the direct spending in Nebraska due to these investments and the "multiplier impact" that occurs as initial spending circulates further in the state economy. Program investments are also expected to generate economic impacts in future years as these investments allow households to divert income from energy consumption to spending on other goods and services. The aggregate economic impact is measured in terms of output, value added, employment and job-years created.

The analysis also estimates the environmental impacts of the NEO's investments in the Energy Loan and Weatherization Assistance programs. Estimates are made of reductions in emission of greenhouse and other pollutant gases as a result of the investments. These estimates are converted into economic benefits based on both the long-term potential costs of these emissions and the more immediate costs from pollution including health impacts, water pollution and reduced farmland productivity. This section also includes impacts from improved comfort, health and safety for program participants.

Results of the analysis are in the following table. Over the period examined, the NEO spent just over $6 million on energy related projects, with two-thirds of the expenditures going to the Energy Loan program. That investment generated about $3.5 million in future expected energy savings. It also generated about $9.5 million in output, $5.7 million in value added, $4.6 million in labor income and created 125 job-years of employment. Finally, the investment generated about $3.7 million in environmental, comfort, health and safety impacts.

Summary of Energy, Economic, and Environmental Results
From Energy Loan and Weatherization Assistance Programs

		Energy Loan Program	Weatherization Assistance Program	Total
Nebraska Energy Office Investment				
NEO Investment		$4,038,616	$1,980,176	$6,018,792
Matching Investment		$4,038,616	- - -	$4,038,616
Total Investment		$8,077,232	$1,980,176	$10,057,408
Energy Impacts				
Electric Energy Savings	(kWhs)	253,025	238,722	491,747
Natural Gas Energy Savings	(therms)	109,538	56,730	166,268
Annual Dollars of Energy Savings		$141,226	$81,756	$222,983
PDV of Future Savings		$2,151,487	$1,346,950	$3,498,437
Economic Impacts				
Output		$8,122,360	$1,334,801	$9,457,161
Value-Added		$4,789,475	$916,438	$5,705,913
Labor Income		$3,576,867	$1,014,284	$4,591,152
Job-Years		92.52	32.12	124.64
Environmental Impacts				
Carbon Dioxide	(CO_2)	21,593,951	14,480,918	36,074,869
Sulfur Dioxide	(SO_2)	22,599	27,144	49,743
Nitrogen Oxide	(NO_X)	26,252	22,338	48,590
Particulate Matter < 2.5 micro-meters	($PM_{2.5}$)	393	473	866
Volatile Organic Compounds	(VOC)	868	1,045	1,913
Particulate Matter < 10 micro-meters	(PM_{10})	630	759	1,389
Total PDV		$2,084,478	$1,662,063	$3,746,540

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I. Introduction

Demand side management ("DSM") is a term that refers to efforts to encourage energy efficiency by reducing consumers' energy demands. Initially, DSM programs were developed and employed by energy providers. However, with the advent of energy deregulation, the responsibility for the implementation and ongoing management of DSM programs has shifted toward state agencies[1]. DSM programs employ tools that encourage and facilitate energy savings through the induction of behavioral changes and the deployment of more efficient energy appliances and equipment.

One strategy used in DSM is increasing energy efficiency, generally through the deployment of more efficient technologies. This is typically accomplished through the replacement of appliances such as air conditioners and furnaces with more efficient units, and the addition of heat pumps. Lighting-related efficiency investments include replacing of traditional light bulbs with compact fluorescent lamp ("CFL") or light emitting diode ("LED") technologies. Other investments include insulation, replacement of leaky doors and windows, caulking and other means of sealing a home's exterior, insulating water heaters, and sealing leaks in ventilation systems. These improvements are usually achieved through the deployment of various financial incentives, such as subsidizing improvement costs and low interest or shared loans. For low-income consumers, programs may completely subsidize direct replacement of older appliances and supporting infrastructure with more efficient substitutes.

The Nebraska Energy Office hired the University of Nebraska to examine various impacts associated with two of its DSM programs: the Energy Loan Program (LN) and the Weatherization Assistance Program (WX). We sought to quantify the energy savings realized as the result of the investment from these two programs in more energy efficient technologies. This was done through examination of energy usage prior to the investments as compared to energy usage after the investments. Further, we identified the economic impact of these programs on output, value added, labor income and jobs added. We also examined the environmental impacts of the programs in term of reductions in a variety of emissions and the economic saving that the emission reductions produce.

II. Methodology

The DSM projects supported through the NEO's Energy Loan and Weatherization Assistance programs are designed to reduce consumers' energy usage. However, these programs can have consequential economic and environmental impacts as well. We measure all three in this analysis.

A. Energy Impacts

A two-phased approach is used to measure the energy impacts of the NEO's Energy Loan and Weatherization Assistance programs. In the first phase, monthly energy usage is modeled as a function of cooling degree days, heating degree days and other factors. The impacts that cooling and heating

[1] See Demand-Side Management and Energy Efficiency in the United States, David S. Loughran and Jonathan Kulick, The Energy Journal, Vol. 25, No. 1, 2004.

needs have on usage are allowed to change once the energy efficient investments supported by the DSM programs have been made. We expect those investments to reduce energy needs for cooling and heating.

In the second phase, the changes in energy used per heating or cooling degree day are modeled as functions of the types of investments made under the DSM programs. Changes in both natural gas and electric usage are modeled as functions of investments in several categories of energy-related improvements. Conversion to a heat pump, for example, may have a very different impact on heating than replacement of energy-inefficient windows. A replacement heat pump may also have a different impact on energy need per heating degree day as opposed to energy needed per cooling degree day. The analysis estimates the change in kilowatt hours of electricity or therms of natural gas that accrue from each dollar invested in a variety of energy-related improvements.

The results of the analysis are combined with the actual investments made under the Energy Loan and Weatherization Assistance programs to estimate the impact of those programs on energy usage. Annual savings in kilowatt hours for electricity and therms for natural gas are estimated. These estimates are then converted into dollars using current prices. The useful lives of the underlying energy improvements are used to calculate the present discounted value of anticipated savings as well.

B. Non-Energy Benefits

A large body of research is examined in order to calculate the non-energy benefits associated with the WX and LN programs. These non-energy benefits include 1) improved comfort, health and safety for households that participate in energy efficiency projects, 2) reduced pollution that results from a reduction in energy consumption, and 3) the economic impact in terms of jobs and economic output that results from investments in energy efficiency. The research team consulted extensive literature to develop estimates of the first two types of non-energy benefits. Research on comfort, health and safety benefits utilized survey techniques to determine household "willingness to pay" for these benefits. Survey participants in the WX program indicated how these benefits compared to their savings on energy costs. This allowed the research team to develop a ratio between comfort, health and safety benefits and energy savings. This ratio was used to estimate the total value of comfort, health and safety benefits given the energy savings, which are identified. A different approach was taken for estimating the benefits from reduced pollution. Economic literature was consulted to develop the relationship between 1) home energy consumption (electric and natural gas) and emission of greenhouse and other pollutant gases and 2) the economic cost of this pollution. Specifically, an estimate of the economic cost was identified per pound of emission of each type of gas. These economic cost estimates included both the long-term potential costs of global warming from greenhouse gas emissions and more immediate costs from pollution including health impacts, water pollution and reduced farmland productivity. These estimates from the literature allow our research team to calculate how much pollution costs are reduced as energy efficiency projects reduce household energy consumption.

The economic impact of energy efficiency investments in terms of jobs and economic output was estimated based on both the direct spending in Nebraska due to these investments and the "multiplier impact" that occurs as initial spending circulates further in the state economy. Direct spending includes all spending from the WX and LN program that occurred in Nebraska. This included most program spending; however, some equipment (appliances, doors, windows, etc.) were purchased from wholesalers located in other states. The multiplier impact captures the additional spending that occurs in Nebraska as construction crews working on WX and LN projects purchase services within the state or crew members spend their paychecks within the state. The IMPLAN software, which provides a spending model of the Nebraska economy, is utilized to calculate the multiplier impact for each dollar of direct project spending in Nebraska. Separate multipliers are developed for each potential type of investment project. The total economic impact is the sum of the direct spending impact and the estimated multiplier impact. Energy savings investments also are expected to generate economic impacts for years into the future, given that spending patterns would change in more energy efficient households. In particular, energy spending would decline but spending would rise on other household goods and services such as food, retail items, entertainment and recreation. An economic impact analysis also is provided for these changes in household spending patterns.

III. Energy Impacts

A. Introduction

A two-phased approach is used to measure the energy impacts of the NEO's Energy Loan and Weatherization Assistance programs. In the first phase, monthly energy usage per cooling or heating degree day is modeled as functions of pre- and post-investment periods. In the second phase, the changes in energy used per heating or cooling degree day are modeled as functions of the types of investments made under the DSM programs. Results of the analysis are combined with the actual investments made under the Energy Loan and Weatherization Assistance programs to estimate the impact of those programs on energy usage.

B. Phase I

In the first phase, electric and natural gas energy usage are modeled as functions of heating degree days, cooling degree days, prices, income, normal growth over time and a dummy variable that delineates pre-energy-improvement investment periods from post-energy-improvement investment periods. The dummy variable that takes a value of zero in periods before the energy investment was made and a value of one in periods after the investment was made. Finally, two autoregressive terms are included where appropriate to account for time-related statistical anomalies in the data.

Although many parameters are estimated in Phase I, five are of particular interest. The first three parameters relate to electricity usage. Of these three, the first measures a general shift in electricity usage after the improvement. This may be due to investments in non-weather-sensitive efficiency improvements such as lighting or refrigeration. It may also be due to changes in usage as the marginal cost of heating and cooling falls with weather-sensitive improvements. The second and third coefficients measure the differential impact that heating and cooling degree days have on electricity usage once the efficiency-improving investment has been made. The final two parameters relate to natural gas usage. Of these two, the first measures a shift in natural gas usage after non-weather-sensitive improvement. The second measures the differential impact that a heating degree day has on natural gas usage once the efficiency-improving investment has been made.

1. Project and Energy Data Collection

a. Selecting a Sample Period

In order to perform the analysis, we needed to obtain energy usage data from periods both before and after the projects were undertaken. Since the usage data were collected from the utilities, we were dependent upon their recordkeeping to acquire historical usage amounts. Utilities across the state varied in the amount of historical data they collected and retained. Consequently, we chose to examine the impacts of loan and weatherization projects undertaken during the year 2009 and the first quarter of 2010. This would allow us to use data from 2008 as the pre-project period and data from the second quarter of 2010 through the first quarter of 2011 as the post-project period. In addition, this 15-month period allowed for the collection of data from the largest number of projects possible.

b. Project Data Collection

For this analysis, a project is considered to be all completed loan or weatherization applications related to a particular property.

Data from the Weatherization Assistance program were obtained manually. Each participating non-profit agency is required to file a Batch Control Job Order (BCJO) in order to receive reimbursement from the Weatherization Assistance program. During our analysis period, a total of nine agencies participated in the NEO Weatherization Assistance program. This study encompassed five of these providers: Central Nebraska Community Services, Inc. (CNCS), Southeast Nebraska Community Action, Inc. (SENCA), Northwest Community Action Partnership (NCA), Community Action Partnership/Panhandle Community Services (PCS) and Community Action Partnership of Mid-Nebraska (MNCA).

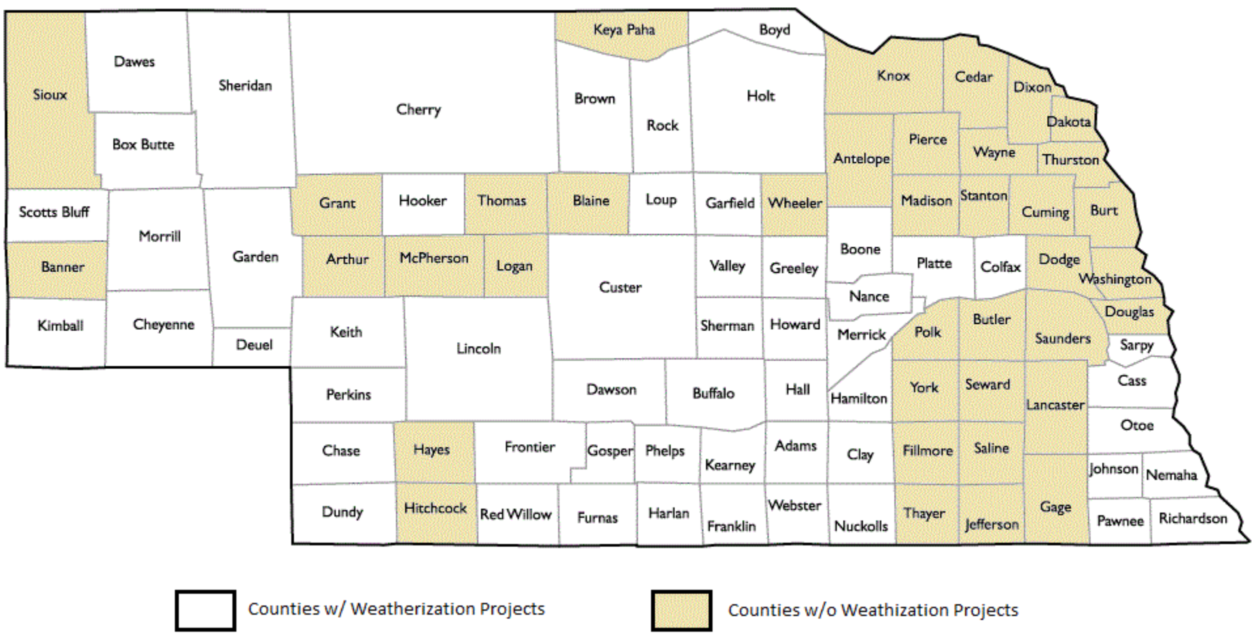
The BCJO generally contains the participant's name, location information, building type, building ownership, source of funding for project, date information and summary of investments.

During the analysis period, while most funding requests included a standard summary page, the supporting documents were in large part unique to each participating agency and varied greatly from agency to agency. A significant amount of time was devoted to the review and interpretation of the filed supporting documentation in an effort to ensure comparable categorization of investments between agencies.

A total of four researchers were assigned to review the BCJOs and related supporting documentation. The NEO staff provided all BCJOs that were submitted for payment during 2009 and 2010. BCJOs from the four non-profit agencies that were not part of our analysis were excluded and not reviewed. If the BCJO or supporting documentation indicated that all or a majority of the work was not performed during the January 2009 through March 2010 timeframe, the project was excluded. If further examination indicated that the primary heating source for the residence was not electricity or natural gas, the project was excluded from our analysis.

In total, information on 835 projects was obtained. The investment data collected from the weatherization projects encompassed 54 of the 93 counties within Nebraska, as shown in the map in Figure 1 below. These 54 counties account for 67 percent of the total land area in the state, but only 38 percent of the population. In many cases, the other 39 counties were provided weatherization services through non-profit agencies not included in this analysis.

Figure 1
Map of Counties Providing Weatherization Data



For projects included in our analysis, energy improvements were assigned into the following 12 categories:

- Air Infiltration
- Windows
- Doors
- Insulation
- HVAC
- Air Conditioning
- Furnace
- Hot Water Heater (HWH)
- Lighting
- Safety
- Unallocated Labor
- Miscellaneous

Costs pertaining to both material and labor were collected for each type of improvement. To the extent labor costs or miscellaneous expenses were not allocated to a specific investment category, we endeavored to assign those costs. In the event that project information did not contain adequate data with which to make an accurate assignment of unallocated labor costs, those values were assigned to the "Unallocated Labor" category. Expenditures that were undertaken solely for health and safety concerns and deemed unlikely to result in energy efficiency gains were assigned to the "Miscellaneous" category.[2]

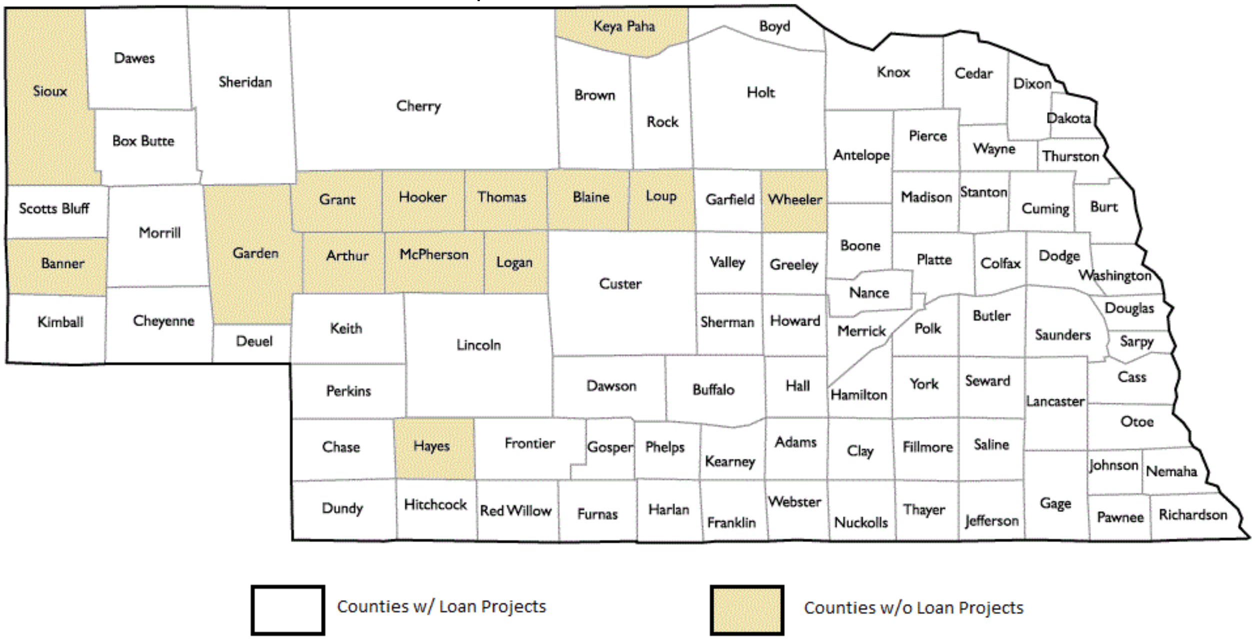
Information about loan projects undertaken during the sample period was developed in cooperation with the state data center. The only date available regarding NEO loan projects was the "NEO Participation" date which was the date the NEO provided notice that the project was eligible for a loan. NEO staff indicated that in some instances the work on a loan project may not have been completed for six to 12 months after the NEO participation date. Also, in some cases projects were approved while work was ongoing or even after work was completed. Based on this information, we extracted data with "NEO Participation dates" from between 7/1/2008 through 3/31/2010. We used the survey process discussed later in this document to eliminate projects that did not occur during our sample period.

Investment and other data from the Energy Loan Program were obtained electronically. Four databases were accessed to obtain relevant data on the loan program. The "Loan Summary" database contained the date the project was approved by the NEO. The "Project Summary" database contained data on the location of the project, the congressional and legislative districts, and total project expenditure amounts. The "ECM" database contained data on the specific types of improvements that were made under each project. The "Fuel Supplier" database contained data pursuant to the electrical and natural gas providers for each project. The data obtained from each of these databases were combined based on the unique loan identification number assigned to each project. Similar to the weatherization projects, projects that indicated they had heating sources other than electric or natural gas were excluded.

A total of 984 records were obtained and 120 different classes of improvements were identified. In some cases, an individual property had more than one loan project undertaken. These projects were consolidated and a property file was created. The property file shows the aggregate of loan projects undertaken on each unique property. The data from the loan program encompasses 79 of Nebraska's 93 counties as shown in the map in Figure 2 on the next page. It is worth noting that 11 of the 14 counties that did not receive any funding from the Energy Loan Program also did not receive Weatherization Assistance Program funding from the five non-profit agencies included in this analysis. While weatherization services in these areas may have been provided by a non-profit agency not included in the study, it may be beneficial to follow up with public education in these counties to make sure that residents are aware of the Weatherization Assistance and Energy Loan programs.

[2] A total of $38,678 from 105 projects was assigned to the "Unallocated Labor" category. A total of $27,330 from 291 projects was assigned to the "Miscellaneous" category. These amounts represent 2.0% and 1.4%, respectively, of the total investments identified for the five agencies during our analysis period.

Figure 2
Map of Counties with Loan Data



In total, there are 1,819 properties for which we have information -- 984 unique properties that had at least one loan project undertaken and another 835 unique properties that had at least one weatherization project undertaken. As shown in Table 1 below, four loan properties had more than one loan. Each weatherization project was unique.

Table 1
Breakdown of Energy Loan and Weatherization Projects and Properties

	Energy Loan	Weatherization	Total
Projects	988	835	1,823
Properties	984	835	1,819

To create consistent analysis across programs, the 12 Weatherization Assistance Program categories and 120 Energy Loan program categories were combined into a total of 10 investment categories. Table 2 on the following page shows the categories of energy improvements considered and briefly describes improvements included in each category.

Table 2
Types of Energy Improvements

Type	Description
Air Conditioning	New air conditioning units and repairs to existing units, including related labor costs.
Doors & Windows	Replacement of existing doors & windows, addition of storm doors & windows, repair of existing doors and windows, weather stripping, and repair of existing walls for air infiltration purposes, including related labor costs
Furnace	New furnace units and repair to existing units, including related labor costs.
Heat Pump	Addition of new heat pumps and replacement of existing heat pumps, including related labor costs.
Hot Water Heater	New hot water heaters and repair of existing hot water heaters, including related labor costs.
HVAC	Repair to existing ducts system, including related labor costs.
Insulation	Addition of new insulation and replacement of existing insulation, including related labor costs
Lighting	Replacement of existing light bulbs with CFLs.
Miscellaneous	Health and Safety improvements and other non-energy efficiency investments such as pressure testing, and unallocated labor costs.
Other Appliances	Appliances such as refrigerators, dishwashers, clothes washers, freezers, and fireplace inserts.

Table 3 on the next page breaks down the number of properties and total investments for each type of improvement by Energy Loan and Weatherization Assistance programs. Air conditioning, heat pumps and other appliances were almost exclusively financed under the loan program. Insulation, lighting and miscellaneous investments were almost exclusively the domain of the Weatherization Assistance Program. While the five other types of investments were undertaken by both programs, weatherization had more of each.

Table 3
Number of Properties with Each Type of Improvement

Improvement Type	Loan		Weatherization	
	N	Investment	N	Investment
Air Conditioner	131	$412,540	2	$5,397
Doors & Windows	389	$3,782,954	754	$637,967
Furnace	306	$1,096,411	413	$594,345
Heat Pump	342	$2,400,988	---	---
Hot Water Heater	46	$50,558	225	$66,794
HVAC	287	$67,805	645	$34,604
Insulation	30	$238,063	691	$543,086
Lighting	---	---	676	$10,886
Miscellaneous	44	$11,203	562	$87,097
Other Appliances	8	$16,711	---	---
Total	929	$8,077,233	822	$1,980,176

Table 4 below breaks down the average dollar value of the investment in each type of improvement per improved property by Energy Loan and Weatherization Assistance programs. The average investment per improved property was larger for the loan program than for weatherization. Of particular note are the "Doors & Windows" and "Insulation" categories, where the average investment for loan projects was more than 10 times greater than the average investment for weatherization projects.

Table 4
Average Investment per Improved Property

Type	Loan	Weatherization
Furnace	$3,583	$1,439
Hot Water Heater	$1,099	$297
Heat Pump	$7,020	---
Air Conditioner	$3,149	$2,699
Other Appliances	$2,089	---
Doors & Windows	$9,725	$846
HVAC	$236	$54
Insulation	$7,935	$786
Lighting	---	$16
Miscellaneous	$255	$155
Average per Property	$8,695	2,409

c. Authorization Forms

In order to participate in either the Weatherization Assistance or Energy Loan programs, an applicant must sign a form authorizing his or her energy provider(s) to release requested billing information to the NEO or authorized parties. These authorization forms are retained only in the form of paper copies. The authorization forms for the Energy Loan Program were retained on-site at the NEO. For some of the Weatherization Assistance projects, the authorization forms were included with the supporting information attached to the BCJO. For the remainder of the projects, the authorization forms were retained by participating non-profit agencies. Paper copies were made of the authorization forms that were on-site at the NEO. The participating non-profit agencies were contacted and paper copies were obtained of the authorization forms that were not on-site at the NEO. The paper copies were scanned into Adobe PDF files for each participating project.

d. Energy Data Collection

Many of the projects did not contain information that identified the name of the electric and natural gas energy providers. Further, a cursory review indicated that not all energy providers contained in the records were accurate. Consequently, a review of energy provider service territories was undertaken. Each property was assigned to up to three possible electrical providers and two possible natural gas providers based upon providers' defined service territories. Each property address was then sent to its assigned possible electrical and natural gas provider(s). The authorization forms associated with each project were sent to the energy providers, if requested. Each utility was asked to provide monthly data for properties that they served. The data requested spanned the period from 2008 through the latest date available. The requested data included:

- Customer Name
- Service Address
- Billing Period
- Meter Read Date
- Days in Billing Period
- Usage during Billing Period
- Unit of Measure
- Actual or Estimated Usage
- Charge for Usage

A total of 1,120 electrical records and 922 natural gas records were received from the energy providers. The majority of these responses were received electronically in the form of Excel spreadsheets. The spreadsheets were formatted in a consistent manner and then the electric records were aggregated into a single file as were the natural gas records. The responses that were not received electronically or in Excel format were hand entered into the appropriate electric and natural gas aggregated files.

These records were then checked for accuracy. Five tests were performed on the records received from the utilities in an effort to ensure their accuracy before the records were processed further.

1. <u>Test of pre-investment data.</u> The earliest billing period for each property was identified. If the earliest billing period occurred after January 2008, the property was excluded. The test was designed to ensure that enough utility billing information was available to measure reasonably pre-improvement usage. In addition, if the earliest billing period was prior to January 2005, the property was excluded. This additional test was designed to identify billing information that did not contain a valid date.

   Excel stores dates as a number. The number zero corresponds to the date of January 1, 1900 date. Each additional whole number represents one day, with the number one representing the date of January 2, 1900. Accordingly, if a date filed was left blank, Excel would interpret the zero value as a date of January 1, 1900. If a usage value of 100 was inadvertently entered in the date field, Excel would interpret the value of April 9, 1900. By eliminating records with dates prior to January 2005, our review of the provided billing information attempted to eliminate these possible types of errors.

2. Test of post-investment data. Next, the latest billing period for each property was identified. If the latest billing period was before December 2010, the property was excluded. This test was designed to ensure that enough utility billing information was available to measure reasonably post-improvement usage. Further, if the value associated with the latest billing period was greater than October 2011, the property was also excluded. This test was also designed to ensure that the billing information contained valid date values. The use of the October 2011 date value coupled with the January 2005 date value from Step 1 was designed to identify properties that likely contained inaccurate billing date information.

   As discussed earlier, Excel stores dates as numeric values. January 1, 2005 is represented by the value of 38,353 and October 2011 by the value 40,847. Accordingly, properties with billing records containing values in the billing date field outside of the range of these two values were excluded. We also excluded projects with blanks date fields or other values which were inaccurately placed in the date field.

3. Test for billing periods. The number of billing periods provided for each property was compared to the estimated number of months between the earliest and latest billing dates identified in the two previous steps. If the count was not within one billing period of the estimated number of months, then the property was excluded. This test was designed to ensure that for each property, on average, there was one billing record per month.

4. Test for number of days. The total number of days included in the billing information for each project was compared to the number of days between the earliest and latest dates calculated in the first two steps. If the variance between the two values was greater than two percent, the property was excluded. This was designed to validate further overall accuracy of the information provided for a given property.

5. Name test. The data were checked to see if more than one name appeared in the billing information for each property. If more than one name was found the property was excluded. This was done in an effort to determine if a change in resident had occurred at the property.

As a result of these tests, 636 electrical records were determined to be valid: approximately 57 percent of the 1,120 records received. Of the 636 electrical records, 477 of these records were derived from actual meter readings, while the remaining 159 records were based, at least in part, on billing estimates. For natural gas, 404 records were determined to be valid: approximately 44 percent of the 922 records received. Of the 404 records, 310 of these records were derived from actual meter readings, while the remaining 94 records were based, at least in part, on billing estimates.

To create a symmetric property panel, the monthly billing records for each property were examined in order to ascertain that there were 36 billing records, generally for the period of January 2008 through December 2010.

1. The first step was to determine if there was a billing record for January 2008. In an effort to deal with the various billing cycles and periods, the billing information for each property was first examined to determine if it contained a billing record that began in the first half of January 2008, then the second half of December 2007, then the second half of January 2008 and then the first half of December 2007. The first identified billing period date was then used as the starting date for the panel data of a given property. If a date within the four discrete periods described above could not be identified then the property was excluded from the analysis.

2. Next, given the requirement for 36 consecutive monthly billing records, the data were examined to determine if 36 billing period records existed between the starting date from the previous step and from a date 36, 35 or 37 months later. Similar to the previous step, billing records for a property were examined to determine if a billing record existed for the first half of the month 36 months from the first date, the second half of the month 36 months from the first date, the first half of the month 35 months from the first date, the second half of the month 35 months from the first date, the first half of the month 37 months from the first date and the second half of the month 37 months from the first date. Next, to the extent a valid date was identified for any of these six periods, the number of monthly billing records was counted for each property from the starting date through the potential end date. If there were 36 billing records between the first date and identified date, then that date was used as the last date for the purposes of identifying 36 periods of billing information for use in the panel analysis. If a billing record could not be identified within the six date periods described above or if none of the six possible last dates resulted in a count of 36 monthly billing records, the property was excluded from the analysis.

   As a result of this process, 29 electrical and 58 natural gas records were eliminated.

2. Program Participant Surveys

The purpose of this part of the evaluation was to identify households that had participated in the Nebraska Energy Office NEO Energy Loan and Weatherization Assistance programs and that had made no additional substantial changes that would likely affect energy usage. To do this, we surveyed as many households as possible that participated in the Energy Loan and Weatherization Assistance programs in 2009, to ask them about improvements, modifications and/or additions they may have made to their homes or households during the 2008 to 2010 period.

a. Design and Item Selection

The Nebraska Energy Loan and Weatherization Surveys were designed to meet the data needs for the evaluation of the program. Two separate, but similar, surveys were created: one for those households that received weatherization grants and one for those households that took out energy loans.

Literature reviews were conducted to identify household and structure changes that could impact energy consumption by households and businesses such as the purchase of new appliances or the installation of additional insulation. Although there are many changes that could affect energy usage, interest focused on identifying changes that have a substantial impact. Experts at the Nebraska Energy Office reviewed the universe of possible energy changes and selected those most likely to have a substantial impact. The following modifications were selected:

1. Replacement of furnace
2. Replacement of central air conditioning or install new central air
3. Replacement of heat pump or install new heat pump
4. Replacement of water heater
5. Installation of additional window air conditioners
6. Installation of addition of insulation to walls, ceiling, attic, or crawl space
7. Replacement of windows and doors throughout the structure
8. Replacement of lighting throughout the structure
9. Replacement of stove, oven or clothes dryer if changing fuel source
10. Addition or subtraction of fireplace or heating stove
11. Addition or subtraction of a hot tub or Jacuzzi
12. Major home additions or changes (e.g., heating garage, adding a room)
13. Disconnection of gas or electricity or heating/cooling not working for more than one week
14. Additions/subtractions to the number of people occupying the structure
15. Change in the amount of time when the structure was occupied or vacant
16. Other changes that may have substantially changed energy usage

Questions were constructed for the survey to assess if any of the 16 types of changes occurred a year prior to or after the modification funded through the Nebraska Energy Office. In addition to questions about changes affecting energy usage, questions were included to determine the type of structure (e.g., single family dwelling, mobile home, apartment), whether the occupant rented or owned the building, whether propane was used as a fuel source, the names of their utility companies, how likely residents were to make energy improvements without assistance and whether the energy loan or grant caused residents to make other changes to improve energy efficiency.

After each survey was drafted, the interview schedule was programmed on the computer and piloted. For piloting, interviewers were instructed to be particularly observant for problems in wording, item ordering and skip patterns. Following the pilot interviews, a debriefing discussion was held with the interviewers to go over the schedule and to discuss problems encountered and reactions to the interview. Pilot interviews were completed by professional interviewers, all by telephone. The results of the pilot interviews and any necessary changes to the interview schedule were incorporated in the final instrument.

b. Schedule Construction

The Computer Assisted Telephone Interviewing (CATI) system was used for the data collection. Development of the interview schedule on the CATI system required that all of the question items be entered on the computer. Next, instructions were prepared for each item, indicating its position in the interview, skip patterns and appropriate response categories. An advantage of the CATI system is that the interviewer's task remains simple regardless of the complexity of the interview. The computer makes the decisions about question ordering and skip patterns on the basis of the responses to earlier items.

c. The Sample

The list of participants in both the Energy Loan and Weatherization Assistance programs was developed from the previously described data. Any person on the list without a valid phone number was placed into a "tracking" file (or locating file) so that a staff member could attempt to locate a valid phone number. Multiple attempts to locate a phone number were made using free services available via the Internet.

d. Interviewer Training, Supervision, and Quality Control

The interviewing was completed by professional interviewers. All of the interviewers had previous experience in telephone interviewing; several were highly skilled with many years of interviewing experience. Interviewers were supervised by permanent staff.

Training for the interviewers involved two steps. First, the study director and permanent staff met all interviewers and discussed in detail the schedule and the procedures to be used. The interviewers were trained to use the Computer Assisted Telephone Interviewing (CATI) techniques and spent several hours of practice time becoming accustomed to using CATI. Each interviewer was given a short instruction manual which they were told to read carefully and which they were required to bring with them each time they interviewed. Second, all new interviewers were required to complete practice interviews. These practice interviews were carefully examined by staff for errors, inadequate records on open-ended questions and the like. All interviewing was done in interviewing labs and offices. Supervisory staff was available during calling hours to oversee the interviewing and to answer questions.

The proximity of interviewer workstations, as well as the use of telephone monitoring equipment, provided opportunities for careful supervision as the data were collected. The study director and others on staff were always accessible so that questions from the interviewers could be handled immediately and, if necessary, the respondent could be called back. Further, supervisors regularly monitored interviews while they were being conducted. This helped to identify interviewing problems and difficulties. Interviews were very carefully edited by the staff. This was done on a regular basis so that errors could immediately be brought to the attention of the interviewers and corrected. If answers were recorded incorrectly or in an incomplete manner, the interviewer was asked to call the respondent back and correct the error.

The interviewing staff was paid by the hour, not by the number of interviews completed. This method of payment was used to ensure the high quality of the data collected. The progress and productivity level of each interviewer, however, was monitored to detect problems in the method of interviewing. Various rates were calculated to reflect the completion rate per hour, the total number of attempts per hour, a refusal rate, etc., to monitor the progress of each interviewer compared to the entire group of interviewers. Individual attention was given if an interviewer's rates strayed from the overall mean.

e. The Interviewing Process

A few business days prior to phone calls, an advanced letter was sent to households in the sample. The letter informed respondents of the impending survey phone call and provided information about the survey in order to help increase our completion rate.

In order to make certain that respondents could be reached at a time when they were available to complete the survey, multiple attempts were made to reach each person in the sample at varying days and times including daytime, evenings and weekends. Additionally, interviewers were instructed to leave a voicemail or message after five or more attempts when possible.

The data were collected from April 13, 2011 until July 27, 2011. Table 5 displays the final outcome for all respondents in the sample by program type. The first column in Table 5 shows that interviews were completed with a total of 1,173 respondents: 754 households from the Energy Loan program and 419 households from the Weatherization Assistance Program. Comparing these to the total number of interviews attempted (column (7) of Table 5), the overall response rate for the Energy Loan program was 81 percent. The response rate for the Weatherization Assistance Program was 51 percent. The response rate as a whole was 67 percent.

Table 5
Survey Results

	(1) Completed Interviews	(2) Refusal	(3) Non-Trackable - Attempt	(4) Non-Trackable - No Phone	(5) Non-Complete	(6) Ineligible (did not participate in program or deceased respondent)	(7) Total
Loan	754	35	90	0	42	6	927
Weatherization	419	56	208	70	55	11	819
Total	1,173	91	298	70	97	17	1,746

Column (2) of Table 5 above shows the number of respondents who refused an interview. They totaled about five percent of the sample. Column (3) entitled 'Non-Trackable - Attempt' indicates the number of records for which a phone number was attempted, but it was either a wrong number or disconnected and we were unable to locate another working number. In total, they accounted for about 17 percent of the entire sample. However, they accounted for 25 percent of the weatherization sample. Column (4) entitled 'Non-Trackable - No Phone' indicates the number of records where no phone number was found; therefore no call attempt was completed. All of these were for the Weatherization Assistance Program.

The 'Non-Complete' column indicates the number of records for which an interview was not completed prior to the end of the study (i.e. the last disposition was a no answer, answering machine, callback, etc.)

The 'Ineligible' column indicates the number of records for which the respondent claimed he or she did not participate in the program or the respondent was deceased. Combining columns (3) through (6), almost 15 percent of the households that participated in the loan program during 2009 were unreachable by 2011, while more than 40 percent of weatherization participants were unreachable.

f. Processing of Completed Interviews

Completed interviews were carefully processed and recorded by the staff to ensure that each interview was accounted for and its progress along the various steps of editing, coding, merging and uploading could be monitored. As previously mentioned, interviews were conducted using CATI software, which saves responses on a networked file server. Each day, automatic backups were made of all directories containing information relevant to the survey, and the responses (both numeric and open-ended) were scanned for apparent errors or problems by the staff. Because the data were directly entered on the computer at the time of the interview in computer-readable form, no additional data entry steps were needed. The open-ended data were edited and spell-checked for typographical errors, then sorted and merged.

g. Loan Results

There were 754 complete interviews for the Energy Loan Program. All 754 confirmed they were the recipients of the loans. When asked if they lived in or owned the homes at the addresses in question, all confirmed they did. However, some corrected the address. Others indicated they lived at the address, but the loan was for a rental unit at another address. Others clarified the time they had lived in the home. Some moved in less than a year prior to the improvement and some moved out of the home within a year after the improvement. The large majority of homes were detached single family homes (97 percent) with a few mobile homes, duplexes, apartments and other types of homes.

A series of questions was asked pertaining to energy improvements the respondent had made and whether those improvements were part of the loan program. Some of these questions searched for consistence between the survey answers and the data gathered from the loan program itself. These questions related to heat pumps, furnaces, air conditioners, insulation, water heaters, window and door replacement, lighting and other appliances and HVAC. Other questions asked if the entire project was funded by the loan program or if other funds were used as well.

Another series of questions related to other changes in the dwelling or household composition that would influence energy consumption independent of any energy improvements financed by the loan program. These included questions about the addition or subtraction of fireplaces, heating stoves, hot tubs and Jacuzzis. There were questions that asked about major home additions or changes. Other questions explored changes in usage due to shutting off utilities, adding or subtracting people living in the dwelling, substantial changes in the time that the dwelling was occupied or any other types of major changes that would affect energy usage.

Results from the survey indicate that 495 properties had to be excluded from the first stage analysis based on survey results. The main reasons for exclusion were that the project was not funded entirely through the loan or there was a significant change in energy usage, the dwelling or the household.

There were approximately 232 properties excluded from the initial analysis (almost half of the exclusions) solely because not all of the energy improvement was financed through the loan program. Another 104 (21 percent) were excluded from the initial analysis solely because of a significant change in energy usage, the dwelling or the household. Another 115 were excluded for both reasons. The remaining 44 were excluded for other reasons.

The excluded properties were not included in the statistical analysis to develop parameters that explain energy saving as a function of the investment. They were, however, included when we quantified the overall impact of all improvements made during the sample period.

h. Weatherization Results

There were 419 complete interviews for the Weatherization Assistance program. All 419 confirmed they were the recipients of the loans. When asked if they lived in or owned the home at the addresses in question, all confirmed they did. However, some corrected the address. Others indicated they lived at the address, but the loan was for a rental unit at another address. Others clarified the time they had lived in the home. Some moved in less than a year prior to the improvement and some moved out of the home within a year after the improvement. The large majority of homes were detached single family homes (86 percent) with 11 percent living in mobile homes and a few living in duplexes, apartments and other types of homes.

Results from the survey indicate that 196 properties had to be excluded from the first stage analysis based on survey results. More than half were excluded because there was a significant change in energy usage, the dwelling or the household. Only a quarter were excluded from the initial analysis solely because not all of the energy improvement was financed through the Weatherization Assistance Program. The remaining households were excluded for other reasons.

Energy Loan and Weatherization Assistance Program survey results are summarized in Table 6, below.

Table 6
Number of Properties with Useable Energy Data

	Electricity			Natural Gas		
	Total	Loan	Wx	Total	Loan	Wx
Received Data from Energy Provider	1,120			922		
Valid Data	636			404		
Consecutive 36-month Panel	607	381	226	346	228	118
Residential and Meets Survey Standards	339	181	158	187	102	85

3. Explanatory Parameters

Next we sought to identify the various factors that generally influence either electric or natural gas usage, or both. We identified the following categories:

Category	Description
Constant	Accounts for the impact of factors other than those described below.
Energy Prices	Accounts for changes in the price consumers pay for energy.
Incomes	Accounts for change in consumer income.
Cooling Degree Days (CDDs)	The difference between the average temperature for a day and 65 degrees. If the average temperature is below 65 degrees the value is zero. CDDs are the standard measure of the impact which temperature has on the use of cooling sources.
Heating Degree Days (HDDs)	The difference between the average temperature for a day and 65 degrees. If the average temperature is greater than 65 degrees the value is zero. HDDs are the standard measure of the impact which temperature has on the use of heat sources.
Trend	Accounts for normal changes in consumers' energy usage over time.

We also included auto-regressive (AR) and moving average (MA) factors, where appropriate, in order to correct for observed auto-correlation.[3]

We assumed that the DSM investments would not impact energy prices, consumer income, the underlying trend in usage or the auto-regressive terms. Accordingly, we added dummy or indicator variables to the constant, CDD and HDD terms. Hence, there were five dummy variables: one on each of the constant, CDD and HDD terms in the electric equations and one on each of the constant and HDD terms in the natural gas equation. The dummy/indicator variables took the value of zero for periods prior to the DSM investments and one for periods after the DSM investments were made. The use of these variables allows the measures of the change in usage that occurred as the result of the DSM investments.

The CDD and HDD values provide baseline measures of how much cooling and heating is typically required for a given day. The energy usage necessary to fulfill the baseline requirements for cooling and heating should decline once investments are made in equipment such as air conditioning, furnace and heat pumps. The constant term should account for changes in energy usage not directly related to outside temperature, including items such a lighting and hot water heaters. The constant term should also measure changes in consumer behavior, which may occur as a result of the DSM investments reducing energy expenditures.

We were not able to obtain complete measures of energy prices for natural gas providers. Also, natural gas is not typically use for cooling purposes. Accordingly, the producer price and CDD values were not included in the statistical analysis of natural gas usage.

[3] Autoregressive and moving average terms account for statistical anomalies related to time that may be in the data. Autocorrelation relates to a link between time and the disturbance term in the estimation equation.

Many of the projects did not include a precise measure of when the DSM investments were completed. As discussed earlier, the loan information did not contain a date for when the project improvement was completed. Also, on many of the weatherization projects, the only date provided was the date of the final inspection, which could have occurred weeks after a project was completed. Further, completion dates did not always conform to the billing cycles of energy providers. Thus, the effective date of the implementation of the energy efficiency measures was estimated based upon analysis of changes in the patterns of energy usage of each given consumer.

The 36 periods of energy usage associated with each given project were run through a specified statistical model with the dummy for the project completion month starting in January and progressing month by month through December. The month that resulted in the model best fitting the underlying energy usage was selected as the billing period during which the DSM investments became effective. The selection was based on the Akaike Information Criterion, which is a standard statistical measure of how well a statistical model matches the underlying data that it seeks to explain[4].

4. Results

Table 6.1 on the following page summarizes the results for the five dummy variables from the Phase I analysis. Again, these dummy variables indicate the change in either the constant or usage per CDD or HDD resulting from an energy-improving investment.

Table 6.1
Results from Phase I Analysis

	Total	Projects with Negative Coefficients		Projects with Positive Coefficient	
	Count	Count	Average	Count	Average
Electricity Usage					
Constant (Non-Weather-Sensitive Component)	339	149	-527.78	190	340.26
CDD (Cooling Degree Days Component)	339	172	-1.21	167	1.05
HDD (Heating Degree Days Component)	339	171	-0.33	168	0.46
Natural Gas Usage					
Constant (Non-Weather-Sensitive Component)	187	95	-14.80	92	17.23
HDD (Heating Degree Days Component)	187	139	-0.03	48	0.02

In terms of the changes in electric usage that is not a function of outdoor temperature, 44 percent (149) of the projects indicated a reduction in electric usage and 56 percent (190) were observed to have an increase in electric usage. The changes in electric usage associated with outdoor temperatures were fairly evenly split between observed decreases and increases in electric usage. Relative to natural gas usage, the usage changes associated with non-weather-sensitive components were even distributed between observed decreases and increase in usage. However, for heating degree days, nearly 75 percent (139) of the observations were for decreases in natural gas usage.

[4] See Hill, Griffiths, and Lim (2011)

C. Phase II

In the second phase of the analysis, we modeled the coefficient on each of the five dummy variables as a function of the investments in the various energy efficiency improvements that were made as part of the Energy Loan and Weatherization Assistance programs. As shown previously, those investments fall into the following 12 categories:

- Air Infiltration
- Windows
- Doors
- Insulation
- HVAC
- Air Conditioning
- Furnace
- Hot Water Heater (HWH)
- Lighting
- Safety
- Unallocated Labor
- Miscellaneous

In addition to explaining energy savings as a function of the actual dollars invested in each of the above categories, two constant terms are used as well. The constant terms identify any behavioral changes brought about by the investments. The behavioral changes reflect changes in the marginal cost of energy to consumers resulting from the energy efficiency under the NEO's DSM programs. As a result of the energy efficiency measures, it may be beneficial to some consumers to increase their base usage. For instance, a consumer may now be able to maintain a winter temperature of 70 degrees instead of 68 degrees. Also in some cases, increases in energy consumption may be observed as a result of the replacement of a faulty or non-working unit, although we attempted remove these types of observations through our survey results and outlier analysis.

The results of the Phase II analysis showed three impacts that these investments have on energy usage. The first is the direct impact of the investment. These results should be non-positive, meaning that the direct impact of DSM investments must either have no impact or reduce energy consumption. If a more efficient appliance is installed, for example, it should reduce consumption. If an increase in consumption is observed it is likely the result of some other factor.

The second type of impact reflects observed increases in energy consumption due to behavioral changes in the consumer as discussed above. These behavioral effects are also referred to as "bounce back" factors[5]. Behavioral changes are secondary effects, which are often observed in DSM programs. The third impact is the total impact -- the net of the direct and behavioral impacts.

1. Data

To begin with, the data were reviewed to identify any anomalies. We employed a two-stage analysis through which we identified and excluded projects whose energy usage data appeared to be anomalous. Under the first test, we identified any properties that had changes in usage, either positive or negative, which exceeded five standard deviations. Assuming a normal distribution, there is less than a 1/100,000 chance that a value that is greater than or equal to 5 standard deviations from the sample average is related to the rest of the sample data. In other words, we are 99.9999 percent certain that such a value is not a valid observation. Accordingly, these values were excluded.

[5] See Braithwait and Caves (1994)

Next, we analyzed the remaining data using Chauvenet's criteria[6] to identify any further information that might be spurious. We only eliminated projects that were indicated spurious during a single pass through the data using Chauvenet's criteria. This was done to remove projects with likely inaccurate energy usage data or those projects in which items such as an air conditioner or furnace were not functioning prior to the DSM investment. In such cases, one would expect to see large spikes in energy usage in the periods after the DSM investments. These projects do not allow an accurate measurement of the changes that occurred as a result of the DSM improvements. Table 6.2 on the next page shows outliers in each analysis.

Table 6.2
Outlier Analysis

Coefficient	Initial Records	5 Standard Deviation	Chauvenet's Criteria	Remaining Records
Electrical Constant	339	1	4	334
Electrical CDD	339	2	5	332
Electrical HDD	339	1	5	333
Natural Gas Constant	187	0	6	181
Natural Gas HDD	187	1	4	182

Table 6.3 below shows the adjusted results from the Phase I analysis for each model, once outliers were removed. The split of projects with negative and positive components did not change significantly as a result of the outlier analysis. However, the average coefficients were lower with particular note of the 14 percent and 20 percent declines in the electric constant negative coefficient and natural gas constant positive coefficient averages.

Table 6.3
Results from Phase I Analysis after Outlier Analysis

	Total	Projects with Negative Coefficients		Projects with Positive Coefficient	
	Count	Count	Average	Count	Average
Electricity Usage					
Constant (Non-Weather-Sensitive Component)	334	146	- 455.21	188	319.45
CDD Component	332	168	-1.10	164	0.90
HDD Component	333	170	-0.31	163	0.35
Natural Gas Usage					
Constant (Non-Weather-Sensitive Component)	181	94	-14.22	87	13.87
HDD Component	182	136	-0.03	46	0.02

[6] See Lin and Sherman (2007)

One additional pass was performed using Chauvenet's criteria. Any records this second pass identified as possible anomalies were assigned an additional constant term. We used this second constant term to test whether there were other behavioral factors within a subset of the projects that underlie the changes in energy usage that had been observed. The magnitude of changes in energy usage identified through the second constant term was significantly larger than those identified through the first constant term. However, these second constant terms were identified in a subset of less than five percent of projects within each dataset. Accordingly, in order to estimate the effect that the observed coefficient for the second dummy variable will have the general population, its effect must be adjusted to reflect that observed behavioral change will only occur in a small subset of the population. After the necessary adjustments were made, the observed impacts of the second dummy variables were smaller than the observed changes in the general population.

2. Analysis

As we designed our statistical analysis, we made the following initial assumptions or null hypotheses:

1. The direct impact of the investments in energy efficiency would be similar between the Energy Loan and Weatherization Assistance programs.

2. The behavioral changes resulting from the investments would differ between participants in the Energy Loan and Weatherization Assistance programs.

3. The direct impact of investments in energy efficiency should only be to reduce energy consumption. Any increases that may appear to be correlated to a given investment are likely caused by changes in behavior and should be more appropriately accounted for in the constant terms.

4. Heat pump replacements would likely have different results than the addition of heat pumps to an existing natural gas heating system.

   In order to identify if a heat pump investment was for a new or replacement heat pump, we analyzed the usage pattern for the projects with heat pump investments and for which we were provided electric usage data by energy providers. A project was deemed to have an existing heat pump if both the pre-improvement and post-improved electrical usage indicated increased usage in the winter periods (January, February and March) above the project's average usage.

5. New heat pumps added to existing natural gas systems and hot water heaters would potentially result in increased electrical and natural gas usage, respectively.

As mentioned above, we analyzed the impact of the investments made through the NEO's DSM programs in terms of the change in energy usage after the investments had been made. These changes were measured in how a participant's energy use changed for: 1) general purposes, as measured by the constant terms; 2) cooling purposes, as measured by the CDD terms; and 3) heating purposes, as measured by the HDD terms.

The post-improvement results associated with the constant, CDD, and HDD values measure the change in energy usage that occurred after the DSM investment was made for a given project. As discussed earlier, we obtained measurements on changes in energy usage for five different categories – three for electric usage and two for natural gas usage. Among the electric measures is the general change in usage, which is not a function of the outside temperature. This category should encompass changes in electric usage related to items such as lighting and other items used for reasons other than cooling and heating purposes. The second category in electric usage is the change that corresponds to CDDs. This category measures energy usage changes for such items as air conditioning. The third category is the change in electric usages corresponding to HDDs. This should encompass changes in electric usage related to heat pumps.

Natural gas usage contains the last two measures. One is the general change in natural gas usage, which is not a function of outside temperature. Usage in this category should include investments in items such as hot water heaters. The final category is the change in natural gas usage corresponding to HDDs. This category should measure changes in natural gas usage related to natural gas furnaces.

Some of the identified investment types may encompass multiple energy usage categories. Electric energy usage related to heat pumps likely will be a function of both cooling and heat degree days. However, many of the investment usage types are related to a single usage category. For example, one would anticipate that lighting would solely impact general electric usage and not be effected by either cooling or heating degree days while usage related to air conditioning should be affected only by cooling degree days. Further, most investment types are unlikely to impact both electric and natural gas usage. The noted exceptions are furnaces and heat pumps. The reason for the observed crossover effects of these two investment categories is discussed in detail later.

Table 7.1 shows the categories of investment for which we identified statistically significant impacts on electric usage for each of the three electric dummy variable coefficients estimated in Phase I of this analysis.

Table 7.1
Statistically Significant Investment Categories for Electric Usage

Dataset	Investment Category	Coefficient
Electric Constant Dataset	Furnace	-2.33E-02
	Insulation	-3.24E-02
	Lighting	-6.19E+00
Electric CDD Dataset	Air Conditioning	-9.64E-05
	Furnace	-9.84E-05
	Heat Pump	-3.04E-05
	Insulation [0.01]	-3.57E-01
Electric HDD Dataset	Heat Pump	2.58E-05
	Heat Pump Replacement	-4.96E-05
	Insulation [0.01]	-2.26E-01

A negative sign on a coefficient indicates an observed reduction in energy usage. The electric coefficients shown in Table 7.1 are negative with the exception of the coefficient for heat pumps associated with heating degree days. This result was not unexpected. Heat pumps are designed to heat more efficiently conditioned spaces thereby reducing the energy consumption related to other heating sources. In Nebraska the predominant traditional heating source is natural gas, while heat pumps use electricity for their energy requirements. The installation of new heat pumps will increase electric usage. However, there should be a corresponding reduction in natural gas usage for heat pump investments associated with heating degrees. If investments in heat pumps are energy efficient, any energy savings associated with natural gas usage will exceed the increases in electric usage. This is in fact what we observed and is discussed later in this paper.

The statistical results indicated a non-linear relationship between electric savings and DSM investments in insulation. This is shown by the superscript 0.01 in the insulation categories and represents an exponential value. Since the exponent is less than 1.00, each additional dollar of insulation investment results in a smaller energy savings than did the preceding dollar of insulation investment. This is often referred to as a diminishing return. The same effect was observed in natural gas savings and is shown in Table 7.2 below. The exponent is larger (0.18) but is still less than 1.00, resulting in diminishing returns as well.

Table 7.2 shows the categories of investment for which we identified statistically significant impacts on natural gas usage for the two natural gas dummy variable coefficients estimated in Phase I of this analysis.

Table 7.2
Statistically Significant Investment Categories for Natural Gas Usage

Dataset	Investment Category	Coefficient
Natural Gas Constant Dataset	Doors & Windows	-1.09E-03
	Furnace	-1.28E-03
	Hot Water Heater	5.90E-03
Natural Gas HDD Dataset	Furnace	-1.82E-06
	Heat Pump	-1.99E-06
	HVAC	-3.01E-05
	Insulation ^ 0.18	-2.69E-03

In Table 7.2, negative coefficient values indicate an observed reduction in natural gas usage as a result of the monies expended in the associated investment category. All of the coefficients are negative with one exception. An increase in usage was observed for investments in hot water heaters. We attribute this observation to two possible sources. First, in many cases, recently installed water heaters may have greater capacity than those they replaced. This great capacity could lead to greater use of hot water and higher energy usage. Second, some of the hot water heater investments may have been to repair non-working units, and these instances were not removed through our survey and outlier analyses.

To determine the observed effect of the NEO's DSM programs on electric usage, for each loan and weatherization project the DSM investments were multiplied by the applicable coefficients from the electrical constant, CDD and HDD datasets. The results obtained represent the effects observed in the billing period.

To annualize the impact, we first calculated the average number of billing periods per year based on the information contained in the usage material provided by the energy providers. There were, on average, 11.99 and 11.98 billing periods per year in the electric and natural usage data, respectively. The usage changes measured by the electric CDD and HDD datasets represent the effects observed per cooling and heating degree day. We used normalized annual cooling and heating degree days to annualize the results from the CDD and HDD datasets. The results were summed for the Energy Loan and Weatherization Assistance programs to estimate the total direct effect observed in each program. The results were also aggregated by energy sources. These totals are shown in Table 8.1 and 8.2 below.

Table 8.1
Observed Direct Effect Annual Savings by Program
(Excludes Behavioral Changes)

Category	Annual Savings		
	Loan	Weatherization	Total
Air Conditioning	$3,343	$44	$3,387
Doors & Windows	$54,619	$9,211	$63,380
Furnace	$66,034	$35,796	$101,830
Heat Pumps	$30,786	---	$30,786
Other HVAC	$14,113	$7,203	$21,316
Hot Water Heaters	-$3,947	-$5,215	-$9,162
Insulation	$14,731	$159,589	$174,320
Lighting	---	$64,670	$64,670
Total Direct Effect	$179,679	$271,297	$450,976

Table 8.1 shows the observed direct effects, which exclude behavioral changes, by the DSM program for each investment category. Seven of the eight investment categories showed energy savings for both the Energy Loan and Weatherization Assistance programs. The investment categories "Furnace" and "Insulation" were observed to have the biggest impact on energy savings, accounting for more than 60 percent of the total observed savings.

The one exception is a hot water heater investment that shows a negative savings amount, indicating an observed increase in energy usage. This is likely the result of two factors. First, when replacing a hot water heater, participants in the NEO's DSM programs are electing to install larger-capacity units, which is leading to more hot water usage and thus higher natural gas usage. Second, the energy change observed relative to hot water heater investments is less than 5 percent of the total observed change. Projects in which broken hot water heaters were repaired could have been missed because of the small impact of hot water heater on overall usage.

Table 8.2 provides a breakdown of the observed direct effects by energy source for each category of investments both in terms of units of energy (kWhs and Therms) and dollars saved. A few results are of particular interest. Investments in doors and windows have a significant impact on natural gas usage. Furnace investments save both electricity (in fan use) and natural gas. They may also replace supplemental localized electric heating. Heat pump investments correlate to an overall increase in electric usage. Heat pumps are designed to be used for both heating and cooling purposes, thereby reducing air conditioner and furnace usage. Both heat pumps and air conditioners use electric energy for cooling purposes. Given the assumption that a combined heat pump and air conditioning system is more efficient than an air conditioner alone, a reduction in electric usage was expected. However, while heat pumps use electric energy, furnaces in Nebraska typically use natural gas. When a heat pump is added, an expected transfer of energy use from natural gas to electric is expected. As such, the true measure of any benefits associated with the addition or replacement of heat pumps must be based on total energy savings. Thus, while we observed a relatively small increase in electric usage related to heat pump investments, the reduction in natural gas usage was more than 10 times as large. Thus, the aggregate effect of heat pump investment is a reduction in energy usage and expenditure.

Table 8.2
Observed Direct Effect Annual Savings by Energy Source
(Excludes Behavioral Changes)

Category	Electric		Natural Gas		Total Dollars
	kWhs	Dollars	Therms	Dollars	
Air Conditioning	42,339	$3,387	---	---	$3,387
Doors & Windows	---	---	57,791	$63,380	$63,380
Furnace	646,961	$51,757	45,335	$50,073	$101,830
Heat Pump	-27,485	-$2,199	29,864	$32,985	$30,786
Other HVAC	---	---	19,299	$21,316	$21,316
Hot Water Heater	---	---	-8,295	-$9,162	-$9,162
Insulation	1,675,239	$134,019	36,487	$40,300	$174,320
Lighting	808,371	$64,670	---	---	$64,670
Total Direct Effect	3,145,425	$251,634	180,481	$199,341	$450,976

As mentioned earlier, when consumers face a lower marginal cost of heating or cooling due to investments in new equipment, they may spend some of that savings on greater indoor comfort. Hence, there can be a behavioral or "bounce-back" effect associated with many of the investments undertaken through the Energy Loan and Weatherization Assistance programs. Table 9 summarizes the observed direct and total effects. The table also shows the estimated behavioral effect, which is derived as the difference of total effect less the direct effect. Table 9 shows the observed bounce-back factor in the NEO's DSM programs. This factor measures the amount by which the observed behavioral changes reduce the direct energy reduction impact of the DSM investments.

Table 9
Summary of Observed Effects
Changes in Energy Usage

	Electric (kWhs)	Natural Gas (Therms)
Energy Loan Program		
Direct Effect	-596,075	-119,738
Total Effect	-236,722	-109,538
Behavioral Effect	343,049	10,201
Bounce-Back Factor	57.55%	8.52%
Weatherization Assistance Program		
Direct Effect	-2,550,910	-60,135
Total Effect	-238,722	-56,730
Behavioral Effect	2,312,188	3,405
Bounce-Back Factor	90.64%	5.66%

The numbers indicate only a small bounce-back factor for natural gas usage. However, the bounce-back factor for electrical usage is significantly larger. More than half of the reduction in observed energy usage reduction for the direct DSM investments is eliminated by the bounce-back factor for the Energy Loan program. The impact is even great for the Weatherization Assistance program, with more than 90 percent of the energy savings being lost due to the bounce-back factor.

Savings in the previous tables were annual values. We can also calculate the present discounted value of total savings related to each investment category. DSM investments typically last a number of years. Consequently, we first identified the expected useful lives for each investment category. We then created a specific present discounted value (PDV) factor for each investment category based upon the expected useful life, time value of money and expected growth in energy prices and energy consumption. These factors were then applied to the observed annual savings amounts associated with each investment category to develop an expected total impact of DSM investments over their useful lives. Table 10.1 compares the amount of DSM investments in each category under the Energy Loan program to the observed annual savings and estimated present discounted value of those annual savings.

Table 10.1
Lifecycle of Benefits Compared to Investments
Energy Loan Program Projects

Investment Category	Useful Life	Investment	Annual Savings		PDV of Annual Savings	
			Amount	Ratio	Amount	Ratio
Air Conditioning	16.5	$412,540	$3,556	0.9%	$46,306	11%
Doors & Windows	25.0	$3,782,954	$54,619	1.4%	$967,716	26%
Furnace	17.5	$1,096,411	$66,230	6.0%	$903,103	82%
Heat Pumps	15.0	$2,400,988	$30,780	1.3%	$371,601	15%
Other HVAC	18.0	$67,805	$13,999	20.6%	$195,077	288%
Hot Water Heaters	12.0	$50,558	-$3,947	-7.8%	-$39,656	-78%
Insulation	30.0	$238,063	$14,701	6.2%	$294,002	123%
Lighting	3.0	---	---	---	---	---
Total Direct Impact	20.6	$8,049,319	$179,937	2.2%	$2,738,150	34%
Behavioral Impact			-$38,711		-$586,663	
Total Net Impact		$8,049,319	$141,226	1.8%	$2,151,487	27%
Miscellaneous		$11,203				
Other Appliances		$16,711				
Adjusted Net Impact		$8,077,233	$141,226	1.7%	$2,151,487	27%
NEO's Share (50%)		$4,038,616	$141,226	3.5%	$2,151,487	53%

The weighted average useful life of the investments under the NEO's loan program is slightly over twenty years. The most significant investments were made in doors & windows, furnaces and heat pumps, with these three categories accounting for more than 90 percent of the total funds invested. Investments in furnaces, other HVAC and insulation were observed to have the largest energy savings relative to the dollars invested. These same three categories have the largest present discounted values as well. When measured by annual savings, insulation only has a 3 percent greater savings than furnaces. However, when measured by present discounted value, insulation has a 50 percent greater impact. This increase is due to the 30-year useful life of insulation compared to the 17.5-year useful life of furnaces. The total observed energy savings related to investments in other HVAC and insulation more than cover the amounts invested in these two categories.

The direct impact of annual savings and the present discounted value of those annual savings represent 2.2 percent and 34 percent respectively of the total dollars invested the eight investment categories. After accounting for the impact of behavioral changes, these numbers decline to 1.8 percent and 27 percent. Further, there are two additional categories of investment: miscellaneous and other appliances, for which a statistically significant relationship between investment and changes in energy usage was not found. When these additional costs are included in the analysis, the ratios decline slightly to 1.7 percent and 27 percent. However, under the loan program, the NEO only bears a portion of the total cost. With the NEO share at 50 percent, the present discounted value of the energy savings is 53 percent. In other words, for every $1.00 of cost borne by the NEO under its Energy Loan Program, energy savings of $0.53 are realized.

Table 10.2 below shows results for the Weatherization Assistance program. The weighted average useful life of the investments in the program is slightly longer at longer than 23 years. Just as with the Energy Loan program, the significant investments as measured by total dollars, were made in doors & windows and furnaces. However, no investments were made in heat pumps under the program, while significant investments were made in insulation. The three categories, doors & windows, furnaces and insulation, represent nearly 94 percent of the total investments under the NEO's Weatherization Assistance program. Investments in insulation had the largest observed total energy savings, followed by furnaces and then lighting. Lighting had the largest impact relative to its investment level with an observed annual savings of nearly six times and a present discounted value of more than 16 times the amount invested. While this ratio seems large, it fits well within the range of expected values for the replacement of incandescent light bulbs with compact fluorescent light (CFL) bulbs. The Energy Star[7] program estimates an annual savings of two times the amount invested and a return of 13 times over a CFL's lifetime. The Environmental Working Group estimates the annual savings of CFL bulbs over incandescent bulbs to be nearly 12 times the cost.

Table 10.2
Lifecycle of Benefits Compared to Investments
Weatherization Assistance Program Projects

Investment Category	Useful Life	Investment	Annual Savings		PDV of Annual Savings	
			Amount	Ratio	Amount	Ratio
Air Conditioning	16.5	$5,397	$49	0.9%	$638	12%
Doors & Windows	25.0	$637,967	$9,211	1.4%	$163,198	26%
Furnace	17.5	$594,345	$35,741	6.0%	$487,351	82%
Heat Pumps	15.0	---	----	----	---	---
Other HVAC	18.0	$34,604	$7,235	20.9%	$100,822	291%
Hot Water Heaters	12.0	$66,794	-$5,215	-8.7%	-$52,391	-78%
Insulation	30.0	$543,086	$158,801	29.2%	$3,175,846	585%
Lighting	3.0	$10,886	$64,670	594.1%	$183,472	1,685%
Total Direct Impact	23.3	$1,893,080	$270,492	14.3%	$4,058,936	214%
Behavioral Impact			-$188,736		-$2,711,986	
Total Net Impact		$1,893,080	$81,756	4.3%	$1,346,950	71%
Miscellaneous		$87,097				
Other Appliances		---				
Adjusted Net Impact		$1,980,176	$81,756	4.1%	$1,346,950	68%

7 Energy Star is a joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy designed to help consumers save money and protect the environment through energy efficient products and practices.

The direct impact of annual savings and present discounted value of the annual savings represent 14.3 percent and 214 percent respectively of the total dollars invested in the eight investment categories. After accounting for the impact of behavioral changes, the ratios decline to 4.3 percent and 71 percent, and with the inclusion of miscellaneous and other appliance investments the ratios fall further to 4.3 percent and 68 percent.

The observed energy savings per dollar of investment in insulation was more than four times greater for the Weatherization Assistance Program than for the Energy Loan Program. The regression analysis indicated a non-linear relationship between insulation investment and energy savings, while linear relationships were observed for the other investment categories relative to changes in energy usage. With a linear relationship, the changes in energy usage remain constant without regard to the level of investment. However, with a non-linear relationship the observed change in energy usage is not constant. In this case, each additional dollar results in a smaller reduction in energy usage. The average project insulation investment was $786 for the Weatherization Assistance Program and $7,935 for the Energy Loan Program. The non-linear relationship estimates observed energy reductions of $237 and $494 for these average investments. While the energy savings observed under the Energy Loan Program is more than two times greater, when expressed as a ratio to the investments it is actually more than four times smaller.

Unlike the Energy Loan program, the NEO bears the entire cost of DSM investments under the Weatherization Assistance program. When compared based upon the cost realized by the NEO, the results of the Energy Loan and Weatherization Assistance programs are similar. The annual savings are 3.5 percent and 4.1 percent, respectively. The present discounted value ratios are 53 percent and 68 percent, respectively.

The results in Tables 10.1 and 10.2 underrepresent energy savings associated with the NEO's investments in the Weatherization Assistance and Energy Loan programs. During our survey of program participants, we found that a number of households used their own funds to increase their investments beyond the amount funded by the NEO. To the extent those private dollars also bring about energy savings, our estimates of energy savings from NEO funding underestimate the true energy savings.

A limitation of this analysis is that it does not account for the relative efficiency of equipment that is being replaced or augmented. For example, while two households may be adding $500 in insulation, one may be starting from an R-8 while another may be starting from an R-12. The efficiency gains from those two projects would vary. We have no information on the starting R-value. As another example, one household may be upgrading an 80 percent efficient furnace with a 94 percent efficient furnace, while another may be replacing a 90 percent efficient furnace. While the dollar costs of the two investments would be similar, the energy savings from the two investments would be different.

We can, however, develop working estimates of some efficiency gains indicated by our analysis. These estimates are developed starting in Table 11.1 on the next page. The first column of Table 11.1 shows eight of the nine investment categories analyzed.[8] Column (2) shows the average spending in each category. Column (3) shows the net energy savings in therms derived from our analysis. Columns (4) through (6) include working estimates of the efficiency portion of the total cost. As an example, the data suggest that the typical cost of a central air conditioner is $3,272, but that figure includes the base cost of a standard air conditioner as well as the incremental cost of going from a standard unit to a more energy efficient unit. Since there were no data to inform the analysts about the magnitude of efficiency upgrades, or the extra cost of going from a less efficient to a more efficient solution, this assessment applies representative data from NPPD to provide a range from low to high incremental costs. These values are shown in Columns (4) and (5). If the total cost of an air conditioner is typically $3,272, then drawing on NPPD analysis, the suggestion is that the incremental energy efficiency improvement might range from a low of $150 to a high of $1,228. Column (6), labeled "Incremental Cost 15% Rule", provides a third data point. This draws on a study by Ehrhardt-Martinez (2008) which suggests that in the absence of discrete data, the so-called "efficiency premium" might equal about 15 percent of the total cost. In this case, 15 percent of $3,272 suggests an efficiency premium of $491. The efficiency premium, or incremental cost, applies only to the first five investment categories shown in Table 11.1. The last four categories are designed primarily as efficiency measures. Hence, the full cost and the incremental cost are shown as being the same.

Table 11.1

Measure	Average Cost	Net Energy Savings (Therms)	NPPD Incremental Cost		Incremental Cost 15% Rule
			Low	High	
Air Conditioner	$3,272	11.3	$150	$1,228	$491
Doors and Windows	$3,867	50.5	$617	$1,381	$580
Furnace	$2,351	93.7	$386	$1,300	$353
Heat Pump	$6,523	52.3	$1,300	$1,934	$978
Heat Pump All-Electric	$8,014	84.9	$1,300	$1,934	$1,202
Other HVAC	$110	20.7	$110	$110	$110
Insulation	$1,083	139.2	$1,083	$1,083	$1,083
Lighting Improvements	$16	40.5	$16	$16	$16

Given the incremental costs shown in Table 11.1, Table 11.2 shows the payback periods associated with the NPPD low and high incremental costs as well as with the 15 percent cost estimate. In essence, Columns (2) through (4) of Table 11.2 show the number of years needed to recoup the cost of the incremental investment necessary to purchase relatively more efficient equipment. As a point of reference, Column (5) of Table 11.2 shows the estimated useful life of investments in each category. For most investments, the payback is shorter than the useful life. Air conditioners have paybacks either shorter or longer than their useful lives, depending on assumptions about the cost of incremental

[8] Hot water heaters are excluded given their expected negative energy saving.

efficiency improvements. Only heat pumps complementing natural gas furnaces have a payback longer than their useful lives.

Table 11.2

	Range of Paybacks (Yrs)			
Measures	Low	High	15%	Useful Life
Air Conditioner	5.7	46.3	18.5	18
Doors and Windows	11.1	24.8	10.4	30
Furnace	2.7	9.2	2.5	18
Heat Pump	60.1	89.5	45.3	18
Heat Pump All-Electric	5.8	8.6	5.3	18
Other HVAC	4.8	4.8	4.8	10
Insulation	4.3	4.3	4.3	30
Lighting Improvements	0.2	0.2	0.2	7

IV. Non-Energy Benefits

A. Introduction

Investments in the NEO's Energy Loan and Weatherization Assistance programs yield a variety of benefits to participating households in addition to energy savings and lower energy bills. These benefits include improved comfort, health and safety. Beyond the benefits to participant households, there are also impacts and benefits to society as a whole. Specifically, society benefits from reduced pollution when participating households improve energy efficiency. There is also an economic impact on society in terms of employment, labor income and economic output from energy efficiency investments in the Energy Loan and Weatherization Assistance programs.

Each of these non-energy benefits and impacts are considered below. Non-energy benefits to households are considered first, especially the value that households place on the increased comfort, health and safety that result from a more energy efficient home. We estimate the non-energy benefits associated with each dollar of savings on energy bills.

Environmental benefits are considered second. These environmental benefits refer to the reduction in air, water and ground pollution that occurs when homes that received WX and LN investments utilize less energy. We estimate the environmental benefits associated with the consumption of fewer kilowatts of electricity and therms of natural gas.

Economic impacts are considered last. The economic impacts are the increase in economic output, jobs and labor income associated with investments in energy efficiency. We estimate the increase in output, jobs and labor income associated with each dollar of WX and LN program investments.

B. Benefits for Participant Households

Benefits for participant households include improved comfort, health and safety. Improved comfort results when participating households increase their energy usage in response to lower costs of heating or cooling an energy efficient home (i.e., the bounce back). This increased energy usage may reduce the energy benefits of energy efficiency programs but create comfort benefits that should be valued. Other types of comfort, health and safety benefits also flow from energy efficiency investments. Some components of energy efficiency investments include repairs to windows and doors and improvements to insulation that reduce the draftiness of homes. This contributes to comfort and health. Further, reduced energy usage and the replacement of heating and cooling systems reduce indoor air pollution, which also influences comfort and health. The replacement of heating systems such as older furnaces also improves safety by reducing the risk of fire.

A literature review was conducted in order to estimate the level of non-energy benefits associated with energy efficiency investments. This literature review is provided in Appendix 2. The review found that completed literature to date utilized contingent valuation techniques to determine the level of comfort and health benefits associated with projects. These techniques used surveys of WX program participants and asked questions designed to elicit the relative value program participants place on non-energy benefits. Information on the design of key studies and study questions are provided in Appendix 2. Multiple sets of questions and techniques were utilized, and respondents revealed the relative value they placed on the improved comfort and health benefits associated with an energy efficient home. Respondents were asked to compare the value of these benefits relative to their savings on energy bills. In the various evaluations, households revealed a valuation of comfort and health benefits that was between 60 percent and 100 percent of the dollar value of energy savings associated with investments in energy efficiency. The lower-bound value of 60 percent was utilized for the economic benefit analysis in this study, consistent with the conservative nature of the study. The estimated value of non-energy benefits due to comfort and safety was equal to 60 percent of the reported dollar value of energy savings, either on an annual basis or in terms of present value, as is seen in Table 12 below.

Table 12
Non-Energy Benefits for Participant Households

Benefit Type	Investments Impacted	Benefit Level
Comfort and Health	All Investments	60% of value of energy savings
Fire Safety	Furnace Replacement	$37.21 per furnace replacement per year

Table 12 also shows the annual safety benefits associated with each furnace replacement project. The method for calculating this annual energy savings is provided in Appendix 2. Calculations are based on engineering relationships of the reduced likelihood of a fire when an older furnace is replaced by a new furnace. A flat annual fire safety benefit of $37.21 is applied to all furnace replacement projects. This benefit value is primarily a safety benefit but also includes the benefits of reduced fire damage.

C. Environmental Benefits

Environmental benefits from the WX and LN programs are the benefits that accrue to society at large when these energy efficiency programs lead to less energy usage and less of the pollution associated with energy production. These environmental benefits are classic examples of "externalities" that affect society as a whole rather than only the households participating in the WX and LN programs. These social benefits should also be measured as a consequence of the two programs.

An externality occurs when a third party, other than the producer or the consumer of a good or service, is indirectly affected, either positively or negatively, by the production or consumption of that good or service. It has an important implication for resource allocation. When an externality is present, the market equilibrium is no longer efficient, for some people bear the costs (in this case, pollution) of goods they did not ask for. Consequently, the presence of externalities often creates a motivation for government programs, such as the WX and LN programs. By reducing energy consumption, the programs also reduce pollution. This section measures the value of this reduction in pollution. A review of the literature informs the choice of methodology, helping determine both the amount of pollution associated with energy production and consumption in Nebraska and the economic cost of that pollution. Energy efficiency programs such as WX and LN help avoid these pollution costs, creating an environmental benefit. Of the dozens of studies that were reviewed, the most comprehensive analysis of external cost of electricity production and consumption and natural gas consumption was conducted by the National Research Council (2010). This study uses the damage cost method, which directly assesses the damages caused by energy production and consumption. The National Research Council's analysis (2010) was not only the most comprehensive, but it was also consistent with the wider literature, which is discussed in Appendix 3. The National Research Council (2010) is therefore used as the key source for pollution costs estimates in this study. The main steps followed in that study to estimate the externalities were:

1. Estimate the burden (such as air pollutant emissions) from electricity production and consumption.
2. Estimate the exposure of the populations or environment to the air pollutants.
3. Estimate the consequences/damages based on this exposure.
4. Assign monetary value to these damages.

The National Research Council (2010) study examined externalities related to the emission of criteria air pollutants such as PM, SO_2, NO_x etc. The criteria air pollutants affect human health, crop yields, climate change etc. The study considered both externalities related to climate change (such as global warming due to carbon emissions) and those not related to climate change (that have a direct impact to the adjacent community, such as effects on human health, crop yield, etc). Estimated values of these two types of externalities are provided for electricity produced from all fuel types and for natural gas.

Table 13 shows the emissions per kWh of electricity or therm of natural gas consumed for major types of emissions. Note that the emissions data for electricity reflect a weighted average of emissions for coal, natural gas and nuclear powered electricity production. Weights for each fuel were based on production patterns among the fuels in Nebraska electricity production. Further, natural gas consumption occurs in the home but electricity production occurs at power plants before electricity is transmitted and distributed to homes. Cost estimates reflect a loss ratio of 9 percent during transmission and distribution (Deru and Torcellini, 2007).

Table 13
Pollutant Emissions Per kWh of Electricity Production and per Therm of Natural Gas Production

Pollutant	lbs of emissions/kWH	Lbs of emission/them (natural gas)
SO_2	0.004856	0.000060
NO_x	0.002243	0.009400
$PM_{2.5}$	0.000085	2.012E-12
PM_{10}	0.000136	-
VOC	.000187	1.456E-12
CO_2	.406109	11.684518

These engineering relationships naturally play a large role in cost estimates for pollution. These cost estimates are presented in Table 14 for both electricity consumption and natural gas consumption. Again, the estimates in Table 14 also reflect the mix of fuel consumption among coal, natural gas and nuclear power at Nebraska electric power plants as well as losses in transmission and distribution. The pollution cost for electricity consumption is $0.047 per kWh. The pollution cost for natural gas consumption is $0.220 per therm. These are the benefits generated for society when energy efficiency investments through the WX and LN programs reduce a kWh of electricity consumption or a therm of natural gas consumption. These environmental benefits were applied to the energy savings estimates calculated earlier.

Table 14
Environmental cost of Pollution Per kWh and Therm

Program	Unit	Cost/Unit
Electricity	kWh	$0.047
Natural Gas	therm	$0.220

D. Economic Impacts

Energy efficiency programs also change the economy in two other ways: 1) by increasing construction activity and equipment purchases, and 2) by changing household spending patterns. To see this, recall that funding for WX and LN lead to not only increased construction activity and equipment purchases (such as furnaces or new doors and windows) but also increased government employment to oversee the program. Further, in the case of the LN program, bank activity is required to review and process loans. This results in construction (and government and banking) jobs and earnings and also spillover effects, such as gains for other businesses that supply the construction industry (or banking industry or government sector).

These energy efficiency investments also influence future household consumption by reducing the amount of household energy consumption and increasing consumption of other goods and services such as food, entertainment and retail items, to provide a few examples. This change in consumption patterns also can have a net economic impact since spending on energy may have a different impact on the economy in terms of job creation and other factors than spending on other household goods and services.

We estimated the economic impact of both the one-time energy efficiency investments and the ongoing change in household consumption patterns for both the WX and LN programs. The economic impact results first from the change in construction activity (and associated government employment and banking activity) and the change in direct purchases of energy (reduced spending) and other household items (increased spending) as household consumption patterns change in subsequent years. These changes are known as the "direct effects" or direct impacts on the Nebraska economy. The study also considers the "multiplier" effect, which reflects how businesses throughout the Nebraska economy benefit as the initial spending circulates further within the state economy. For example, the multiplier effect occurs as employees of firms involved in WX construction projects spend their paychecks on goods and services at businesses within the local economy. The multiplier effect also occurs as these construction firms make purchases from their own vendors and suppliers such as purchasing construction materials, or accounting or legal services.

The multiplier effect specifically shows the total economic activity created by each dollar of direct economic activity. Following the case described above, the multiplier effect indicates the total economic activity at all businesses in the economy that results from one dollar of spending on a WX construction project. To provide a numerical example, an economic multiplier of 1.5 would indicate that there is a total of $1.50 in economic activity for each $1 of spending on a WX construction project. Of the $1.50, $1 of spending would occur at the construction firm, but the remaining $0.50 would occur at businesses throughout the economy such as building-supply wholesalers, retail stores and others, due to the multiplier effect.

Table 15 shows the total economic impact from each $1 of spending on construction activity or appliance and equipment purchases (such as furnaces or doors and windows) in WX and LN projects. The economic impact reflects both the direct economic impact from the construction activity, equipment purchases and program monitoring activity (plus financial services in the case of the LN program), as well as the multiplier effect. The economic impact is the total of the direct impact and multiplier effect. Given that these economic impacts differ by type of investment, impact results are presented for nine types of investments for both the WX and LN programs. Note that the impacts are typically $0.15 higher for LN programs due to the banking activity necessary for this loan program.

Table 15
Total Economic Impact per Dollar of Project Spending By Project Type

Program and Type of Spending	Total Economic Impact Per Dollar of Spending			
	Output	Value Added	Labor Income	Employment/$ Million
WX				
Air Conditioning	$0.89	$0.54	$0.38	9
Windows/Doors	$0.64	$0.41	$0.29	6
Insulation	$1.04	$0.60	$0.43	10
HVAC	$0.99	$0.59	$0.42	10
Furnace	$0.99	$0.59	$0.42	10
Water Heater	$0.95	$0.57	$0.40	9
Lighting	$0.57	$0.35	$0.26	6
Miscellaneous	$0.57	$0.35	$0.26	6
LN				
Air Conditioning	$1.17	$0.66	$0.43	10
Windows/Doors	$0.92	$0.53	$0.34	7
Insulation	$1.32	$0.72	$0.47	11
HVAC	$1.27	$0.71	$0.47	10
Furnace	$1.27	$0.71	$0.47	10
Water Heater	$1.23	$0.69	$0.45	10
Lighting	$0.85	$0.47	$0.31	7
Miscellaneous	$0.85	$0.47	$0.31	7

Table 16 shows the net economic impact from each $1 of reduced energy spending on either electricity or natural gas. These net economic impacts result from changes in household spending patterns, particularly less spending on energy alone and more spending on other household items. These changes in annual spending patterns also influence the local economy. Many types of household spending have larger economic multipliers than spending on energy such as natural gas or electricity. This is especially true for employment and worker income in local areas. The electricity and natural gas industries are very capital-intensive, meaning there are relatively few workers and minimal pay for each dollar spent on the industry. At the same time, it is also true that some types of household spending may have smaller economic impacts than the electricity and natural gas industries. Spending on gasoline is a good example. Most of the cost of a gallon of gasoline goes towards extracting and refining the gasoline. This activity occurs in other states and other nations. It is only the markup portion of gasoline sales that leads to an economic impact on the local economy. This markup portion is just a fraction of the total purchase price of gasoline.

Table 16
Total Economic Impact of Reduced Energy Spending

Program and Energy Type	Impact per Dollar of Reduced Energy Spending			
	Output	Value Added	Labor Income	Employment/$ million
WX				
Electricity	-$0.33	-$0.32	$0.08	8
Natural Gas	-$0.21	$0.02	$0.21	10
LN				
Electricity	-$0.41	-$0.39	$0.03	7
Natural Gas	-$0.31	-$0.05	$0.17	9

As seen in Table 16 above, the net result is that it is ambiguous whether reduced energy spending and increased spending on other items due to the WX and LN programs will lead to a net positive or negative economic impact on the state economy. The impact is much more likely to be positive, however, in the case of the employment and labor income impacts, since energy industries are very capital-intensive industries that employ relative few workers per dollar of revenue. On the other hand, a negative net impact is much more likely due to the LN program. The reason is that there is also an annual cost to repaying the loan, leading to a reduction in household spending.

The total economic impact from the WX and LN programs is the present value from the initial investment project (Table 15) and the stream of annual net impacts from the change in household consumption patterns (Table 16).

Note, however, that the estimates in Table 15 are based on each dollar spent on WX and LN projects, while the estimates in Table 16 are based on each dollar of electricity or natural gas saved. Combining the impacts in Tables 15 and 16 will depend on the specific energy savings associated with each type of construction impact. For example, a dollar of construction investment for some types of projects yields much higher amounts of annual energy savings than other types of construction investments. This implies that the ratio between the construction spending and amount of energy savings is the key factor. If a particular construction project yielded no energy savings, then the construction economic impact would be the only type of economic impact resulting from the project. However, if another particular construction project yielded large energy savings per dollar investment in construction, then the energy savings impact would be a big part of the overall economic impact resulting from the project.

In the reporting tool, the present value economic impact of a specific project can be estimated by taking the construction spending in that project by category and the resulting energy savings, and applying the relevant economic multipliers. Projections can be made by placing the total estimated investment into the categories displayed in Table 15. The model then calculates the energy savings in natural gas and electricity for each type of investment. Parameters from Tables 15 and 16 are then applied to yield the predicted present value of economic impact.

V. Summary of Results

Table 17 summarizes the energy, economic and environmental impacts of the investments made through the Nebraska Energy Office's Energy Loan and Weatherization Assistance programs based on expenditures from 2009 and early 2010.

Table 17
Summary of Energy, Economic and Environmental Results

		Energy Loan Program	Weatherization Assistance Program	Total
Nebraska Energy Office Investment				
NEO Investment		$4,038,616	$1,980,176	$6,018,792
Private Matching Investment		$4,038,616	- - -	$4,038,616
Total Investment		$8,077,232	$1,980,176	$10,057,408
Energy Impacts				
Electric Energy Savings	(kWhs)	253,025	238,722	491,747
Natural Gas Energy Savings	(therms)	109,538	56,730	166,268
Annual Dollars of Energy Savings		$141,226	$81,756	$222,983
PDV of Future Savings		$2,151,487	$1,346,950	$3,498,437
Economic Impacts				
Output		$8,122,360	$1,334,801	$9,457,161
Value Added		$4,789,475	$916,438	$5,705,913
Labor Income		$3,576,867	$1,014,284	$4,591,152
Job-Years		92.52	32.12	124.64
Environmental Impacts				
Carbon Dioxide	(CO_2)	21,593,951	14,480,918	36,074,869
Sulfur Dioxide	(SO_2)	22,599	27,144	49,743
Nitrogen Oxide	(NO_X)	26,252	22,338	48,590
Particulate Matter < 2.5 micro-meters	($PM_{2.5}$)	393	473	866
Volatile Organic Compounds	(VOC)	868	1,045	1,913
Particulate Matter < 10 micro-meters	(PM_{10})	630	759	1,389
Total PDV		$2,084,478	$1,662,063	$3,746,540

The NEO invested more than $6 million in its DSM program during the period analyzed with 67 percent of the total investment made under the Energy Loan program and the remainder made via the Weatherization Assistance program. The $6 million in DSM investments resulted in a reduction of 500,000 kWh of electricity and 160,000 therms of natural gas usage. These reductions in energy usage resulted in an estimated $3.5 million in savings for the affected consumers over the useful life of the DSM investments, a savings ratio of $0.58 for every $1.

Further, these investments generated $9.4 million in output, $5.7 million in value added, labor income of $4.5 million and created more than 120 job-years. The observed reductions in energy usage reduced a variety of harmful emissions produced in the generation and use of electric and natural gas usage. The reductions in emissions along with the improvements in comfort, health and safety created benefits of more than $3.7 million over the life cycle of the DSM investments.

VI. Reporting Tool

The collective results were then combined into an Excel-based reporting tool. This includes all the factors that were developed during the course of our analysis. The file also contains a detailed analysis of each project, which was identified during our examination of the sample period. It also provides a summary of investments, number of projects, and total energy, economic and environmental impacts of the Energy Loan and Weatherization Assistance programs by county, legislative district and congressional district.

Within the NEO's loan program, at least one project was undertaken in each of Nebraska's 49 legislative districts. Districts 44 and 24 had the most projects, with 68 and 66 projects respectively. District 44 consists of ten counties in the corner of Nebraska, which is bordered by Kansas and Colorado and includes the city of McCook. District 24 encompasses three counties and includes the cities of York and Seward. Also, loan projects were funded in each of Nebraska's three congressional districts. The majority of these projects were in the 3rd District, which had 579 projects with more than $4.8 million of investment.

As discussed earlier, loan projects encompassed 79 of the 93 counties in Nebraska. The counties of Lancaster with 127, Hall with 48 and York with 45 had the most projects. In terms of total investment, Lancaster County again ranked the highest with $1.4 million. Douglas County, despite have only 33 projects ranked second, with over $400,000 of investment.

The results obtained from the NEO's Weatherization Assistance Program did not encompass the same geographical breadth as those from the loan program. As discussed earlier, the analysis contained herein only included data from five of the nine providers of DSM services under the NEO's Weatherization Assistance Program. The analysis of the Weatherization Assistance Program included projects from 23 of Nebraska's 49 legislative districts. The 48th, 49th, and 33rd legislative districts had the most projects with 98, 84, and 70 projects, respectively. The 48th district encompasses the county and city of Scottsbluff as well as the city of Gering. The 49th district includes part of Sarpy County and the cities of Gretna and La Vista. The 33rd district encompasses the majority of Hall County and includes the city of Hastings. The Weatherization Assistance Program made investments in all three of Nebraska's congressional districts and, similar to the loan program, the majority of the projects with in the 3rd District which accounted for 674 projects and $1.6 million of investment.

As mentioned above, investments under the NEO's Weatherization Assistance Program were made in 54 of Nebraska's 93 counties. Scottsbluff County had the most weatherization projects with 100, followed by Adams County with 66 and Dawes County with 62. In terms of total investments, Lincoln County with 51 projects had investments of $242,541 followed by Hall County with 39 projects and $141,867 of investments.

VII. Technical Appendix

A. Appendix 1: Energy Impacts

The analysis is broken into two parts. In the first part, energy usage is explained as a function of cooling degree days, heating degree days, energy prices, consumer income, a trend variable and dummy variables that delineate pre-energy-improving investment periods from post-energy-improving investment periods. In the second part, the coefficients that measure the observed impact demand-side management has on energy usage are described as functions of the DSM investments themselves. The impacts can be classified into two categories. First, there are impacts that reflect decreases in energy usage because less energy is needed as a result of the DSM investments. Second, there are impacts that <u>increase</u> energy usage as the marginal cost of a unit of cooling and/or heating falls as energy efficiency increases.

Phase 1 – Usage as a Function of Heating and Cooling Degree Days:

A unit of observation for this part of the analysis is one property, *i*, during one billing period, *t*. The variables used to explain energy usage are described in Table A1.1a below.

Table A1.1a
Energy Usage Variables

Variable	Denotes	
$Usage_{EL,i,t}$	Electric Usage for Property *i*, during Billing Period *t*	
$Usage_{NG,i,t}$	Natural Gas Usage for Property *i*, during Billing Period *t*	
$PP_{EL,t}$	Electric Price during Billing Period *t*	
W_t	Average Statewide Real Wage Rate during Billing Period *t*	
CDD_t	Cooling Degree Days during Billing Period *t*	
HDD_t	Heating Degree Days during Billing Period *t*	
$Post_t$	Dummy Variable	Zero in periods before DSM Investment
		One in periods after DSM Investment
$Trend_t$	Trend Variable, 1 through 36	
$ARMA_1$	Autoregressive Term 1, if indicated	
$ARMA_2$	Autoregressive Term 2, if indicated	

Dropping the *i* and *t* subscripts on the independent variables for sake of clarity, the following two models describe electric and natural gas usage:

$$(1a) \quad Usage_{EL} = \begin{bmatrix} \beta_{1,0} & + (\beta_{1,1} * PP_{EL}) & + (\beta_{1,2} * W) & + \\ (\beta_{1,3} * CDD) & + (\beta_{1,4} * HDD) & + (\beta_{1,5} * Post) & + \\ (\beta_{1,6} * CDD * Post) & + (\beta_{1,7} * HDD * Post) & + (\beta_{1,8} * Trend) & + \\ (\beta_{1,9} * ARMA_1) & + (\beta_{1,10} * ARMA_2) & & \end{bmatrix}$$

$$(1b) \quad Usage_{NG} = \begin{bmatrix} \beta_{2,0} & + (\beta_{2,2} * W) & + (\beta_{2,4} * HDD) & + \\ (\beta_{2,5} * Post) & + (\beta_{2,7} * HDD * Post) & + (\beta_{2,8} * Trend) & + \\ (\beta_{2,9} * ARMA_1) & + (\beta_{2,10} * ARMA_2) & & \end{bmatrix}$$

Equation (1a) describes electric usage as a function of the independent variables described in Table A1.1a. The coefficients of particular interest are $\beta_{1,5}$, $\beta_{1,6}$ and $\beta_{1,7}$. The first of these measures a general shift in electric usage after the improvement. This may be due to investments in non-weather-sensitive efficiency improvement such as lighting or refrigeration. It may also be due to changes in usage as the marginal cost of heating and cooling falls with weather-sensitive improvements. The latter two coefficients measure the differential impact that heating and cooling degree days have on electricity usage once the DSM investment has been made.

Equation (1b) describes natural gas usage as a function of the independent variables described in Table A1.1a. Natural gas prices on a statewide basis were not available and were not used in this equation. Further, typically natural gas is only used for heating purposes and therefore cooling degree days were not used in the equation. The coefficients of particular interest are $\beta_{2,5}$ and $\beta_{2,7}$. The former measures a general shift in natural gas usage after the improvement that is not weather-sensitive. The latter measures the differential impact that a heating degree day has on natural gas usage once the DSM investment has been made.

Expected energy usage for a billing period before a loan- or weatherization-sponsored DSM investment takes place can be estimated using equations (1a) or (1b) with the *Post* variable equal to zero. Expected energy usage after a loan- or weatherization-sponsored investment takes place can be estimated using equations (1a) or (1b) with the *Post* variable equal to one. The difference between the pre-investment and post-investment periods represents the savings due to the DSM investments. Billing period savings can be annualized by incorporating the number of billing periods per year, as well as normalized heating and cooling degree days per year. These annualizing factors are represented as Υ_E for electric billing periods per year, Υ_N for natural gas billing periods per year, Υ_C, for annual normalized cooling degree days, and Υ_H for annual normalized heating degree days. The first two factors are calculated as:

$$(2a) \quad \gamma_E = \frac{365}{\text{Average Days per Electric Bill Period}} = \frac{365}{30.41880} = 11.99916 \quad \text{Annual Billing Periods}$$

$$(2b) \quad \gamma_N = \frac{365}{\text{Average Days per Natural Gas Bill Period}} = \frac{365}{30.45677} = 11.98420 \quad \text{Annual Billing Periods}$$

The normalization of cooling and heating degree days is explained in detail in the data section. This process resulting in the following values:

$$(2c) \quad \gamma_C = 1{,}051 \quad \text{Annual Cooling Degree Days}$$

$$(2d) \quad \gamma_H = 6{,}262 \quad \text{Annual Heating Degree Days}$$

Phase 2 – Explaining the Parameters:

In the second phase of the analysis, we explain the five coefficients of interest ($\beta_{1,5}$, $\beta_{1,6}$, $\beta_{1,7}$, $\beta_{2,5}$ and $\beta_{2,7}$) as functions of constant terms and the various energy efficiency-improving investments that are made as part of the Energy Loan and Weatherization Assistance programs. The general form of these equations is:

$$(3a)\ \ \beta_{1,5} = \begin{matrix} \begin{bmatrix} C_{1,1} * Ln \ + \\ C_{1,2} * Wx \end{bmatrix} \\ + \\ \begin{bmatrix} C_{1,3} * Ln * D_1 \ + \\ C_{1,4} * Wx * D_1 \end{bmatrix} \end{matrix} + \begin{bmatrix} AC\$ * \alpha_{1,1} + & DW\$ * \alpha_{1,2} + \\ Furn\$ * \alpha_{1,3} + & HP\$ * \alpha_{1,4} + \\ HVAC\$ * \alpha_{1,5} + & HWH\$ * \alpha_{1,6} + \\ Insl\$ * \alpha_{1,7} + & Lite\$ * \alpha_{1,8} + \\ HP\$(Repl) * \alpha_{1,9} & \end{bmatrix}$$

$$(3b)\ \ \beta_{1,6} = \begin{matrix} \begin{bmatrix} C_{2,1} * Ln \ + \\ C_{2,2} * Wx \end{bmatrix} \\ + \\ \begin{bmatrix} C_{2,3} * Ln * D_2 \ + \\ C_{2,4} * Wx * D_2 \end{bmatrix} \end{matrix} + \begin{bmatrix} AC\$ * \alpha_{2,1} + & DW\$ * \alpha_{2,2} + \\ Furn\$ * \alpha_{2,3} + & HP\$ * \alpha_{2,4} + \\ HVAC\$ * \alpha_{2,5} + & HWH\$ * \alpha_{2,6} + \\ Insl\$ * \alpha_{2,7} + & Lite\$ * \alpha_{2,8} + \\ HP\$(Repl) * \alpha_{2,9} & \end{bmatrix}$$

$$(3c)\ \ \beta_{1,7} = \begin{matrix} \begin{bmatrix} C_{3,1} * Ln \ + \\ C_{3,2} * Wx \end{bmatrix} \\ + \\ \begin{bmatrix} C_{3,3} * Ln * D_3 \ + \\ C_{3,4} * Wx * D_3 \end{bmatrix} \end{matrix} + \begin{bmatrix} AC\$ * \alpha_{3,1} + & DW\$ * \alpha_{3,2} + \\ Furn\$ * \alpha_{3,3} + & HP\$ * \alpha_{3,4} + \\ HVAC\$ * \alpha_{3,5} + & HWH\$ * \alpha_{3,6} + \\ Insl\$ * \alpha_{3,7} + & Lite\$ * \alpha_{3,8} + \\ HP\$(Repl) * \alpha_{3,9} & \end{bmatrix}$$

$$(3d)\ \ \beta_{2,5} = \begin{matrix} \begin{bmatrix} C_{4,1} * Ln \ + \\ C_{4,2} * Wx \end{bmatrix} \\ + \\ \begin{bmatrix} C_{4,3} * Ln * D_4 \ + \\ C_{4,4} * Wx * D_4 \end{bmatrix} \end{matrix} + \begin{bmatrix} AC\$ * \alpha_{4,1} + & DW\$ * \alpha_{4,2} + \\ Furn\$ * \alpha_{4,3} + & HP\$ * \alpha_{4,4} + \\ HVAC\$ * \alpha_{4,5} + & HWH\$ * \alpha_{4,6} + \\ Insl\$ * \alpha_{4,7} + & Lite\$ * \alpha_{4,8} + \\ HP\$(Repl) * \alpha_{4,9} & \end{bmatrix}$$

$$(3e)\ \ \beta_{2,7} = \begin{matrix} \begin{bmatrix} C_{5,1} * Ln & + \\ C_{5,2} * Wx & \end{bmatrix} \\ + \\ \begin{bmatrix} C_{5,3} * Ln * D_5 & + \\ C_{5,4} * Wx * D_5 & \end{bmatrix} \end{matrix} + \begin{bmatrix} AC\$ * \alpha_{5,1} + & DW\$ * \alpha_{5,2} + \\ Furn\$ * \alpha_{5,3} + & HP\$ * \alpha_{5,4} + \\ HVAC\$ * \alpha_{5,5} + & HWH\$ * \alpha_{5,6} + \\ Insl\$ * \alpha_{5,7} + & Lite\$ * \alpha_{5,8} + \\ HP\$(Repl) * \alpha_{5,9} & \end{bmatrix}$$

Each equation has three sets of variables on the right-hand side. The variables in the first set of brackets are constant terms that apply to all observations for the weatherization and loan programs. The variables in the second set of brackets are additional constant terms that represent special cases in the data. The variables in the third set of brackets are the energy efficiency investments as defined in Table A1.1b below.

Table A1.1b
Energy Efficiency Investments

Variable	Description	Variable	Description
$AC\$_1$	Air Conditioning Investment under Loan Program	$AC\$_2$	Air Conditioning Investment in WX Program
$DW\$_1$	Doors & Windows Investment under Loan Program	$DW\$_2$	Doors & Windows Investment under WX Program
$Furn\$_1$	Furnace Investment under Loan Program	$Furn\$_2$	Furnace Investment under WX Program
$HP\$_1$	Heat Pump Investment under Loan Program	$HP\$_2$	Heat Pump Investment under WX Program
$HVAC\$_1$	HVAC Investment under Loan Program	$HVAC\$_2$	HVAC Investment under WX Program
$HWH\$_1$	Hot Water Heater Investment under Loan Program	$HWH\$_2$	Hot Water Heater Investment under WX Program
$Insl\$_1$	Insulation Investment under Loan Program	$Insl\$_2$	Insulation Investment under WX Program
$Lite\$_1$	Lighting Investment under Loan Program	$Lite\$_2$	Lighting Investment under WX Program
$HP(Repl)_1$	Heat Pump Replacement Investment in Loan Program	$HP(Repl)_2$	Heat Pump Replacement Investment in WX Program

After careful statistical analysis, some of the variables in Table A1.1b could be dropped from equations (3a) through (3e). The coefficients in the electric equations, 4a, 4b, and 4c, are significant at the 91st percentile. The level of significance is based upon a one-tailed test for investment coefficients with the exception of the coefficient for new heat pump investment relative to HDDs, $\alpha_{3,4}$. The alternative hypothesis for these coefficients was $H_1: \alpha < 0$. Two-tailed tests were performed on the constant terms and the coefficient for new heat pump investment relative to HDDs, $\alpha_{3,4}$. The alternative hypothesis for these terms was $H_1: \alpha \neq 0$.

The coefficients in the natural gas equations, 4d and 4e, are significant at the 92nd percentile with the exception of the hot water heater investment coefficient, $\alpha_{4,6}$, sub-set constant term, $C_{4,3}$, and the constant term, C_5, which are significant at the 85 percent, 89 percent, and 88 percent levels respectively. The significance of investment coefficients with the exception of hot water heater investment was tested using a one-tailed test with the alternative hypothesis $H_1: \alpha < 0$. The significance of the constant terms and hot water heater investment coefficient was based on a two-tailed test with the alternative hypothesis $H_1: \alpha \neq 0$.

$$(4a) \quad \beta_{1,5} = \begin{bmatrix} C_{1,1} * Ln \; + \\ C_{1,2} * Wx \end{bmatrix} + \begin{bmatrix} C_{1,3} * Ln * D_1 \; + \\ C_{1,4} * Wx * D_1 \end{bmatrix} + \begin{bmatrix} Furn\$ * \alpha_{1,3} \; + \\ Insl\$ * \alpha_{1,7} \; + \\ Lite\$ * \alpha_{1,8} \end{bmatrix}$$

$$(4b) \quad \beta_{1,6} = [C_{2,2} * Wx] + \begin{bmatrix} C_{2,3} * Ln * D_2 \; + \\ C_{2,4} * Wx * D_2 \end{bmatrix} + \begin{bmatrix} AC\$ * \alpha_{2,1} \; + \\ Furn\$ * \alpha_{2,3} \; + \\ HP\$ * \alpha_{2,4} \; + \\ Insl\$^{0.01} * \alpha_{2,7} \end{bmatrix}$$

$$(4c) \quad \beta_{1,7} = [C_{3,2} * Wx] + \begin{bmatrix} C_{3,3} * Ln * D_3 \; + \\ C_{3,4} * Wx * D_3 \end{bmatrix} + \begin{bmatrix} HP\$ * \alpha_{3,4} \; + \\ Insl\$^{0.01} * \alpha_{3,7} \; + \\ HP\$(Repl) * \alpha_{3,9} \end{bmatrix}$$

$$(4d) \quad \beta_{2,5} = [C_4] + [C_{4,3} * Ln * D_4] + \begin{bmatrix} DW\$ * \alpha_{4,2} \; + \\ Furn\$ * \alpha_{4,3} \; + \\ HWH\$ * \alpha_{4,6} \end{bmatrix}$$

$$(4e) \quad \beta_{2,7} = [C_5] + [C_{5,4} * Wx * D_5] + \begin{bmatrix} Furn\$ * \alpha_{5,3} \; + \\ HP\$ * \alpha_{5,4} \; + \\ HVAC\$ * \alpha_{5,5} \; + \\ Insl\$^{0.18} * \alpha_{5,7} \end{bmatrix}$$

Combining equations (4a) through (4c) with the annualizing factors, the overall annual impact of the loan program on electricity usage from investments made in any one property can be measured as equation (5a).

$$\text{(5a)}\quad \begin{matrix} Total\ Impact \\ of \\ Loan\ Program \\ on \\ Electric\ Usage \end{matrix} = \begin{matrix} \gamma_E * \left(\begin{matrix} [C_{1,1}] \\ + \\ [C_{1,3} * D_1] \end{matrix} + \begin{bmatrix} Furn\$_{1,i} * \alpha_{1,3} & + \\ Insl\$_{1,i} * \alpha_{1,7} & + \\ Lite\$_{1,i} * \alpha_{1,8} & \end{bmatrix} \right) \\ + \\ \gamma_C * \left([C_{2,3} * Ln * D_2] + \begin{bmatrix} AC\$_{1,i} * \alpha_{2,1} & + \\ Furn\$_{1,i} * \alpha_{2,3} & + \\ HP\$_{1,i} * \alpha_{2,4} & + \\ Insl\$_{1,i}{}^{0.01} * \alpha_{2,7} & \end{bmatrix} \right) \\ + \\ \gamma_H * \left([C_{3,3} * Ln * D_3] + \begin{bmatrix} HP\$_{1,i} * \alpha_{3,4} & + \\ Insl\$_{1,i}{}^{0.01} * \alpha_{3,7} & + \\ HP\$(Repl)_{1,i} * \alpha_{3,9} & \end{bmatrix} \right) \end{matrix}$$

The first line on the right-hand side of equation (5a) measures the non-weather-sensitive impacts of the loan program on electricity usage. It includes furnace, insulation and lighting investments, as well as constant terms. The second term estimates cooling degree day-sensitive impacts of the loan program. It includes air conditioning, furnace, heat pump and insulation investments, as well as constant terms. The third term estimates heating degree day-sensitive impacts of the loan program. It includes heat pump, insulation and replacement heat pump investments, as well as constant terms. By including the constant terms in equation (5a), we essentially measure the net impact of the investments on energy usage. This includes the decrease in energy usage because less energy is needed for general usage and per heating or cooling degree day as a result of the DSM investments. However, it also includes the increase in energy usage as the marginal cost of a unit of heating or cooling falls when energy efficiency increases.

Combining equations (4d) and (4e) with the annualizing factors, the overall impact of the loan program on natural gas usage from investments made in any one property can be measured as equation (5b).

$$\text{(5b)}\quad \begin{matrix} Total\ Impact \\ of \\ Loan\ Program \\ on \\ Natural\ Gas\ Usage \end{matrix} = \begin{matrix} \gamma_N * \left(\begin{matrix} [C_4] \\ + \\ [C_{4,3} * D_4] \end{matrix} + \begin{bmatrix} DW\$_{1,i} * \alpha_{4,2} & + \\ Furn\$_{1,i} * \alpha_{4,3} & + \\ HWH\$_{1,i} * \alpha_{4,6} & \end{bmatrix} \right) \\ + \\ \gamma_H * \left([C_5] + \begin{bmatrix} Furn\$_{1,i} * \alpha_{5,3} & + \\ HP\$_{1,i} * \alpha_{5,4} & + \\ HVAC\$_{1,i} * \alpha_{5,5} & + \\ Insl\$_{1,i}{}^{0.18} & \end{bmatrix} \right) \end{matrix}$$

In an analogous manner, the overall impacts of the Weatherization Assistance Program on electricity usage and on natural gas usage are defined in (5c) and (5d), respectively.

$$
(5c)\quad \begin{matrix} Total\ Impact \\ of \\ WX\ Program \\ on \\ Electric\ Usage \end{matrix} = \begin{matrix} \gamma_E * \left(\begin{bmatrix} C_{1,2} \\ + \\ C_{1,4} * D_1 \end{bmatrix} + \begin{bmatrix} Furn\$_{2,j} * \alpha_{1,3} & + \\ Insl\$_{2,j} * \alpha_{1,7} & + \\ Lite\$_{2,j} * \alpha_{1,8} & \end{bmatrix} \right) \\ + \\ \gamma_C * \left(\begin{matrix} C_{2,2} \\ + \\ [C_{2,4} * D_2] \end{matrix} + \begin{bmatrix} AC\$_{2,j} * \alpha_{2,1} & + \\ Furn\$_{2,j} * \alpha_{2,3} & + \\ HP\$_{2,j} * \alpha_{2,4} & + \\ {Insl\$_{2,j}}^{0.01} * \alpha_{2,7} & \end{bmatrix} \right) \\ + \\ \gamma_H * \left(\begin{bmatrix} C_{3,2} \\ + \\ C_{3,4} * D_3 \end{bmatrix} + \begin{bmatrix} HP\$_{2,j} * \alpha_{3,4} & + \\ {Insl\$_{2,j}}^{0.01} * \alpha_{3,7} & + \\ HP\$(Repl)_{2,j} * \alpha_{3,9} & \end{bmatrix} \right) \end{matrix}
$$

$$
(5d)\quad \begin{matrix} Total\ Impact \\ of \\ WX\ Program \\ on \\ Natural\ Gas\ Usage \end{matrix} = \begin{matrix} \gamma_N * \left([C_4] + \begin{bmatrix} DW\$_{2,j} * \alpha_{4,2} & + \\ Furn\$_{2,j} * \alpha_{4,3} & + \\ HWH\$_{2,j} * \alpha_{4,6} & \end{bmatrix} \right) \\ + \\ \gamma_H * \left(\begin{bmatrix} C_5 \\ + \\ C_{5,4} * D_5 \end{bmatrix} + \begin{bmatrix} Furn\$_{2,j} * \alpha_{5,3} & + \\ HP\$_{2,j} * \alpha_{5,4} & + \\ HVAC\$_{2,j} * \alpha_{5,5} & + \\ {Insl\$_{2,j}}^{0.18} * \alpha_{5,7} & \end{bmatrix} \right) \end{matrix}
$$

Equations (5a) through (5d) are used to estimate the energy impact of projects that were undertaken during the January 2009 through March 2010 period. Each equation has constants and investment-sensitive components. By including the constants in these equations, we essentially measure the net impact of the investments on energy usage. This includes the decrease in energy usage because less energy is needed per heating or cooling degree day as a result of the investments, which we call the "direct effect". However, it also includes the increase in energy usage as the marginal cost of a unit of heating or cooling falls when energy efficiency increases, which we call the "bounce-back" effect. When the constants are removed, all that is left are the direct effects from the investment. These direct effects are shown in equations (6a) through (6d).

$$
(6a) \quad \begin{matrix} Direct\ Effect \\ of \\ Loan\ Program \\ on \\ Electric\ Usage \end{matrix} = \begin{matrix} \gamma_E * \begin{bmatrix} Furn\$_{1,i} * \alpha_{1,3} + \\ Insl\$_{1,i} * \alpha_{1,7} + \\ Lite\$_{1,i} * \alpha_{1,8} \end{bmatrix} \\ + \\ \gamma_C * \begin{bmatrix} AC\$_{1,i} * \alpha_{2,1} + \\ Furn\$_{1,i} * \alpha_{2,3} + \\ HP\$_{1,i} * \alpha_{2,4} + \\ Insl\$_{1,i}{}^{0.01} * \alpha_{2,7} \end{bmatrix} \\ + \\ \gamma_H * \begin{bmatrix} HP\$_{1,i} * \alpha_{3,4} + \\ Insl\$_{1,i}{}^{0.01} * \alpha_{3,7} + \\ HP\$(Repl)_{1,i} * \alpha_{3,9} \end{bmatrix} \end{matrix}
$$

$$
(6b) \quad \begin{matrix} Direct\ Effect \\ of \\ Loan\ Program \\ on \\ Natural\ Gas\ Usage \end{matrix} = \begin{matrix} \gamma_N * \begin{bmatrix} DW\$_{1,i} * \alpha_{4,2} + \\ Furn\$_{1,i} * \alpha_{4,3} + \\ HWH\$_{1,i} * \alpha_{4,6} \end{bmatrix} \\ + \\ \gamma_H * \begin{bmatrix} Furn\$_{1,i} * \alpha_{5,3} + \\ HP\$_{1,i} * \alpha_{5,4} + \\ HVAC\$_{1,i} * \alpha_{5,5} + \\ Insl\$_{1,i}{}^{0.18} * \alpha_{5,7} \end{bmatrix} \end{matrix}
$$

$$
(6c) \quad \begin{matrix} Direct\ Effect \\ of \\ WX\ Program \\ on \\ Electric\ Usage \end{matrix} = \begin{matrix} \gamma_E * \begin{bmatrix} Furn\$_{2,j} * \alpha_{1,3} + \\ Insl\$_{2,j} * \alpha_{1,7} + \\ Lite\$_{2,j} * \alpha_{1,8} \end{bmatrix} \\ + \\ \gamma_C * \begin{bmatrix} AC\$_{2,j} * \alpha_{2,1} + \\ Furn\$_{2,j} * \alpha_{2,3} + \\ HP\$_{2,j} * \alpha_{2,4} + \\ Insl\$_{2,j}{}^{0.01} * \alpha_{2,7} \end{bmatrix} \\ + \\ \gamma_H * \begin{bmatrix} HP\$_{2,j} * \alpha_{3,4} + \\ Insl\$_{2,j}{}^{0.01} * \alpha_{3,7} + \\ HP\$(Repl)_{2,j} * \alpha_{3,9} \end{bmatrix} \end{matrix}
$$

$$(6d) \quad \begin{matrix} Direct\ Effect \\ of \\ WX\ Program \\ on \\ Natural\ Gas\ Usage \end{matrix} = \begin{matrix} \gamma_N * \begin{bmatrix} DW\$_{2,j} * \alpha_{4,2} + \\ Furn\$_{2,j} * \alpha_{4,3} + \\ HWH\$_{2,j} * \alpha_{4,6} \end{bmatrix} \\ + \\ \gamma_H * \begin{bmatrix} Furn\$_{2,j} * \alpha_{5,3} + \\ HP\$_{2,j} * \alpha_{5,4} + \\ HVAC\$_{2,j} * \alpha_{5,5} + \\ Insl\$_{2,j}^{0.18} * \alpha_{5,7} \end{bmatrix} \end{matrix}$$

Tables A1.2 through A1.4 show the statistically valid coefficients that were observed for the two dummy variables used in our analysis of the five datasets. As with the coefficients calculated for the investments, a negative sign indicates an observed reduction in energy usage while a positive sign indicates an increase in energy use. The dummy coefficients measure changes in energy usage, which are not associated with the DSM investments made through the NEO's Energy Loan and Weatherization Assistance programs. These observed changes are typically behavioral in nature. The dummy coefficients associated with the constant datasets measured changes in behavior, such as leaving lights on for longer periods of time. The dummy coefficients associated with CDD and HDD dataset measured changes in target temperatures, such as setting the thermostat at 70 degrees rather than 68 degrees during the winter.

Table A1.2
Statistically Significant General Population Dummy Coefficients

Dataset	Loan	Weatherization
Electric Constant Dataset	7.47E+01	1.86E+02
Electric CDD Dataset	-------	4.43E-01
Electric HDD Dataset	-------	1.94E-01
Natural Gas Constant Dataset	3.75E+00	3.75E+00
Natural Gas HDD Dataset	-4.52E-03	-4.52E-03

Table A1.2 shows the dummy coefficients for the behavioral changes that were observed in the general population. No statistically significant behavioral changes were observed in the general population for the loan program in either the electric CDD or HDD dataset. The coefficients for the statistically significant dummy variables for the three electric and the natural gas constant datasets were positive, indicating an increase in energy usage. This is a common result observed in DSM programs. The investments made pursuant to DSM programs are designed to reduce energy usage. The reduction in required energy use lower the marginal cost associated with using additional electricity and natural gas. While the actual price associated purchasing energy has not changed, what a consumer must forego has changed. The reduction in energy costs functions much like an increase in income. The consumer must decide how to spend the realized savings. They can spend it on energy or some other goods. The dummy coefficients measure how much of the savings they choose to spend on additional energy consumption.

However, we observed negative values for the general population dummy coefficients associated with the natural gas HDD datasets. This indicates a behavioral change resulting in a reduction in natural gas usage relative to heating degree days. One explanation for this observation is a general decision by consumers to reduce the desired temperature during the winter. However, such a result is contrary to most observations from DSM programs. A more likely explanation is a general level of energy efficiency regarding heating purposes, which was achieved by the DSM investments but cannot be explained as a function of the level of these investments.

Tables A1.2a and A1.2b show the observed statistically significant coefficients related to second or subset dummy coefficients. As discussed earlier these coefficients were only observed in a very small subset of the total population and must be adjusted before they can be used to estimate energy impacts. To determine the adjusted impact, we multiplied the observed impact by the number of projects in the subset and then divided by the number of projects in the total population.

Table A1.2a
Loan Program Statistically Significant Subset Population Dummy Coefficients

Dataset	Observed Coefficient	Subset Population	Total Population	Adjusted Coefficient
Electric Constant	-2.01E+03	4	180	-4.47E+01
Electric CDD	-3.74E+00	4	178	-8.41E-02
Electric HDD	7.37E-01	4	178	1.66E-02
Natural Gas Constant	-1.66E+01	3	99	-5.03E-01
Natural Gas HDD	-------	0	98	-------

Table A1.2b
Program Statistically Significant Subset Population Dummy Coefficients

Dataset	Observed Coefficient	Subset Population	Total Population	Adjusted Coefficient
Electric Constant	-1.84E+03	8	154	-9.57E+01
Electric CDD	4.17E+00	3	154	8.12E-02
Electric HDD	-1.45E+00	1	155	-9.38E-03
Natural Gas Constant	-------	0	82	-------
Natural Gas HDD	-4.23E-02	4	84	-2.01E-03

The coefficients relative to the subset observations have both negative and positive signs, which indicated both observed decreases and increases in energy usage within the subsets. However, these changes, after the appropriate scaling, are significantly smaller than those associated with the general population observations. Table A1.3 shows the combined behavioral change observed. In no case does the observed behavioral subset effect change the sign of the effect observed in the general population.

Table A1.3
Statistically Significant Dummy Coefficients

Dataset	Loan			Weatherization		
	General	Adjusted Subset	Total Effect	General	Adjusted Subset	Total Effect
Electric Constant	7.47E+01	-4.47E+01	3.00E+01	1.86E+02	-9.57E+01	9.02E+01
Electric CDD	-------	-8.41E-02	-8.41E-02	4.43E-01	8.12E-02	5.24E-01
Electric HDD	-------	1.66E-02	1.66E-02	1.94E-01	-9.38E-03	1.84E-01
Natural Gas Constant	3.75E+00	-5.03E-01	3.24E+00	3.75E+00	-------	3.75E+00
Natural Gas HDD	-4.52E-03	-------	-4.52E-03	-4.52E-03	-2.01E-03	-6.53E-03

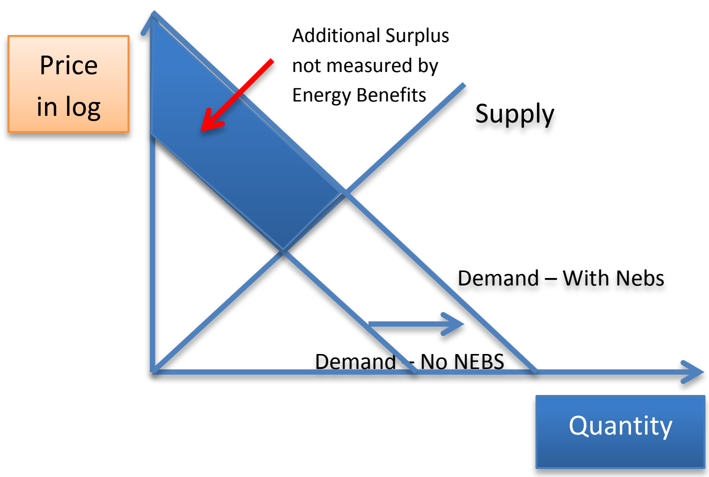
B. Appendix 2: Non-Energy Benefits for participant Households

1. Introduction

Investments in the WX and LN program yield a variety of benefits to participant households including lower energy bills and improved comfort, health and safety. This appendix considers these non-energy benefits (NEBS) that accrue to participant households.

2. Theoretical Framework for Non-Energy Benefits

The motivation behind trying to estimate non-energy benefits is that simply looking at the energy benefits would be underestimated and thus the analysis would lead to an inefficient amount of services and goods provided for the program. A simple way to visualize non-energy benefits would be to consider them in the framework of supply and demand for the goods and services provided by the program.



If we were to analyze the weatherization services in a supply and demand framework, we would assume the demand for weatherization services to be downward-sloping due to diminishing returns for such services, and we can consider the supply of such services as an upward slopping curve due to the increasing marginal costs, which can be thought of as increasing inefficiency caused by the increase in taxes that will pay for such services.

The main idea, however, is that disregarding the non-energy benefits will lead to an underestimation of the surplus value and an inefficient provision of weatherization services because once we account for non-energy benefits our demand is higher, i.e. our demand curve shifts to the right. The above figure shows the increase in surplus (the area in blue) generated by weatherization services.

3. Estimation of non-energy benefits

Non-energy benefits are complicated to assess, especially for the purpose of cost-effectiveness tests. Most of the studies that measure the benefits of similar programs did not attempt to monetize the values of non-energy benefits. The most comprehensive study done in this field is the one by Skumatz Economic Research Associates (SERA). Currently there is another large-scale field study of approximately 550 homes being implemented nationally, as part of the evaluation of the WX Program during years 2009-2011, which was part of the American Reinvestment and Recovery Act. This comprehensive study placed an emphasis on the improvements in indoor air quality in the homes that such services were provided (ORNL 2011). However, the study is still in progress and will bring more insight into the actual indoor air quality improvements. Another such study has been conducted in the weatherization assistance program of houses in Vermont (Riggerts 1999).[9]

Skumatz Economic Research Associates (SERA) developed a construct of valuing benefits from three different perspectives. The derivation of non-energy benefits in the spreadsheet model they used is generally based on the impacts, i.e. program-induced changes, multiplied by the value of these changes as valued by the participants (Skumatz 2002). Thus, some of the benefits are measured using objective information. However values and other benefit assessments are based on the participants' feedbacks.

The non-energy benefits were measured using data from three non-energy benefit studies: The Northeast Utilities Low Income Weatherization Residential Assistance Partnership Program; The Low-Income Weatherization Assistance programs managed by four investor-owned utilities in California (Pacific Gas and Electric Company, Southern California Edison, San Diego Gas and Electric and the Southern California Gas Company); and participants from several PG & E residential programs. Most

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[9] Homes for the study were selected based on a two-stage sampling strategy that first selected geographic areas of the country, and then sampled single-family households scheduled for weatherization by local agencies within each geographic region. The geographic sampling was based on areas defined by the U.S. Census Bureau, known as super-PUMAs (Public Use Microdata Areas), which are areas with a population of at least 400,000. The 532 super-PUMAs in the U.S. were stratified regionally and by radon level by the Census Bureau, and a national sample of 80 super-PUMAs was drawn with probability proportional to the Census 2000 population of 62 single-family, weatherization-eligible households and weatherization funding in PY 2008. (ORNL 2011). This study is measuring pre- and post-weatherization levels of the following indoor air pollutants: carbon monoxide (CO), radon, formaldehyde, and indoor humidity. CO is produced by incomplete combustion from fossil-fueled heating systems, appliances, and other combustion sources and can be a serious problem in homes. (ORNL 2011). Naturally occurring radon gas can accumulate in confined spaces in homes and, being radioactive, is often responsible for the majority of a person's exposure to background radiation. Radon and formaldehyde issues are not formally addressed by energy audits at the present time. Radon problems can be mitigated by weatherization measures that air-seal unheated basements and crawlspaces from the living areas; conversely, it can be exacerbated by overall home weatherization —tightening. (ORNL 2011). Formaldehyde was included in this study to represent the larger class of VOCs that could be present in homes. Additionally, home-energy auditors regularly make note of moisture and mold issues in homes, and ventilation measures are often implemented to deal with these issues. (ORNL 2011). On the other hand the SERA study focuses more on the evaluation of the benefits from the benefiters' perspective and how they evaluate the non-energy benefits from such weatherization services. Therefore one of the most important aspects of NEBS valuation process is basing the benefits on credible and defensible data and making sure that you do not have overlapping benefits (Skumatz 2002).

interviews were conducted for the Venture Partners Pilot program. VPP is a low-income weatherization and education program run by PG & E. (Skumatz 2002).

The Northwester Utilities program is very typical for this type of program and provided services to income-eligible costumers, including a range of energy conservation measures to address lighting, water heating, heating equipment, refrigeration and insulation. Furthermore there were more specific measures such as water heater wraps, low flow shower heads, low flow faucet aerators, weatherization and insulation, repair of broken windows and burner and furnace replacements, etc. (Skumatz 2002). This program is very similar to the Nebraska Weatherization Assistance Program.

The project conducted by SERA used three data collection sources: Participant surveys; Arrearage analysis; and analysis of non-energy benefits. The participant survey was conducted with 425 participants from the Northeast Utility Program. The California study collected data from 321 participants for all four utility companies. 150 program participants were surveyed for the PG&E VPP study, which covered several programs. (Skumatz 2002) Meanwhile, Arrearage analysis was conducted using data from the Northwester Utilities study, analyzing the changes in arrearages, credit, notices and shutoff changes due to the program, using information from both participants and non-participants. For the other programs, secondary data on program-related arrearages were used. Skumatz (2002), for the non-energy benefits analysis, used about three dozen categories of non-energy benefits estimated using program, cost and costumer data from the utilities, as well as survey data (Skumatz 2002).

Due to the lack of non-energy benefit valuations in the literature, Skumatz used different methods to measure the non-energy benefits and the three key methods were: willingness to pay; comparative or relative valuation; and scaled valuations, or modification to the Labeled Magnitude Scale (Skumtaz 2002). The willingness to pay method is frequently used to estimate hard-to-measure benefits (i.e. recreational benefits). It is conducted by asking the participants how much they are willing to pay for the non-energy benefits. It turns out that this procedure did not work as well as hoped for. Respondents didn't understand the questions and thought they may be forced to pay whatever value they gave. The willingness to pay method was used in two of the three studies. To somehow correct for this, the survey included both open-ended questions and responses with prompted values for costumers to choose from (Skumatz 2002). The other method of comparative and relative valuation was used by asking if benefits had higher or lower value than the energy savings and then how much higher or lower. This method was used in all three studies and was easier to answer than the willingness to pay method. The method of scaled valuations, which is a modification of the Labeled Magnitude Scale, is based on previous literature in the field (Green 1993; Bartoshuk 2000). It is conducted by asking the participants to rank the importance of energy savings and non-energy benefits on a scale of 1 to 100. Using previous research, these scaled responses were assigned relative numeric values, which later were translated into dollar terms. This method was used in only one of the studies (Skumatz 2002).

From the participants' viewpoints, the non-energy benefits come from different potential sources such as: lower energy usage, leadings to less time spent paying bills and related activities (i.e. calls to utility company); potential avoided moves and possible reductions on rate subsidies; health benefits, property improvements and equipment maintenance reductions; possible water savings; changes in noise levels;

greater comfort and other similar developments; and benefits from "green" considerations (Skumatz 2002). Table A2.1 provides the benefits categories estimated in SERA's model. All non-energy benefits were computed in the same terms—estimated annual dollar benefits for an average participating household.

Table A2.1
Participant-Perspective NEB Categories Calculated in the Model

Water/Sewer Bill Savings	Improvements in Indoor Air Quality
Fewer Shutoffs	Reduced Mobility and Moving Costs
Fewer Calls to Utility	Fewer Illnesses / Lost Days from Work
Fewer Reconnects	Reduced Transactions Costs
Improved Property Value	Improved Comfort / Reduced Noise and Other Benefits
Fewer Fires	Reduced Hardship

In the surveys, SERA asked about a range of changes and benefits coming from the program, which are illustrated in Table A2.1 above. Questions were asked about positive and negative benefits and the survey took great pains to be neutral in question asking, thus avoiding steering respondents towards either a positive or negative valuation (Skumatz, 2002).

Estimating the participant benefits using the three methods described above was challenging and the researchers maintained a conservative and skeptical approach toward the results due to the difficulty in measuring such benefits. Thus all of the following estimates are conservative and were downsized whenever the results seemed a bit implausible (Skumatz, 2002). The method that was used in all three studies was that of valuing non-energy benefits from program-induced changes relative to energy savings. The program participants were asked which categories of benefits they realized and whether the change from the program was a positive or negative value to them. The participants were then asked whether the non-energy benefits they described were more valuable, less valuable or of about the same value as compared to the energy savings from the program.

Follow-up questions were then asked about how much more (or less) valuable the benefits were than the energy savings (Skumatz, 2002). Dollar values then were assigned according to the energy savings for each particular study (Skumatz, 2002). Those results are shown in Table A2.2.

Table A2.2.
Results for Non-Energy Benefit (NEB) Multiplier as Percent of Program Energy Savings

Study	NEB multiplier	NEB dollar value
PG&E VPP	60%	$50
California Study	98%	$33-47
WRAP	80-100%	$65-110, two states covered

Table A2.2 shows the ratio between non-energy benefits and the value of energy savings identified in each of the three studies. The PG&E VPP study found a 60 percent ratio between participant valuations of non-energy benefits and energy savings from the program. The California study found a higher multiplier of 98 percent. The WRAP study found a range of participant valuations, from 80 percent to 100 percent of energy savings (Skumatz 2002).

The other method — that of willingness to pay surveys — was conducted only on two of the studies. No WTP study was conducted in conjunction with the PG&E VPP survey. Those results are shown in Table A2.3.

Table A2.3
Results for Willingness to Pay

Program	Annual WTP Results	Percent Reporting the Benefit
California Study	$126.32	25% of the “sum” of individual WTP
WRAP	$220 average	Top 5% of the willingness to pay results were omitted because they skewed the average

Using the method of willingness to pay, the California study participants were willing to pay $126.32 for the total non-energy benefits. This aggregate willingness to pay estimate was only about a quarter of the total willingness to pay estimates for individual benefit categories. This result showed that study participants had overlapping benefit valuations and could not divide total benefits among individual benefit categories. The WARP study had to be adjusted for very high valuations among the top 5 percent of the willingness to pay responses. A willingness to pay of around $220 was identified after this adjustment (Skumatz 2002).

During the survey process, considerable problems were found in having costumers answer all of the willingness to pay questions. Respondents repeatedly asked if they would be required to pay for the benefits and when would they have to pay. This concept was extremely difficult for the participants in the low-income Weatherization Assistance Program. (Skumatz 2002)

Meanwhile for the third method, Labeled Magnitude Scaling, data was available from only one of the studies. The survey responses on the energy importance score, and the percentages of respondents that found the net non-energy benefits to be more valuable, much more valuable, less valuable, much less valuable and of similar value for the benefits categories were used to compute the value of the non-energy benefits from the LMS approach (Skumatz 2002). The multiplier derived for the NU-WARP program computations was 0.99 (or 99 percent). The multiplier ratio is close to the results identified using the relative or comparable values approach (Skumatz 2002) as shown in Table A2.4.

Table A2.4
Results for the LMS approach

Program	NEB multiplier	NEB dollar value
WRAP	$99	$70-110

There were some differences and some similarities across the three studies. The California study was lower than the New England programs, presumably due to the difference in the winter heating loads. Also the WTP results were much larger than the results using the two other approaches. Meanwhile, the multipliers were fairly similar across the three different methods. WTP averages also were not far; however, there was huge variation within each study. It is important to emphasize that the evaluation of non-energy benefits was attempted using conservative estimation approaches because of skepticism regarding measuring non-financial, non-energy benefits (Skumatz 2002). Continuing that conservative approach, this study will utilize the lowest of the non-energy benefits' multiplier estimates, 60 percent. As our energy savings model generates an estimate of the dollar value of energy savings for electricity and natural gas, this 60 percent rate will be applied to both types of energy savings in order to estimate the value of non-energy benefits.

Over the three-year span from 2005 to 2007, heating systems caused 14 percent of residential fires (USFA, 2010). An average of 1.9 people per thousand were killed, 9.3 people per thousand were injured and over $3,500 in damage was lost per fire. Fires caused by heating systems are the leading cause of fires in rural areas (USFA "Heating fires in residential areas", 2001). As heating systems age, the chances of fire increase due to improper maintenance and mechanical failures.

Brown, et al (1993) identifies four ways that weatherization reduces the likelihood and severity of fires caused by heating systems. First, over half of all residential heating fires are caused by mechanical failures in heating systems, with a third of single or double family structure fires occurring due to improper maintenance (USFA, "Heating fires in residential areas", 2001). Part of every weatherization project includes a mandatory inspection of all heating systems. Any problems found with any piece of equipment is fixed if possible, and the entire unit is replaced if not. Thus, the first way weatherization helps to reduce the cost of fires is by replacing these faulty heating systems that then reduce the probability of a fire occurring in the first place.

Secondly, weatherization projects add insulation to walls and ceilings with little to no prior insulation. Cellulose insulation, such as that used by the Weatherization Assistance Program, decreases the property damage caused by fire. Insulation helps stop the fire from spreading throughout a home and can extinguish a fire should an insulated wall or ceiling fall on top of the fire, thus reducing the damage caused.

The last two ways come about due to the decrease in energy bills brought about by the increased energy efficiency of weatherized homes. Lower energy bills decrease the number of households that fall into arrears and thus the number of households affected by shutoffs decreases. A household whose electricity has been shut off by an energy company often turns to alternative means of obtaining heat such as wood stoves, space heaters and other forms of portable heaters. These portable heaters cause an average of 3,800 residential fires every year (USFA, 2010). While this may seem like a small amount, 25 percent of all fatal residential heating fires are caused by portable heaters (USFA, 2010). Similarly, with more efficient heating systems, larger portions of consumers' heating demand can be met by these systems rather than by portable heaters. Thus, the likelihood of fires caused by heating systems is again reduced.

Reducing the likelihood of fires increases benefits for a household in several ways. First off, reducing the number of fires that occur in homes reduces the loss of life due to these residential fires (Brown, et al. 1993). To capture this impact, we use the 2011 value of a statistical life issued by the U.S. Department of Transportation—$6,200,000. Heating system fires are the third leading cause of death due to residential fire (USFA, "Heating fires in residential areas" 2001). Only smoke and arson cause more deaths. However, if one looks specifically at rural areas, heating system fires are the leading cause of death (USFA, "Heating fires in residential areas" 2001).

Another impact of residential fire reductions is the reduced property losses caused by fires (Brown, et al. 1993). In 2010, the CDC reported that there were 384,000 residential fires reported within the United States (CDC 2011). These fires caused a total of $7.1 billion dollars in damages (NFPA 2010). Of those fires, 14 percent were caused by heating systems (USFA 2010). By lowering the number of fires caused by heating systems, the amount of property damage caused will be reduced, saving homeowners money.

First, we look to the value of lives saved by the reduction in fire occurrences. The average household in Nebraska contains 2.49 individuals (U.S. Population Census, 2000). During the chosen period, 867 homes were weatherized as part of the Weatherization Assistance Program. This means roughly 2,159 individuals were impacted by the Weatherization Assistance Program. On average, 2.141 deaths per 100,000 people are caused by household fires every year with 12.9 percent of those caused by heating systems. With 2,159 occupants, the expected number of deaths from fires caused by heating systems in Nebraska would be .00597 deaths per year.

The United States Department of Transportation recommends using a value of a statistical life of $6,200,000. Using the percent of the population of Nebraska that is non-elderly, defined as being 64 years of age and younger, and those who are elderly (65 years and older), we determine that the value of lives saved by replacing faulty heating systems is $34.99 per year.

In addition to lives saved, reducing the chances of heating system fires reduces the amount of property damage incurred. Using the expected number of fires per dwelling, we determine that the expected number of fires to occur in the weatherized homes sample is almost six fires per year, with, on average, one of these each year being caused by faulty heating systems. The National Fire Protection Agency reports that the average loss per residential fire in 2010 was $18,489.58. Assuming the loss for a low-income household is half that of the national average, the average loss for a weatherization-applicable home is $9,244.79. Using a conservative estimate, if replacing faulty heating systems reduces the number of fires a year by 25 percent, $1,927 in possible property loss is saved each year by the Weatherization Assistance Program. For the 867 homes weatherized during the study period, that equals about $2.22 per home per year.

4. Implementation

Non-energy benefits include benefits to households participating in the WX and LN programs from improved comfort and health from a more energy efficient household. There was also a fire safety benefit for projects that address faulty heating systems. These non-energy benefits are included in the reporting tool model. In particular, the energy savings model described earlier generated an estimate of the dollar value of energy savings for both electricity and natural gas. A 60 percent non-energy benefit rate was applied to those energy savings in order to estimate the value of non-energy benefits to participating households. We also conservatively included a flat fire safety benefit of $37.21 per year to all furnace replacement projects, another important type of non-energy benefit to participating households.

C. Appendix 3: Environmental Benefits

This appendix considers the externality benefits generated by the WX and LN programs. An externality occurs when a third party, other than the producer or the consumer of a good or service, is indirectly affected, either positively or negatively, by the production or consumption of that good or service. It has an important implication for resource allocation. When an externality is present, the market equilibrium is no longer efficient, for some people bear the cost (or draw benefit from) of goods they did not ask for. For instance, the market price of electricity does not incorporate the impact of the pollution caused by its production and consumption, but this pollution affects numerous people who do not consume this electricity. Consequently, the presence of externalities (negative) often justifies the need for government intervention in order to mitigate their occurrence. In a like manner, some government programs may have externality reduction implications that are not captured in the economic evaluation of these programs. The WX and LN programs reduce the energy consumption of participant households. As a result, these programs also reduce pollution externalities. An extensive literature review was undertaken to develop the methodology for estimating the environmental benefits from reduced pollution.

1. Key Finding from the Literature Review

Of the dozens of studies that we reviewed, the most comprehensive analysis assessing the external cost of electricity production and consumption and natural gas consumption was conducted by the National Research Council (2010). This study uses the damage cost method to directly assess the damages caused by the energy production and consumption. The main steps followed in this study to estimate the externalities are:

1. Estimate the burden (such as air pollutant emissions) from electricity production and consumption.
2. Estimate the exposure of the populations or environment to the air pollutants.
3. Estimate the consequences/damages based on this exposure.
4. Assign monetary value of these damages.

The National Research Council (2010) examines externalities related to the emission of criteria air pollutants such as PM, SO_2, NO_x etc. The criteria air pollutants affect human health, crop yields, climate change, etc. Next, they monetize the effect of these criteria air pollutants. Additionally, they estimate external costs of greenhouse gas (GHG) emissions for electricity and natural gas usage based on the findings from other research.

The authors organize their analysis into two main components: externalities not related to climate change (that have direct impacts to adjacent community such as effects on human health, crop yield, etc.) and those related to climate change (such as global warming due to carbon emissions). In fact, estimated values of these two types of externalities are provided for electricity production from all fuel types, and for consumption of natural gas. Further, in the case of electricity production, more emphasis is given to the electricity produced by coal and gas as these two accounts for 70 percent of the nation's electricity. It is worth mentioning that they use an LCA (Life Cycle Analysis) approach to estimate the externalities. That is, they consider not only downstream externalities (for example, the effect of producing electricity by burning fuel), which are the externalities experienced during production as well as consumption, but also all other externalities related to upstream, which are the externalities experienced before production begins (for example coal mining and transporting coal from mining to electric plant). In our study, we intended to use the downstream externality only because our study is mainly for one state, and considering upstream may cause a double-counting problem of estimation. For example, coal used to produce electricity in Nebraska may be extracted in other states, so upstream externality belongs to those states. Hence, this should be counted for those states only. In any case, limiting our study to the downstream section of the process does not affect the results. In fact, most of the potential impacts, deriving from the upstream section of the process, were already considered in market mechanisms. For example, high wages (as compensation) for coal mining workers eliminated part of the externality problem since the workers had already been compensated by the high wages. Some are not tractable because of less availability of the relevant data, and others are not statistically significant. For instance, Jaramillo et al. (2007), as cited by the NRC (2010), find that the mid-point GHG factors for coal combustion (at the power plant) and the entire coal lifecycle do not differ significantly.

Overall, the National Research Council (2010) expressed the damage cost both for climate-related and non-climate-related impacts in terms of per-kWh electricity production by different fuel types. Table A3.1 provides an illustration of the impact of producing electricity from coal.

TABLE A3.1:
Illustrative Impacts of Producing Electricity from Coal

	Human Health	Ecosystems	Security and Infrastructure
Upstream			
Coal Mining	Coal miners' mortality and morbidity	Land disturbance, river alteration, acid mine drainage	
Transportation of coal to power plants	Death and injury from accidents	Vegetation damage from air pollution	Load on transportation systems
Downstream			
Burning of coal	Mortality and morbidity from air pollution	Ecosystem effects from cooling Water discharges Ecological changes from climate change	Degradation of building materials Agricultural shifts and coastal community impacts due to climate change
Disposal of waste	Health effects of heavy metals in ash and other waste	Ecosystems effects of ash and other wastes	
Transmission of electricity		Disturbance of ecosystems by utility towers and rights of way	Vulnerability of transmission system to attack or disaster

Source: Adapted from National Research Council (2010) study.

The estimated monetary values of the criteria air pollutant damages per kWh found by the National Research Council (2010) are presented in Table A3.2. Results are presented per kWh for electricity produced at a coal-fired power plant and electricity produced at a natural gas-fired power plant. In the last row, results are presented both on per-kWh and per-therm basis. The benefits per therm also are presented for natural gas consumed in the home. As expected, they found that the estimated externalities for producing electricity by gases are less than the external costs due to electricity production by a coal-fired plant.

Table A3.2

Estimated Results (mean value) of Criteria Air Pollutant Damages[10] (2007 cents)

Pollutants	Mean per kWh (coal fired plant)	Mean per kWh (gas fired plant)	Mean per therm (natural gas consumption)
$S0_2$	3.8	0.018	0.039
$N0_x$	0.34	0.23	3.41
PM2.5	0.30	0.17	0.078
PM10	0.017	0.009	-
VOC	-	-	0.10
NH3	-	-	0.039
Total (equally weighted)	4.4	0.43	
Total (weighted by net generation	3.2/kWh or 93.7/therm	0.016/kWh or 4.69/therm	4.48/therm

Source: Adapted from the National Research Council (2010)

Note that Table A3.2 does not include estimates of the environmental costs of the greenhouse gas (climate change) emissions in the production or consumption of electricity or natural gas. Emissions related to climate change are often considered in terms of CO_2-equivalent [11] (commonly expressed as CO_2-eq). Costs related to emissions of CO_2-equivalent were calculated as follows using the approach taken for consuming natural gas in the home (estimates concerning the electricity part are obtained in similar fashion). The pollution quantity of 11.68lb/therm for the CO2-eq was obtained by converting the CO2-eq of 120lb/MCF to a per-therm unit (one MCF=10.27 therms). Since the environmental damage caused by the CO2-eq is estimated at 10, 30, and $100/ton, depending on the assumptions on the future damages and the discount rate, the conversion to per-therm units contains three values, which are 6, 17.5 and 60 cents per therm of natural gas consumed[12]. The middle value was chosen as the climate change cost per therm of natural gas consumption.

Like many other environmental studies, the National Research Council (2010) study has some limitations. First, it does ignore some potential externalities due to data unavailability. Second, the range of some of the estimated values is wide.

There is indeed a wide array of estimates of environmental damages generated by electricity production and consumption and residential natural gas consumption for heating purposes. Consequently, it is necessary to choose which estimates to use. We reviewed several studies that have estimated the

[10] Damages cost/kWh for each gas was estimated using equal weight to each generation plant. But if net generation is considered then total damages is about 28% less and hence it is expected that damages for some gases, if not each gas, would be less if net generation were considered.

[11] CO_2-eq expresses the global-warming potential of a given stream of GHGs (Green House Gases), such as methane, in terms of CO_2 quantities (Ref: NRC, 2010)

[12] Note that future damages are converted in current value terms, therefore the assumption on these future damages, and the discount rate are of utmost consequences.

values of externalities caused by the different pollutants' emissions. The estimates provided by the National Research Council stand out as reliable estimates we can use, with minor adjustments to fit our particular case. Their reliability stems from reasons that can be summarized as followed.

First, the estimates are the most recent to be produced. Tol (2009) notes that estimates have become less pessimistic as more peer-reviewed studies become available. On that account, current studies are likely to provide better estimates. Second, the model used to calculate the estimates is fully explained in the report, making the estimates understandable and reliable. In fact, the committee used the methodology of the Air Pollution Emission Experiments and Policy (APPEP), which they describe in their appendix. In this model, the authors' focus of externalities considered is health effects associated with criteria-pollutants-forming emissions. The committee also estimated the GHG emission externalities. Additionally, the National Research Council study considered the entire U.S and was therefore not biased by location.

2. Other Literature Review

Different studies provide different estimates for the same type of externalities. We rely on estimates calculated by the National Research Council (2010) study since it appears to be the more reliable for the reasons we expressed above. A question often asked is, "Why do different studies provide different estimates for the same parameters?"

The wide range of the estimates is most often justified by the use of different assumptions underlying the process of estimations (extent of uncertainty, discounting rate). Besides these assumptions, time and location matter for the calculation of the estimates. For instance, estimates expressed in 1990 $US are certainly different from estimates expressed in 2010 $US. Also, the effect of a ton of NOx in a densely populated area is different from the effect of the same ton in a sparsely populated area.

The literature review also suggests that these differences stem from differences in methodology. Conducting a meta-analysis of energy externality studies, Sundqvist (2004) explains the different alternative methods used to assess the externalities of energy usage. According to the author, there are two commonly used methods for evaluating energy externalities: the damage cost approach and the abatement cost approach.

The damage cost approach requires assessing the actual damage caused by energy production and consumption. It is the total damage done by all activities related to energy production, distribution and consumption. The damages include effects on health, morbidity, mortality and environments. All are quantified and monetized. The damage function approach commonly uses two methods: direct (where people are asked to evaluate and state their willingness to pay or accept to avoid the damage) and indirect (based on the actual behavior or changes in the existing situation; for example hedonic pricing, changes in income, productivity etc.) Moreover, the damage cost approach can be subdivided into two categories: top-down and bottom-up (Sundqvist, 2004). In the top-down approach, aggregated data (mostly national) is used to estimate the cost of a particular pollutant. This method is often criticized, mostly because it depends too much on the availability of national level data, and on the estimates of previous studies. On the contrary, the bottom-up approach typically identifies and quantifies damages from a single source through damage functions or impact pathways and then monetizes them using established economic valuation methods (such as contingent valuation, travel costs, hedonic pricing, etc.)

The damage cost approach is preferred to the abatement cost approach method of estimation of energy externalities because the latter uses the abatement cost of a regulated and directed amount of emission which assumes that the emission set by the regulator is socially optimal. That may not be the case, and is usually not.

To illustrate how the damage cost approach is used, we present a study that uses the approach. In fact, since 1991, the European Commission has been commissioning a research project titled ExternE to evaluate the externalities of energy production and consumption. According to the Australian Academy of Technological Sciences and Engineering (ATSE 2009), this ExternE research project is regarded as one of the best scientific resources of the externality estimation. This study uses both damage cost (by impact pathways approach) and abatement cost methods. The long lists of factors (in impact pathways) that have been taken into account in this study are (Watkiss *et al* 2005 as cited in the ATSE, 2009 report):

- Impacts of sea-level rise, erosion, loss of land/coastal wetlands and the need for coastal protection
- Effects on agriculture
- Effects on energy use (including heating and cooling)
- Effects on human health from changes in cold related and heat related effects
- Effects on human health from the disease burden (and other secondary effects)
- Effects on water resources, water supply and water quality
- Changes in tourism potential and destinations
- Effects on ecosystems (loss of productivity and bio-diversity)
- Impacts of drought
- Impacts of flooding
- Impacts of storm damage and extreme weather (including costs to infrastructure)
- Socially contingent effects (arising from multiple stresses and leading to migration, famine, etc)
- Impacts of major events (e.g. loss of thermo-haline circulation (ocean circulation driven by density gradients), collapse of West-Antarctic ice sheet, methane hydrates)

Though ExternE uses both damage cost and abatement cost approaches to assess the externality cost of electricity generation in estimating the greenhouse impact, they prefer the abatement cost approach to the damage cost function approach because the latter excludes, as they argue, a lot of important dimensions that cannot be quantified due to uncertainty involved in estimation. For instance, impacts such as extended floods and more frequent hurricanes with electricity production cannot be taken into account, as there is not enough information about the possible relationship between global warming and these impacts (ExternE, 2005 cited in ATSE, 2009).

The health impact is assessed using the impact pathway approach, which is done in the following sequence:

- Estimation of emission
- Dispersion in the environment
- Dose response function or concentration response function
- Effect on health
- Monetization of the health effect

Gases considered in health impacts are: NO_x, SO_2, PM, VOC, and NH3. The estimation is done using the damage cost approach.

The damage cost function is used in many studies. Some studies focus on only one or two dimensions of non-energy benefits and externalities. For example, Burtraw, et al. (1997) assess the cost benefit analysis of the 'Title IV of the 1990 Clean Air Act Amendments'. The act initiated a substantial reduction in the emissions of sulfur dioxide and nitrogen oxides by electric power plants. This study included health benefits only. According to the authors, the major share of the benefits stem from the reduced risk of premature mortality due to reduced exposure to sulfates. Moreover, the significant benefits are also estimated from the improvements in health morbidity. A similar kind of study by Burtraw and Toman (1997) concludes that policies that reduce greenhouse gases can simultaneously reduce the emission and concentration of the criteria air pollutants, such as SO_2, NO_x, $PM_{2.5}$ etc. in the atmosphere and thus can have a positive effect on human health. They show that emission reductions would reduce the concentration of air pollutants in the environment, which would lead to reduced exposure to sulfates, nitrates and to other air pollutants. Thus, there will be reduced premature mortality and morbidity. For estimating the health benefit, a response function that evaluates the direct health effects, both in terms of morbidity and mortality, caused by changes in the concentration of criteria air pollutants (for example reduction in cardiovascular diseases, and asthma other related diseases) has been used. The impact is monetized. The (dose) response function is mainly used in epidemiological studies to assess the impact of changes in concentration of pollutants on premature mortality and morbidity; the function/coefficients are useful to estimate the impact of some reductions in emissions.

Similarly, Burtraw, et al. (2001) show how some actions to slow greenhouse gases could also reduce air pollution in the United States. They assess the health benefit (monetary) of imposition of carbon tax by different amounts. They estimate that the tax of $25 per metric ton of carbon emissions would yield NOx related health benefits of about $8 per metric ton of carbon reduced in the year 2010 (1997 dollars). They also estimate the additional savings due to the reduction of investment in NO_x and $S0_2$, and this value is $4-$7 per ton of carbon reduced.

Even within the literature that uses damage cost function methodologies, the results still differ due to differences in the gases or air pollutants considered. It is evident that most studies consider only limited types of gases, mainly due to the availability of data. Commonly considered emissions are CO_2, SO_2, and NO_x. However, some studies consider a wide range of emissions types (gases) for estimating externality. For example, Hill, et al. (1998) analyze the environmental impact of WX for Ohio where they focus not only on CO_2 emissions, but also on other forms of emissions such as Sulfur Oxides (SO_x), Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Methane (CH_4) and particulate (TSP). Burtraw, et al. (2001) consider NOx and SO_2 only.

Mattews and Lave (2000) review different studies (using the damage cost function model) conducted in different states during 1990s. During that time, several states directed the investigators to assess not only the direct costs of electricity production but also the indirect costs while making their investment decisions. These indirect costs are termed "externality adders". Table A3.3 shows the unit social damage estimates from air emissions of environmental externalities delineated by those authors.

Table A3.3
Unit social damage estimates of air pollutants ($1992)

Pollutants	Estimated (median values) external costs ($/ton)
SO_2	1,800
$N0_x$	1,060
PM10	2,800
VOC	1,400
$C0_2$ eq.	14

Source: Mattews & Lave(2000)

The study also discusses the implied value cost/abatement cost method[13] (see annex for the detailed table). A study conducted in California also used a similar method for estimating the externalities. It claimed to use marginal cost of abatement with the best technology available. Other states (Nevada, Oregon, New York, Minnesota) also conducted similar studies (EIA, 1995).

A number of studies estimate the non-energy benefits of energy efficiency programs. (It should be noted that externality benefit is a part of non-energy benefit). For example, in assessing different types of non-energy benefits (NEB) for WAP, Schweitzer and Tonn (2002) classify NEB into three major categories: 1) ratepayer benefits; 2) household benefits; and 3) societal benefits. Moreover, they divide the ratepayer benefits into two main subcategories: payment-related benefits (such as avoided rate subsidies, reduced carrying cost in arrearage, lower bad debt write off etc.), and service provision benefits (e.g. fewer energy gas service calls, transmission and distribution loss reductions). The household benefits are categorized in two ways: 1) the benefits that are related to the affordability of low-income housing such as water and sewer savings, property value benefits, reduced mobility, reduced transactions cost, etc.; and 2) the benefits that are related to the safety, health and comfort of residents, such as fewer fires,

[13] One of the common examples of this method along with value adders is The Commonwealth of Massachusetts Department of Public Utilities (MDPU) order to implement and assess the externality cost in their integrated resource planning. According to MDPU orders every plant required to submit the social cost of energy production which included externality cost for resource planning. It was found that cost of electricity production is less in coal fired plant if externality not included but it became expensive compared to natural gas plant if externality had been included. Although they asked the firms to submit their findings, they preferred implied valuation method/abatement cost method as a proxy of actual externality cost (EPA 1995). However, this method works best when pollution control set by the govt. is socially optimal.

fewer illness and improved comfort. In the societal benefits, the authors include economic, social and environmental dimensions. Similarly, Riggert, et al. (2000) conduct a meta-study on the non-energy benefits of weatherization and low-income residential programs. The study summarizes the quantified non-energy benefits based on the findings from 91 publications. Along with other benefits, this study also discusses environmental and health benefits. The study summarizes the specific estimated values of avoided air pollutants. Table A3.4 shows some of its findings.

Table A3.4
Reported Benefit of Avoided Air Emissions

Air Pollutants	$/ton of pollutants	Cents/kWh
$S0_x$	110-2,030	1.15
$N0_x$	44-8,143	1.86
VOC	530-6,673	0.19
C02 eq.	10-77	2.10

Source: Riggert el al (2000)

Several studies emphasize the importance of including the non-energy benefits for evaluating an energy efficiency program. For example, William (2008) gives a comprehensive review of the justifications of energy saving of the home improvement program from social, economic and environmental perspectives. Amman (2006), cited in William (2008), argues that the non-energy saving of the low-income program would be worth 50 to 300 percent of the savings in energy bills. A report by the American Council for an Energy Efficient Economy (Prindle, et al. 2006) (cited in Tonn and Peretz , 2007) shows that the northeastern eight-state Regional Greenhouse Gas Initiative (RGGI) would have a positive impact on the region's economy if, with energy efficiency, it could work to reduce the greenhouse gas emissions. Moreover, the U.S. Environmental Protection Agency (EPA) published a guideline for estimating the non-energy benefits. It discusses the issues, methodology, tools available, research findings of other studies, data sources and a step-by-step explanation of conducting studies related to clean energy. Schweitzer and Tonn (2002) also evaluate non-energy benefits more generally.

3. Literature for Natural Gas

Until this point, our focus has been the exposition of the literature on externality estimation concerning electricity production and consumption. Though some of the results and discussion expounded in the previous sections still apply, there are some differences in the nature of externalities for the consumption of natural gas, hence the need to discuss some of the issues separately. In the followings section, we concentrate the exposition on externality estimations concerning natural gas consumption.

The use of natural gas causes externalities, defined as societal costs that are not considered in the market transaction. The externalities are observed from the explorative stage (upstream externalities) to the end user usage (downstream externalities). For instance, the major constituent of natural gas, methane, directly contributes to the greenhouse effect. In fact, the ability of methane to trap heat in the atmosphere is estimated to be 21 times greater than that of carbon dioxide. Besides methane, the natural gas consumption generates criteria pollutants. The criteria pollutants specified in the Clean Air Act (SO_2, NO_2, O_3, PM, CO, Pb) are reactive gases that promote reactions in the atmosphere yielding the greenhouse gas ozone. These gases indirectly affect the global climate because they produce undesirable lower atmosphere ozone, as opposed to the desirable high-altitude ozone that shields the earth from most of the sun's ultraviolet radiation. Carbon dioxide directly contributes to the greenhouse effect; it presently represents 61 percent of the worldwide global warming potential of the atmosphere's greenhouse gases. Though natural gas combustion generates criteria pollutants, it is worth noting that natural gas emits less criteria pollutants than the other fossil fuels, as shown in Table A3.5.

Table A3.5
Pound of Air Pollutants Produced per Billion of Energy

Pollutant	Natural Gas	Oil	Coal
Carbon Dioxide (CO_2)	117,000	164,000	208,000
Carbon Monoxide (CO)	40	33	208
Nitrogen Oxides (NO_x)	92	448	457
Sulfur Dioxide (SO_2)	0.6	1,122	2,591
Particulates Matters (PM)	7	84	2,744
Formaldehyde	0.750	0.220	0.221
Mercury	0.000	0.007	0.016

Source: EIA (1998)

The greenhouse gases are of concern mainly because of their impact on climate change. Evaluating the monetized estimates of all the effects provides a wide range of values, making these values unreliable for policy planning (Jaramillo et al. (2007) as cited in National Research Council (2010)). Consequently, most studies avoid evaluating the upstream part of the environmental effects of natural gas consumption. We follow this tradition by focusing our study on evaluating the environmental effects at the downstream level of the process. Despite the confinement of the problem to estimates at the downstream level, the literature still provides a wide range of estimates of the environmental damages caused by natural gas consumption. For instance, Jonathan Koomey and Florentin-Kause (1997) present a table summarizing the value of environmental damage estimated by diverse studies. Table A3.6 below is an adapted version of their table.

Table A3.6
Koomey and Florentin-Kause Summary Table

	Dollars/pound ($/lb)						
Study	SO2	NOx	CO (lb of carbon)	ROG	CH4	NO2	Particulates
EPRI (1987) rural PA, WV	0.48	0.07	-	-	-	-	-
EPRI (1987) (Sub)urban	1.27	0.07	-	-	-	-	-
Chernick and Caverhill (1989)	0.92	1.58	0.42	-	0.37	-	>2.63
CEC Staff (1989) CA	5.75	5.80	0.013	1.65	-	-	3.9
Implied by NY PSC (1989)	0.48	0.94	0.0015	0	-	-	1.01
MA DPU (1990)	0.75	3.25	0.04	2.65	0.11	1.98	2.00
NV PSC	0.78	3.4	0.04	0.59	0.11	2.07	2.09
Pace University	2.03	0.82	0.026	-	-	-	1.19

Source: adapted from Jonathan Koomey and FlorentinKause (1997)

Specific to natural gas consumption, Schweitzer and Tonn (2002) present a literature review of the non-energy benefits of the program. In their literature review, they construct a table summarizing the diverse estimates of the different studies they reviewed. Table A3.7 below shows the wide range of the estimates.

Table A3.7
Schweitzer and Tonn Estimates

Non-energy Benefit	Range of Benefits (in 2001 $ per participating household: Net Present Value
Air Emissions – Natural Gas	
Carbon (CO2)	40 – 32,189
Sulfur Oxides (Sox)	0.02-6,015
Nitrogen Oxides (NOx)	0.02-2,254
Methane (CH4)	0.07-269
Particulate Matter (PM)	0.01-6,983
Air Emissions – Electricity	
Carbon (CO2)	167-97,857
Sulfur Oxides (Sox)	31-40,872
Nitrogen Oxides (NOx)	11-17,290
Particulate Matter (PM)	0.27-704
Other Benefits	
Heavy Metals (air emissions)	1.39-17,205
Fish Impingement	23.44-23.44
Waste Water and Sewage	3.36-657
Total	68-67,061

Source: Adapted from Schweitzer &Tonn, 2002

The table shows that there is indeed a wide range of estimates of environmental damage generated by residential natural gas consumption for heating purposes. Subsequently, it is necessary to choose which estimates to use. Our review of the literature suggests that the National Research Council (2010) estimates are adequate for our purpose. The reasons for this choice have already been presented above. Table A3.8 shows damage estimates from the National Research Council (2010) for the Midwest region:

Table A3.8

Natural Gas Use for heat: Damage estimates (Excluding greenhouse Gases) (cents per MCF*)

Pollutant	Mean	Standard Deviation	Median
SO_2	0.4	2	0.15
NO_x	35	290	11
$PM_{2.5}$	0.8	7	0.18
VOC	1	9	0.25
NH_3	0.4	2	0
Total	46	370	14

Source: adapted from the National Research Council (2010), *MCF= thousand cubic feet

Monetized estimates of the impact of greenhouse gases are provided separately. The gases are converted in terms of equivalent CO_2, and then the environmental damage per unit of the CO_2 equivalent is calculated. The estimated value, the marginal impact of greenhouse gas emissions, is the net present value of the impact over 100 years of one additional ton of CO_2 equivalent emitted into the atmosphere. As Tol (2009) remarks, the marginal impact of emissions is a more appropriate indicator for policy evaluation, since climate change cannot all together be avoided, and any policy would have only a partial effect on climate change. The National Research Council (2010) concluded that "only rough order-of-magnitude estimates of marginal climate damages are possible at this time." Thus, depending on certain assumptions (for instance, the extent of the future damages, the discount rate used for weighting future damages and the probability of future calamities), the range of estimates of the marginal global damages can vary from $1 per ton to $100 per ton of CO_2 equivalent. This range of estimates is based on the following assumptions of low, middle, and high future damages: 1.5 percent, 3 percent, and 4.5 percent of the discount rate. The range of estimates is $10, $30, and $100 per ton of equivalent CO_2. One MCF of natural gas burnt generates, approximately, 120 pounds of CO_2 equivalent. Based on these rates, it is possible to calculate the marginal environmental effect per unit of natural gas consumed. Conversely, the marginal benefit for every unit of natural gas saved can be evaluated. Indeed, we find approximately 6, 17.5, and 60 cents per therm of natural gas consumed or saved, depending on the assumption mentioned above. We used the middle value.

4. Summary of Literature Review

To summarize, the literature review shows that there is a wide range of estimates of energy externalities. This fact suggests that special care must be taken in choosing estimates of externalities for the current study, since we rely heavily on previous studies. Sundqvist (2010) explains why different studies provide different estimates. The reasons for the divergences of estimates are manifold. First, there are two main methodological approaches for evaluating energy externalities—the damage cost and the abatement cost approaches—and they provide different results. Second, externality estimations are difficult to circumscribe, constraining researchers to make assumptions. Different authors opt for different assumptions on concepts such as the discount rate or the extent of the damage. Third, the studies are often conducted in different locations and at different time periods. Further, many of these studies are not peer reviewed, making their credibility questionable. However, Tol (2009) notes that estimates have become less pessimistic, as more peer-reviewed studies become available. Therefore, recent studies should be given more weight in the choice of estimates of externalities. Indeed, we found the estimates of the National Research Council (2010) convincing, because the report is recent, transparent and extensive in its literature review. Consequently, our study relies heavily on the estimates provided by the National Research Council (2010).

5. Implementation of the Model

Table A3.9 shows the final estimated benefit value from reducing pollution per kWh of electricity and per therm of natural gas. These costs include both greenhouse gas emissions and other types of pollution. These values can be applied to estimates from the model of annual savings in kWh of electricity and therms of natural gas due to the WX and LN investments. The present value of reduced pollution would then be calculated from an annual stream of benefits, following the approach used earlier to calculate the present value of energy savings benefits.

Table A3.9
Estimated (mean value) Costs (cents)

	Cost Estimates (mean values)			
Pollutant	For Coal Fired Plant	For Gas Fired Plant	For Nebraska	Cost per Therm for Natural Gas
SO_2	3.8	0.018	2.54	0.039
NO_x	0.34	0.23	0.23	3.400
$PM_{2.5}$	0.30	0.17	0.20	0.077
VOC[14]	0.19	-	0.13	0.097
PM_{10}	0.017	0.009	0.01	-
NH_3	-	-	-	0.039
CO_2-eq	3.0	1.5	2.04	17.500
Total (equally weighted)	7.64	1.93	5.15	21.15
TOTAL[15, 16] (weighted by net generation)	6.97	1.81	4.70	22.00

Source: Author calculations based on National Research Council (2010).

Before calculating the non-energy benefits, let's restate how the estimates were gathered. As the literature review shows, there is a wide array of estimates of externalities generated by residential energy consumption. Consequently, it is necessary to choose which estimates to use. Numerous studies estimating the values of externalities caused by the different pollutants emissions were reviewed. The estimates provided by the National Research Council (2010) stand out as the most reliable estimates for reasons mentioned above. Estimates for calculating environmental benefits are presented in Table A3.9. It is important, however, to mention that the energy saved data for electricity is mainly collected at the household level, while the data on emissions are gathered at the plant level. Hence, we use 1.09 as a multiplier to convert electricity saved at the household level to electricity saved at the plant level. This 1.09 is justified because there is about 9 percent energy loss in the distribution and transmission of the electricity (Deru and Torcellini, 2007).

As seen in Table A3.9, the weighted benefit of reducing non-greenhouse gas pollution is not equal to the unweighted benefit. This is because reductions in energy demand will not occur equally at all plants. Weighted benefit estimates are therefore not equal to the sum of unweighted benefits across all plants. Unfortunately, the National Research Council (2010) only reported total weighted benefits, not benefit by pollutant. The total benefit weighted by net generation is reported in the last row of Table A3.9.

[14] Though all other values are from NRC(2010), this value is from a different source (Riggert et al , 2000).

[15] NRC study uses cost at the plant. But as we have the information of kWh saved in the household, we have to convert this savings (in household) in to saving in the plant, and hence, 9% distribution and transmission loss, i.e. 1.09 converting factor is used.

[16] According to NRC study criteria air pollutants damage (when net generation is considered) is 3.2 cents/kWh for coal fired plant and .16 cents per kWh for gas fired plant. In case of coal fired plant VOC damages (.19 cents /kWh) are also included to estimate total criteria air pollutant damages. And VOC damages are from other source (Riggert et al, 2000). However, VOC damages are not considered for gas fired plant, because emissions of VOC from a gas fired plant are very small compared to that of a coal fired plant (Ref. EPA COBRA(Cost Benefit Risk Analysis) software).

These figures also include the benefit value of reduced greenhouse gas emissions, adjusted for electricity loss in transmission. Specifically, to calculate total damage we used net generation weighted criteria data from the National Research Council (2010) for air pollutant damages (3.39 cents/kWh for coal fired plant and 0.16 cents/kWh for gas fired plant) and total climate change damage (3 cents/kWh and 1.5 cents/kWh for coal and gas fired plant, respectively). Both factors also were adjusted for the multiplier for transmission loss. We then created an average benefit value for Nebraska given the share of coal fired, gas fired and nuclear power plants in Nebraska power production. This overall result for Nebraska is reported in the second to the last column and is $0.047 per kWh. The result for natural gas consumption in the home is reported in the last column and is $0.220 per therm. As noted earlier, these benefit values can be applied to estimates of energy savings to calculate the aggregate environmental benefits from the WX and LN programs.

Annex: Table: Massachusetts Externality Values (1989 Dollars per Ton)

Pollutant	Value	Basis for Value Deviation
Nitrogen oxides (NOx)	$6,500/ton	Based on the cost of installing selective catalytic reduction on a 10 MW natural gas turbine
Sulfur oxides (SOx)	$1,500/ton	Based on the cost of installing flue gas scrubbing systems on utility generators
Volatile organic compounds (VOC)	$5,300/ton	Based on a U.S. Office of Technology Assessment study on costs of control technologies for ozone nonattainment areas, and on two studies conducted for the Environmental Protection Agency on the costs of complying with various Clean Air Act targets
Total suspended particulate (TSP) matter	$4,000/ton	Based on the cost of installing an electrostatic precipitator on a high sulfur coal plant with low resistivity fly ash
Carbon monoxide (CO)	$870/ton	The total consists of a $820/ton ambient air quality component (cost of increased oxygenation of gasoline) and a $50/ton greenhouse gas component (the global warming potential of CO relative to CO_2)
Carbon dioxide (CO_2)	$22/ton	In anticipation of CO_2 regulations. Based on the marginal cost of planting trees in a moderate effort to sequester carbon (Some individuals contend that tree planting costs alone may understate mitigation and control costs since tree planting can offset only a small fraction of CO_2 emissions. But other estimates are much less, say $15/ton.)
Methane (CH4)	$220/ton	Considering the warming potential relative to CO_2
Nitrous oxide (N2O)	$3,960/ton	Considering the warming potential relative to C CO_2

Source: from EPA, 1995. Electricity Generation and Environmental Externalities: Case Studies. Washington. DOE/EIA-0598 Distribution Category UC-950

D. Appendix 4: Economic Impacts

The WX and LN programs change the Nebraska economy by helping households become more energy efficient. This is the primary economic outcome of the programs, and the benefits in terms of energy savings and reduced pollution are discussed elsewhere in this report. However, the programs also change the economy in two ways: 1) by increasing construction activity and equipment purchases, and 2) by changing household spending patterns. Funding for the WX and LN programs lead to increased construction activity. This results in construction jobs and earnings and also spillover effects, such as gains for other businesses that supply the construction industry. Energy savings due to WX and LN investments also influence household spending patterns. Households spend less money on energy, freeing up more income to spend on other aspects of household consumption such as food, entertainment and retail items. These changing spending patterns also have an economic impact. The methodology for calculating these economic impacts is discussed below.

1. Methodology

The economic impact of the WX and LN programs flow from two sources: 1) the increase in construction spending and equipment purchases, and 2) the change in household consumption. Both types of spending result in a change in final demand in the Nebraska economy. The increase in construction spending is a form of investment in the construction and appliance industries. The change in household consumption patterns is simultaneously a decrease in demand for energy purchases and an increase in demand for purchases of other components of household spending such as food, entertainment and retail items. The LN program also increases demand for banking activity.

Given these changes in final demand, a model of the economic impact of WX and LN must reflect how these changes in final demand filter into the wider state economy. This filtering is known as the "multiplier effect", which reflects how businesses throughout the Nebraska economy benefit as the initial spending circulates within the state economy. For example, the multiplier effect occurs, in part, as employees of firms involved in WX construction projects spend their paychecks on household goods and services. The multiplier effect also occurs as these construction firms make purchases from their own vendors and suppliers such as purchasing construction materials, or accounting or legal services.

The multiplier effect specifically shows the total economic activity created by each dollar of direct economic activity. Following the case described above, the multiplier effect would indicate the total economic activity at all businesses in the economy that results from one dollar of spending on a WX construction project. To provide a numerical example, an economic multiplier of 1.5 would indicate that there is a total of $1.50 in economic activity for each $1 of spending on a WX construction project. Of the $1.50, $1 of spending occurs at the construction firm, but the remaining $0.50 occurs at businesses throughout the economy such as building supply wholesalers, retail stores, and others, due to the multiplier effect.

There are also multipliers that show the total employment or total labor income (wages, salaries, benefits and proprietor income) associated with the direct spending. For example, a wage multiplier might show that there is $0.60 of labor income for each $1 spent of spending on a WX construction project, including $0.40 of wages and benefits for workers at the construction site and the remaining $0.20 for workers at businesses throughout the economy.

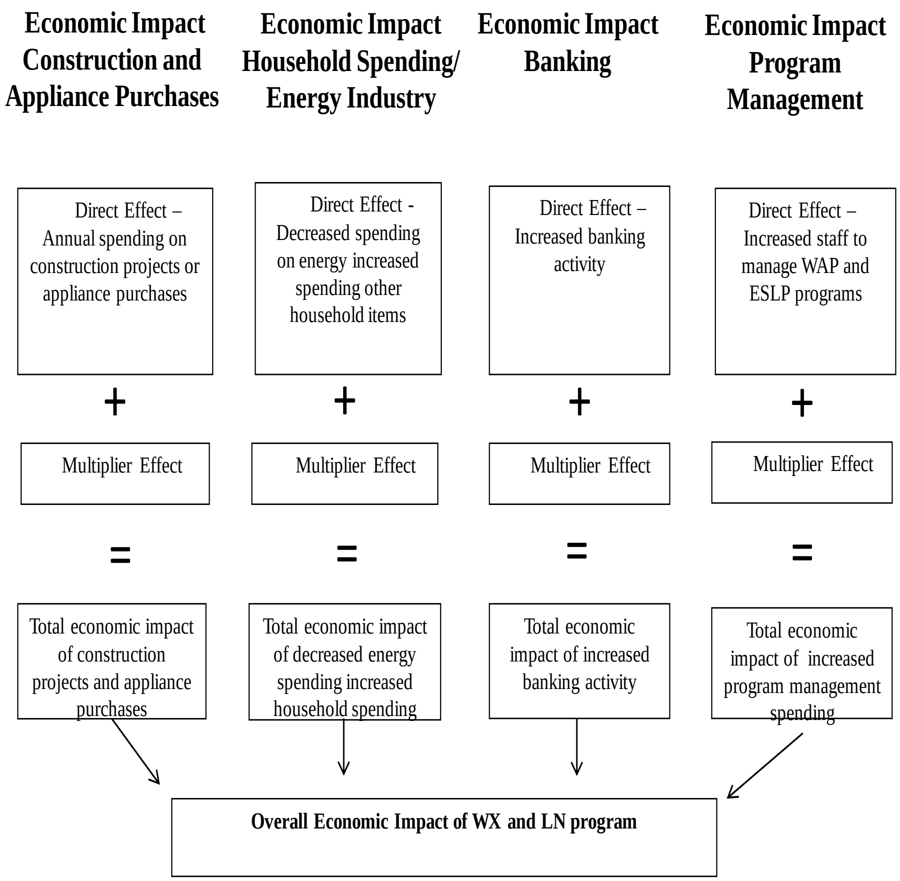
The value of these economic multipliers changes based on the industry and the economy. Industrial businesses such as manufacturers typically have higher multipliers since these businesses heavily utilize parts and supplies and also tend to pay higher wages. Further, all industries tend to have higher economic multipliers in larger economies. Any business is more likely to find local suppliers for key equipment or specialized services in a larger economy with a more diverse group of businesses present. As a result, economic multipliers will be larger in a state with a larger economy and population.

An economic model is required to estimate the appropriate multiplier for a given industry within a specific state or local economy. The current study utilizes the IMPLAN model to develop economic multipliers for construction and other relevant industries in Nebraska. The IMPLAN model software is the leading multiplier model in the country and has been utilized in thousands of economic multiplier studies. The authors have utilized in the IMPLAN software in dozens of individual studies. The IMPLAN software has capacity for use in estimating the economic impact of businesses and organizations in over 400 industries, in cities, counties, states or combinations of counties. These multipliers will show the total economic output, total value-added, total labor income and total employment associated with each dollar of spending on construction associated with the WX and LN programs.

Much of the economic impact of the WX and LN programs will result from the new economic activity in the construction industry as repairs and renovations take place. Some project spending, however, is more accurately characterized in the wholesale appliance industry, particularly in the LN for projects that primarily include purchasing and installing furnaces or heat pumps. In the case of the LN program there is also a direct economic impact on the banking sector, since these financial institutions evaluate and originate the loans for the program. Finally, both the WX and LN programs require management and support from the Nebraska Energy Office, or in the case of WX, from community action agencies located throughout the state. Program resources to support this management function also yield an economic impact.

Further, as noted, WX or LN investment installation projects can alter household spending patterns into the future. The investments typically reduce energy expenditure, freeing household income for spending on other household goods and services. Thus, there is a direct economic impact on a variety of industries associated with consumer spending including food, retail items, shelter, insurance or recreation. Each of these four components of the economic impact: construction/appliance, program management, banking and household spending, are illustrated in Figure A4.1.

Figure A4.1
Approach for calculating the 2011 Nebraska Economic Impact of WX and LN Investments



As seen in Figure A4.1, a total economic impact estimate will be generated for each of the four types of spending. The total economic impact for each component is the sum of the direct effect and the multiplier effect. The overall economic impact is the sum of the total economic impact from each of these components.

2. Construction Impact

The WX and LN programs have an immediate economic impact through the sponsoring of construction activity and appliance purchases. This construction activity occurs shortly after the program funds are dispersed. These energy savings investments directly fund employment with construction contractors or at businesses that wholesale appliances. Alternatively, in some parts of Nebraska, work crews employed by community action agencies complete construction projects. These direct economic impacts in construction and appliance sales lead to a multiplier effect in businesses throughout the economy. These multiplier effects occur as construction businesses purchase supplies and as construction workers spend their paychecks.

The first step in calculating the economic impact of construction activity is to determine the construction activity and appliance sales occurring in Nebraska. This is straightforward in the case of construction services as Nebraska WX and LN funds go to support projects occurring in Nebraska. The situation is more complicated, however, in the case of equipment purchases such as purchases of windows or doors or HVAC equipment. First, normally only the markup portion of equipment sales contributes to Nebraska's economy. Most equipment sold at wholesalers was manufactured somewhere else in the United States, or overseas. Only the markup portion of the wholesale price (i.e., wholesale margin) supports employment and economic activity in the state. In other words, only the markup portion of the sale price of equipment creates an economic impact on Nebraska. A second issue is that equipment such as windows and doors or HVAC equipment can be purchased from stores and wholesalers located in Nebraska but can also be purchased in other states. As a result, while most WX and LN spending will result in a direct economic impact on the Nebraska economy, some spending will not. In particular, spending to purchase equipment from wholesalers located in other states does not have a direct economic impact on the Nebraska economy. For each type of WX or LN project, it is necessary to determine how much of the spending on the project results in a direct economic impact on Nebraska.

The first step is to determine the share of project spending that goes to construction services versus the purchase of equipment such as appliances, windows and doors, and others. All spending on construction services, the actual work by laborers installing equipment and making repairs, will lead to a direct economic impact on Nebraska. As noted above, spending on appliances and equipment will often lead to a direct economic impact on Nebraska but sometimes will not. The second step in the analysis is to determine the share of appliance and other equipment purchases that occurs in Nebraska versus elsewhere.

Such an analysis was conducted for WX spending in Nebraska, since the research team had detailed information on how WX funds were spent (equipment versus labor), due to program information measured by the Nebraska Energy Office. The research team also conducted a survey of WX program construction contractors or teams to determine whether or not their supplies were purchased in Nebraska. Identified suppliers were called to determine if the appliances or equipment they sold were manufactured in the state of Nebraska. If so, this also would contribute to the economic impact. As noted earlier, only the "markup" portion of equipment sales are counted as the economic impact, as most wholesalers sell items that were manufactured somewhere else in the United States or overseas. Only the wholesale margin, or markup, contributes to the local or state economy. However, if an item is also manufactured in Nebraska, the entire sale price is counted.

We found that 69.5percent of all equipment was purchased in Nebraska and 2.2percent was also manufactured in Nebraska. Analysis was conducted for a group of eight project categories: 1) air conditioning, 2) windows and doors, 3) insulation, 4) HVAC, 5) furnace 6) water heating, 7) lighting and 8) miscellaneous. Results of the analysis are shown in Table A4.1. Note that results for each of these spending categories also were utilized for similar types of spending within the LN.

Table A4.1
Spending Breakdown and Source of Equipment By Type of Project

	Spending Pattern		Location of Equipment Suppliers and Manufacturers			
	Share of purchases		Supplied		Manufactured	
	Equipment	Construction	In Nebraska	Outside Nebraska	In Nebraska	Outside Nebraska
Air Conditioning	65.6%	34.4%	83.3%	16.7%	0.0%	100.0%
Windows/Doors	80.9%	19.1%	66.7%	33.3%	0.0%	100.0%
Insulation	59.3%	40.7%	76.9%	23.1%	7.7%	92.3%
HVAC	59.2%	40.8%	89.3%	10.7%	0.0%	100.0%
Furnace	59.2%	40.8%	89.3%	10.7%	0.0%	100.0%
Water Heater	62.3%	37.7%	89.3%	10.7%	0.0%	100.0%
Lighting	76.5%	23.5%	12.5%	87.5%	0.0%	100.0%
Miscellaneous	76.5%	23.5%	12.5%	87.5%	0.0%	100.0%

Source: Contractor Survey and IMPLN

Construction and equipment spending were the primary sources of economic impact on the Nebraska economy from the WX and LN programs. There were, however, also administration costs for the program and bank activity associated with establishing loans. Budget information provided for the WX program suggests administrative costs of approximately 10 percent of project spending, with those monies split between central administration at the Nebraska Energy Office and the Community Action Agencies. In the case of the LN program, the Nebraska Energy Office also has administrative responsibilities but banks establish and monitor loans at the local and regional level. We identified the potential increase in bank activity from the loan program by considering the present value of the return that banks would receive. Bank activity in support of each loan could not exceed this expected return. The present value to the bank would be approximately 20 percent of the principal of the loan assuming a 10-year loan and that banks would receive a payment at a 4 percent rate but could borrow money from bank depositors at 1 percent. Therefore each $100 of LN project spending (on equipment and construction services by contactors) would yield an additional $20 in economic activity in the banking sector. Overall, the WX program would create additional economic activity in the government sector (due to administration) and the LN would create additional economic activity in the government sector and the banking sector. This economic activity is also part of the direct economic impact of the two programs.

Table A4.2 shows the direct economic impact in Nebraska for each dollar spent on WX and LN programs by type of program. Note that values differ since WX has higher government administrative costs but LN has administrative costs as well as an impact on the banking sector. The impact of LN is $0.15 higher per dollar spent. Within project types, direct impacts are higher for project-types where construction services are a larger share of spending, and a larger share of equipment purchases take place in Nebraska (see Table A4.1).

Table A4.2
Direct Economic Impact per Dollar of Project Spending By Project Type

Project Type	Direct Economic Impact Per Dollar of Spending
WX	
Air Conditioning	$0.55
Windows/Doors	$0.39
Insulation	$0.64
HVAC	$0.61
Furnace	$0.61
Water Heater	$0.58
Lighting	$0.35
Miscellaneous	$0.35
LN	
Air Conditioning	$0.70
Windows/Doors	$0.54
Insulation	$0.79
HVAC	$0.76
Furnace	$0.76
Water Heater	$0.73
Lighting	$0.50
Miscellaneous	$0.50

Source: Bureau of Business Research calculations

Table A4.3 shows the total economic impact per dollar of project spending. The total impact is the sum of the direct economic impact in Table A4.2 and the multiplier effect. As noted earlier, economic multipliers are calculated using the IMPLAN model. A comparison of direct impacts from Table A4.2 and total economic impacts in Table A4.3 suggests that economic multipliers were typically greater than 1.5 but less than 2.0. Table A4.3 also shows the total economic impact of each $1 of spending on other measures of economic activity, specifically, Nebraska value-added, labor income and employment. The results show that economic impacts can vary substantially by type of investment.

Table A4.3
Total Economic Impact per Dollar of Project Spending By Project Type

Program and Type of Spending	Total Economic Impact Per Dollar of Spending			
	Output	Value-Added	Labor Income	Employment/$ Million
WX				
Air Conditioning	$0.89	$0.54	$0.38	9
Windows/Doors	$0.64	$0.41	$0.29	6
Insulation	$1.04	$0.60	$0.43	10
HVAC	$0.99	$0.59	$0.42	10
Furnace	$0.99	$0.59	$0.42	10
Water Heater	$0.95	$0.57	$0.40	9
Lighting	$0.57	$0.35	$0.26	6
Miscellaneous	$0.57	$0.35	$0.26	6
LN				
Air Conditioning	$1.17	$0.66	$0.43	10
Windows/Doors	$0.92	$0.53	$0.34	7
Insulation	$1.32	$0.72	$0.47	11
HVAC	$1.27	$0.71	$0.47	10
Furnace	$1.27	$0.71	$0.47	10
Water Heater	$1.23	$0.69	$0.45	10
Lighting	$0.85	$0.47	$0.31	7
Miscellaneous	$0.85	$0.47	$0.31	7

Source: Author's calculations and IMPLAN

3. Impact on Annual Spending

WX and LN projects, by making homes more energy efficient, also impact the spending patterns of participant households. In particular, savings on energy imply less spending on electricity and natural gas and more spending on the rest of the household budget. The utility savings effectively mean a larger disposable income to spend on everything else including food, retail, recreation, entertainment, furniture, health care and the like. This change in annual spending patterns also influences the local economy. This is because many types of household spending have larger economic multipliers than spending on energy such as natural gas or electricity. This is especially true of local areas' employment and worker incomes. The electricity and natural gas industries are very capital-intensive, meaning there are relatively few workers and minimal pay for each dollar spent on the industry.

However, it is also true that some types of household spending may have smaller economic multipliers than the electricity and natural gas industries. Spending on gasoline is a good example. Most of the cost of a gallon of gasoline goes towards extracting and refining the gasoline. This activity occurs in other states and nations. It is only the "markup" portion of gasoline sales that leads to an economic impact on the local economy. The cents-on-the-gallon markup goes to pay the costs of operating local service stations. The markup portion of gasoline sales typically accounts for less than 20 percent of what is spent on gasoline. Therefore, spending on gasoline has a relatively small impact on the economy, even relative to utilities. A similar argument actually can be made for most types of retail items. Most of the manufactured goods sold by retailers are produced out-of-state, and therefore, only the markup portion of the purchase impacts the local economy.

The net result is that it is ambiguous whether reduced energy spending and increased spending on other items due to the WX program will lead to a net positive or negative economic impact on the state economy. The impact is much more likely to be positive, however, in the case of the employment and labor income impact, since energy industries are very capital-intensive industries that employ relatively few workers per dollar of revenue. On the other hand, a negative net impact is much more likely due to the LN program. The reason is that there is also an annual cost to repaying the loan. This leads to a reduction in household spending that offsets to varying degrees the increase in household spending due to energy savings.

This section calculates the net annual economic impact from each dollar of reduced energy spending resulting from the WX and LN programs, by type of investment. The first step was to consider the increase in household spending for each dollar of energy savings. This was straightforward in the case of the WX program but needed to account for annual loan payments in the case of the LN program. Increases in household spending were then broken down into dozens of individual spending categories. Data on household spending patterns were taken from the *Consumer Expenditure Survey* of the U.S. Department of Commerce. Spending patterns for low-income households were utilized for the WX program while the average spending pattern or all households was utilized for the LN program. The net result was an estimate of the cents of increase in spending on each goods and services category for each dollars saved on energy spending. Economic multipliers were then applied to both the dollar of energy savings and the resulting spending by goods and services category to estimate the net economic impact of each dollar of energy savings. The results are shown in Table A4.4 for the WX and LN programs for both savings on electricity and natural gas. Results differ by type of fuel since the economic impact differs between spending on electricity and natural gas.

Table A4.4:
Total Economic Impact per Dollar of Reduced Energy Spending

Program and Energy Type	Impact per Dollar of Reduced Energy Spending			
	Output	Value-Added	Labor Income	Employment/$ Million
WX				
Electricity	-$0.33	-$0.32	$0.08	8
Natural Gas	-$0.21	$0.02	$0.21	10
LN				
Electricity	-$0.41	-$0.39	$0.03	7
Natural Gas	-$0.31	-$0.05	$0.17	9

Source: Author’s calculations and IMPLAN

The net impact on economic output is generally negative. This economic concept is less affected by the more capital-intensive nature of energy production. Labor income and employment are directly impacted, as is value added, which is the most comprehensive measure of economic activity taking place in the state. Value added is like the national economic concept of gross domestic product (GDP), which is used to measure the U.S. economy and changes in the U.S. economy. Labor income is the largest component of value added. As a result, the value added concept is an important one to consider. The net economic impact of energy savings in terms of value added is near zero for reduced spending on natural gas but is in the range of -$0.32 to -$0.39 in the case of electricity purchases. Electricity sales have a larger economic impact on Nebraska than natural gas sales, leading to the result.

Reduced energy spending on both electricity and natural gas has a positive impact on labor income and employment in Nebraska, in both the WX and LN programs. The net labor income impact is $0.03 to $0.21 per dollar of reduced energy spending. The net employment impact is 8 to 10 per million dollars of reduced spending. Another way to say this is that each $1,000,000 in energy savings yields an employment impact between 7 and 10 jobs.

Note that results in Table A4.4 do not imply that investments in WX or LN have a negative economic impact in terms of output and value added. The present value of these annual economic impacts would need to be added to the economic impact of construction spending, which was uniformly positive.

4. Implementation in the Model

Each WX and LN investment project has both a one-time construction impact and an annual economic impact resulting from reduced spending on energy. The economic model sums those two types of economic impacts across time by calculating the present value of the impacts. The present value is simply the value of a future stream of impacts today. Calculating the present value is straightforward in the case of the construction impacts. The construction and appliance investment would take place in the initial year so the present value of the impact would just be the same as the construction economic impact. Calculating present value would be more complicated in terms of the annual impact from reduced energy spending. There would be an annual stream of energy savings and therefore also an annual stream of net economic impacts. It would be necessary to calculate the present value of these annual economic impacts, utilizing the same approach used in other parts of this study; for example, when calculating the present value of annual energy savings. Once the present value of construction impacts and the present value of annual energy savings impacts are calculated, the two can be combined.

Combing the construction and energy savings impacts will naturally depend on the specific energy savings associated with each type of construction investment. For example, a dollar of construction investment for some types of projects yields much higher amounts of annual energy savings than other types of construction investments. The ratio between the construction investment and amount of energy savings is the key factor. If a particular construction project yielded no energy savings, then the construction economic impact would be the only type of economic impact resulting from the project. If another particular construction project yielded large energy savings per dollar investment in construction, then the energy savings impact would be a big part of the overall economic impact resulting from the project.

As the proceeding suggests, the ratio between the dollars of construction investment and the resulting dollar value of annual energy savings is the key to determining the total economic impact from WX and LN investments. That ratio was estimated for each category of potential project. The next step is to apply the appropriate impact parameters to construction spending and dollars of energy savings for each particular project. Results in Tables A4.3 and A4.4 show that these parameters vary substantially by type of investment, between the WX and LN programs, and between projects that save electricity versus natural gas.

The present value economic impact of a specific project can be estimated by taking the construction Investment in that project by category and the resulting energy savings, and applying the relevant economic multipliers. Projections can be made by placing the total estimated investment into the categories displayed in Table A4.3. Parameters from Tables A4.3 and A4.4 are then applied to yield the predicted present value of economic impact.

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