Residential Retrofit Study in Support of Boulder's Climate Action Plan:
The Potential Role of Residential Energy Conservation Ordinances and other Policy Options

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All comments were offered in the spirit of joining in a common effort to figure out practical ways to enhance the energy efficiency of existing residential buildings in the Boulder community.

We appreciate the practical wisdom shared and suggestions made by others, many of which have been integrated into the text. However, the opinions expressed herein are those of the Synertech Systems Corporation's staff and do not necessarily reflect the views of anyone else or the organizations they represent.

Larry Kinney
October 2008

Foreword

In just a few years, it will be too late to fix things--*unless the United States steps up now and takes the lead in a worldwide effort to replace our wasteful, inefficient energy practices with a strategy for clean energy, energy efficiency, and conservation that Friedman calls Code Green.*

From the Amazon.com September 2008 announcement of *Hot, Flat, and Crowded* by Thomas L. Friedman, 2008.

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Executive Summary

This document presents background information and data analysis for recommending a Residential Energy Conservation Ordinance (RECO) in the city of Boulder. A RECO would reduce energy use and green house gas (GHG) emissions from existing buildings in the residential sector by requiring that specific energy efficiency measures are completed or efficiency thresholds met when triggered by either the sale of any dwelling or the application for—or renewal of—rental licenses for rental dwelling units in the city.

Boulder has a number of circumstances that favor undertaking a RECO:

- Progressive citizenry and leadership who place a high value on environmental matters and who support a Climate Action Program aimed at substantially reducing GHG emissions over the long term.
- Excellent weather whose blue skies allow for substantial solar radiation and large diurnal temperature swings, both of which can be put to use to enhance the energy performance and comfort of buildings while maintaining modest carbon footprints.
- Energy-wasteful housing stock, over half of which is at least 40 years old (waste in conjunction with higher prices of electricity and natural gas yields more cost-effective retrofit work).
- A unique licensing policy through which rental units are required to be inspected for structural and safety integrity at the outset, with follow-up safety inspections required for license renewal every four years. (Rentals constitute well over 50% of the dwelling units in Boulder, with 17,752 of the 24,476 rental units (73%) being single-family detached or attached dwellings.)
- An active landlord organization, the Boulder Area Rental Housing Association, whose membership consists of owners of over 8,000 dwelling units. The Association has an institutional interest in energy efficiency and is developing energy education material for both landlords and tenants.
- The emergence in Boulder County of a unique method for securing low-interest loans used for retrofitting residential structures for energy efficiency and renewables where payment is via tax bills. The implementation of Proposition 1A will make this a reality.
- A professional weatherization program conducted by a unit of Boulder County government, Long's Peak Energy Conservation, whose income thresholds are high.
- Federal and state tax or cash incentives (through the Governor's Energy Office) for undertaking energy efficiency measures and installing renewables.
- A new gas demand-side management (DSM) program and more ambitious electric DSM program being implemented by Xcel Energy as of January, 2009. These programs both provide a wide range of direct incentives for residential energy-efficiency retrofits and write down the cost of energy-efficient lighting and ENERGY STAR appliances in a number of local retail outlets.

To be sure, enacting a RECO program will be challenging. Ignorance of how dwellings waste energy is widespread; building science is still in its infancy; presently known "best practices" are not widely understood, appreciated, or practiced; there are insufficient practitioners of the craft of retrofitting homes to enhance the energy performance of thousands of dwellings; the energy

consequences of work done are rarely measured. Finally, although there are currently four active RECO programs in the US—three city-based, one state-wide—that have been operated for 1 to 2.5 decades, none have been evaluated for actual energy savings.

Boulder should do better. Any RECO program should build in evaluation that tracks retrofit actions and savings obtained via an analysis of the change in consumption due to retrofits. The result should be feedback suitably packaged to be useful to owners, tenants, retrofitters, vendors, program administrators, and policy makers.

A substantial barrier revolves around "free ridership" in the utility DSM program where a RECO may require specific energy efficiency measures for which in turn, Xcel might refuse incentive payment because of the requirement itself. It may be possible to negotiate with Xcel and the Public Utility Commission to solve this problem. However, it may also be practical to design a retrofit program so that Boulder's citizens can take advantage of the DSM rebates, thereby providing advantages to all parties. This report envisions a hybrid design that *prescribes* specific retrofit measures that are not covered by Xcel's rebates and specifies *performance* goals that will stimulate energy-saving actions some of which will likely be eligible for rebates. Dividing consumption data into baseload (separating gas and electricity) and space conditioning (heating and cooling) will enable to a substantial degree separating energy use due to residence choices and that due to inefficiencies in the structure and space-conditioning systems. This can be accomplished quickly via web-based software that could be made available to all. Further, it should facilitate the setting of performance goals quite simply (and adjusting them when evaluation results indicate the usefulness of mid-course corrections).

All homes could be required to meet RECO requirements triggered upon being sold (where the cost is negotiated between buyer and seller, and possibly be added to the buyer's mortgage) and rental units be required to meet requirements every four years. When fully operational, the program would involve roughly 7,000 dwelling units per year. There is a good deal of work necessary to fully prepare for a program of this magnitude. Such work should include training and technical assistance to prepare retrofitters (some of whom will be building owners who do their own work) and inspectors to review the work. In addition, results from the work of the Boulder Energy Project in cataloging housing types and energy usage with a view to recommending optimal retrofit packages needs to be integrated into program plans. Further, results from (1) an expanded residential energy audit program currently being conducted by the Center for Resource Conservation (2) Xcel's new energy audit program, and (3) information flowing from the Smart Grid project will be available to enable the fine tuning of RECO requirements and technical assistance materials. Accordingly, this report recommends that the program be initiated on a voluntary basis for the first two years, while training is made available, performance is monitored, and financing options are developed and publicized--but compliance is by choice. If initiated at the beginning of 2009, this preliminary RECO program period will overlap with the two year period of Xcel's current gas and electric DSM program.

The challenge is to design a RECO that is fair, cost-effective, saves city residents money overall, and makes a significant reduction in the residential sector's GHG emissions. Boulder should seek simplicity in achieving these goals and monitor performance to enable both tracking success and making mid-course corrections. The city is sure to blaze the way for many others.

Section 1
Background

The city council and the majority of citizens of Boulder have determined to undertake a number of steps aimed at meeting and if possible exceeding the Kyoto protocols. This will require reducing greenhouse gases (GHG) in all sectors, primarily by using less fossil-fuel based energy. The Office of Environmental Affairs has been tasked to provide leadership in the resulting Climate Action Plan and has launched a number of programs and educational efforts.

Existing homes afford good opportunities for energy savings; most in Boulder have plenty of room for improvement. In all sectors, the greater the waste, the more likely conservation measures will be cost effective (trading in an SUV for a Prius saves more than trading in a Prism.) Undertaking appropriate energy conserving measures in a systematic fashion not only lowers energy consumption, but also improves the functioning of homes, making them more comfortable, safer, and healthier, and extending their useful lifetimes. They thus become more *valuable* (in some large sense of the term) to their occupants, their neighbors, and the environment.

Although improving the energy performance of existing homes is a high calling, it is by no means simple technically or from the standpoint of policy. The craft of analyzing them, making them more efficient while integrating renewables as practical, and evaluating the results is far from perfected—but it is improving all the time. Building science is no longer in swaddling clothes and is crawling nicely, but it's not yet able to run. Nonetheless, the green movement is growing exponentially (if a bit awkwardly), there's a growing interest in improving the performance of all buildings, and technical innovation is visible in all building sectors. Many in Boulder have a strong sense for the reality of major global energy crises and are eager to contribute in practical ways to helping to resolve it.

These are exciting times.

Natural gas, electricity, and water

Natural gas is a fossil fuel and electricity is mostly (not entirely) produced by fossil fuels for Boulder residents. There is some hydroelectric power in the mix as well as a touch of solar and wind, but burning coal provides well over 80% of the electricity we use in Boulder. Of key importance, undertaking measures which save gas and electricity ultimately result in putting fewer green house gases into the atmosphere. They also result in saving water at the power station, about 0.5 gallons per kilowatt hour of electricity generated in the Boulder area. (Torcellini *et al*, 2003)

Over 90% of the electricity used in residences in Boulder is generated by heat engines whose Carnot efficiency is on the order of 38%; there are other losses associated with transmission, mainly transformer and line losses. Although coal is still quite inexpensive, transmission losses plus the low system efficiency of generation translates into costs that on a common unit basis are roughly three times that of gas. Additionally, the price of coal on the spot market has more than doubled in the last few years and Xcel will lose all its long-term coal contracts (985) by 2012.

Consequently, electricity from coal plants is slated for a major increase in price within several years. The burning of coal to produce a given amount of electricity also puts more green house gases (GHG) into the atmosphere than does burning an energy-equivalent amount of natural gas; it's a factor of five greater. In sum, ***saving electricity (as cost-effectively as practical) is especially desirable because electricity costs three times as much as natural gas and each unit of reduction saves five times as much green house gas emissions.***

How is Energy used in Boulder Homes?

Natural gas is widely used in Boulder for space conditioning, heating water, cooking, and drying clothes. Space conditioning and clothes drying also use electricity for motors that move air and toss clothes in a heated chamber, so saving gas often saves electricity, also. Energy Star™ washing machines save electricity as well as water at the source (the power plant) and at the site (the home). Low-flow devices, especially shower heads, save water and the energy needed to heat it; often they enable turning down thermostats on water heaters which both raises their system efficiency and extends their useful lifetimes. Hanging clothes on a line saves energy (the equivalent of about six person years of labor per year in an average home), extends the lifetime of clothes, provides a bit of exercise for the clothes hanger, raises the humidity in a home during the winter, and thereby improves the health of the family and the planet. Synergies abound.

In general, work on improving the "conditioned envelope" of a home improves efficiency year around. A thermos bottle has zero air leakage and excellent insulation. Accordingly, it keeps ice tea cold or coffee hot. By analogy, air sealing and attic insulation improve comfort year around while saving cooling energy in the summer and heating energy in the winter.

Air leakage in homes is much more complicated to diagnose and much more complicated to treat effectively than is generally understood. (Kinney et al, 2007) Yet proper air sealing can be the difference between an effective retrofit and one that achieves but little savings. Preparing an attic for insulation requires careful attention, and is critical in achieving good energy savings. This is especially true when heating and AC ducts, which tend to be leaky, run through unconditioned attic space. Air sealing homes without sealing and insulating ducts can cause back drafting of appliances, unwanted inefficiencies, indoor air quality issues (including radon problems), and discomfort. Doing the insulation job correctly by including treatment of the ducts can improve comfort, achieve excellent indoor air quality, and lower energy consumption and costs. As critical as is energy efficiency, health and safety need to take precedence. Good professional work can achieve all of these goals, but this entails ensuring that those who work on homes are well trained in the art of building retrofit.

Of course, well-sealed homes need to be properly ventilated, preferable my means of a heat recovery ventilator that pre-heats fresh air with exhaust air. Controls can be automated to adjust ventilation rates in response to the presence of water vapor, CO_2, and unpleasant odors. Alarms responsive to CO and radon are as important as smoke detectors.

Improvements in energy-efficient window technology are quite impressive and a number of innovative technologies are available. Several Boulder-area companies are busy developing techniques that have the potential for raising the net energy efficiency of conventional windows five fold for a cost that will have good paybacks in both energy and comfort. When these and other technologies are ready for the retrofit market, guidelines associated with local, state, and federal policies (like Boulder's Greenpoints program, energy codes, or Residential Energy Conservation Ordinances) need to have the flexibility to incorporate them. Meanwhile, it is possible to improve the energy performance of many windows with appropriate use of extra glazing, films, storm windows, and shading that allows sunlight to penetrate in the winter but not in the summer.

Note that when energy efficiency measures such as the above are taken, less energy is needed to provide comfort. This lowers the cost of meeting needs with either renewables or heating, ventilating and air conditioning (HVAC) systems. By the same token, the efficiencies and performance of new HVAC systems are improving and the systems can to be matched to the reduced energy needs of efficient homes. Heat recovery ventilators capture the energy associated with stale exhaust air while providing fresh outdoor air at close to room temperatures. Condensing furnaces and boilers have system efficiencies well in the 90% area for heating and can be better matched to heating loads than were earlier models. Advances in evaporative cooling technologies and performance have the potential to make this the technology of choice for cooling most homes and apartments in Boulder. Evaporative coolers can save both electric energy and demand by a factor of four or more versus conventional compressor-based air conditioning systems.

Boulder has a climate that is particularly conducive to achieving close-to-zero carbon footprints. We have clear skies that feature plenty of sunshine. Clear skies also translate to large diurnal temperature swings; typical day/night temperature swings are 30F summer and winter. A carefully designed (or cleverly retrofitted) home can collect solar energy passively during sunny winter days, storing it in a well-insulated and air sealed conditioned envelope. If insulating shutters or especially good windows are employed, the storage of warmth of the sun will last through a cold winter night. In the summer, if well designed and controlled shading devices are used to keep direct beam sunlight out, the same well insulated envelope will not overheat before outside air temperatures drop in the early evening. Then natural ventilation, perhaps aided by an efficient whole house fan, can cool the home for a comfortable night's rest.

Given these observations, a home can be usefully viewed as a system in which the building's elements, the weather conditions supplied by Mother Nature, and the residents can be understood as subsystems that interact with one another. If well done, comfortable environments with modest energy bills and small carbon footprints result, thereby pleasing Mother Nature.

Next we examine the circumstances for forging effective policies and actions to enhance both homes and the environment in Boulder.

Section 2
Environmental, Energy, Housing, and Boulder Programs

Distribution of Greenhouse Gases
The residential sector is responsible for 16% of Boulder's greenhouse gases (GHG) (Figure 2-1). This accounts for about 300,000 metric tons of CO2 per year (overall, the city produced 2 million metric tons of CO2 in 2007). Figure 2-2 shows the GHG emissions by energy type.

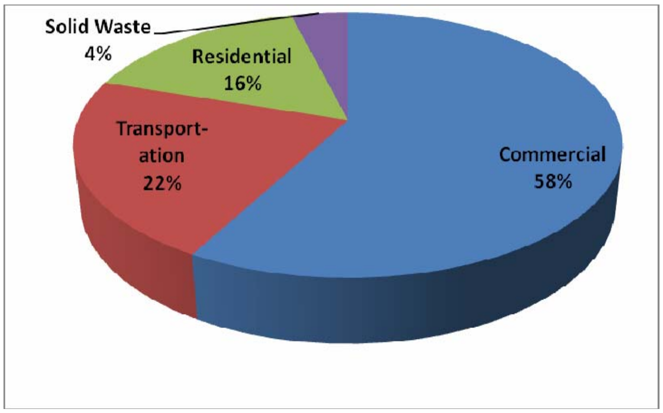


Figure 2-1. Boulder CHG by Sector in 2006
(Source: Boulder Climate and Energy Climate Programs Progress Report, 2007)

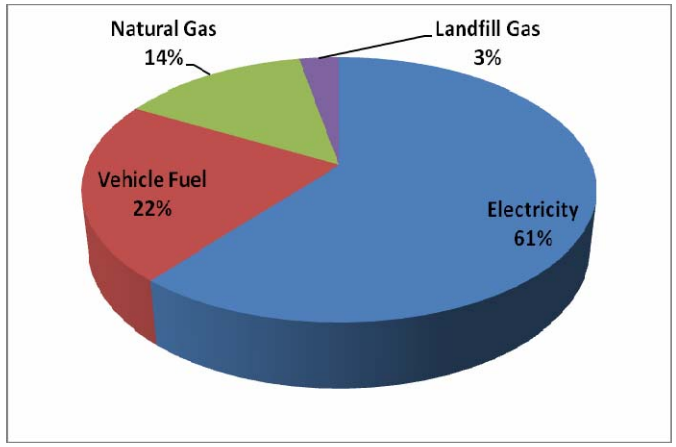
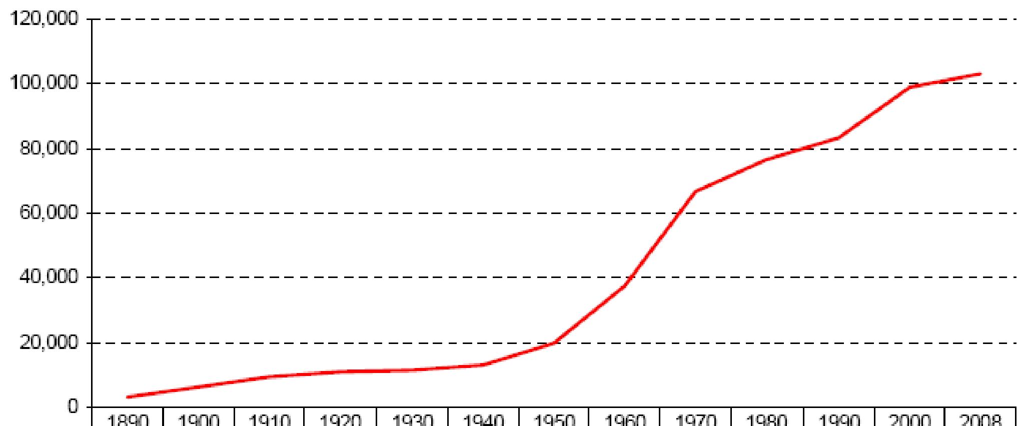


Figure 2-2. Boulder CHG by Energy Source in 2006
(Source: Boulder Climate and Energy Climate Programs Progress Report, 2007)

These data clearly show that electric generation is much more productive of GHG emissions than the other energy sources at play. This reinforces the importance of cutting back on electric energy waste and switching to renewable sources whose GHG emissions are much lower.

Population
Figure 2-3 shows population trends in Boulder over the past 118 years.



	1890	1900	1910	1920	1930	1940	1950	1960	1970	1980	1990	2000	2008
Boulder Population	3,339	6,150	9,539	11,006	11,223	12,958	19,999	37,718	66,870	76,685	83,312	99,093	103,114

Figure 2-3. Population trends 1890-2008. (Source: US Census Data and city of Boulder Planning Department)

Of particular significance is the spurt in population growth between 1950 and 1970 when population grew by a factor of 3.3. A considerable portion of the presently-existing housing stock in the city was built during that era before energy-efficient construction tactics were primary considerations in building.

Housing

The portion of rental dwelling units represents about 30 percent of the total in most of Colorado, but in Boulder, rental units make up more than half of the total. The principal reason is the presence of the University of Colorado. Table 2-1 shows the breakdown in dwelling types by owner-occupied and rental.

Table 2-1. Primary Dwelling Types in Boulder by Owner-Occupied and Rental as of May 2008
(Source: City of Boulder GIS May 5, 2008)

Dwelling Type	Total Dwelling Units (DU)	Portion of DU Type (%)	Portion of total DU (%)
Multifamily* rental	6,531	98.1%	15.0%
Multifamily owner occupied	124	1.9%	0.5%
Mobile home rental	184	13.1%	0.4%
Mobile home owner occupied	1,220	86.9%	2.8%
Single family attached rental	7,890	71.6%	18.1%
Single family attached owner occupied	3,126	28.4%	7.2%
Single family detached rental	9,862	40.8%	22.7%
Single family detached owner occupied	14,309	59.2%	32.9%
Unknown	229	0.5%	0.5%
Total Dwelling Units	43,475		
Total Rental Dwelling Units	24,467	56.6%	
Total Owner Occupied Dwelling Units	18,779	43.4%	

* More than one dwelling unit per building

Note that single-family detached rentals constitute 40.3% of the total rentals and that single-family attached (e.g., town houses) another 32.2%. Most of these units have their own furnaces or boilers and meters for gas and electricity. Generally, tenants pay for both gas and electricity directly to the local power company, Xcel Energy. Multifamily rentals, which constitute 26.7% of the rental units in Boulder, are quite diverse in the manners of metering and allocating electric and gas usage. Here are the main cases:

- Landlord pays electricity and gas either adding a separate cost to the monthly rent bill or building the cost into the rent.

- Renter has own furnace or boiler and DWH heater and pays both gas and electricity directly to Xcel Energy. The landlord pays for common-area heating and electricity metered at a commercial rate.

- Renter has own furnace or boiler and DHW heater. The renter pays for electricity directly to Xcel Energy. The landlord pays for all gas for tenants and common spaces as well as electricity for common spaces. The landlord monitors run time on each tenant's furnace or boiler plus the run time of each tenant's water heater, computes the portion of the gas consumed by each tenant, and charges the tenant for gas use as a part of the tenant's monthly bill.

- Renter pays electricity, landlord has large gas-fired boiler for DHW and separate large boiler(s) that supply hot water for baseboard radiators in each apartment. These are controlled by tenant's thermostats. The landlord monitors elapsed time of calls for heat by each tenant, charges tenants for heating energy used plus an estimate of DHW use.

In some multifamily buildings, individual unit usage is not measured and the cost is apportioned equally or by another scheme such as square footage rented or number of bedrooms in the apartment or simply a fixed fee. Such arrangements provide little incentive to tenants to adopt energy efficient practices.

Housing Sales and Leasing

According to County Assessor data, 2145 dwelling units were sold in the city in 2007. Table 2-2 shows data on sales of residential structures from 2002-2007.

Table 2-2. Sales of Residential Buildings in Boulder, 2002-2007

Year	**2007**	**2006**	**2005**	**2004**	**2003**	**2002**
Single family residences	964	869	777	688	572	465
Duplexes and triplexes	33	34	45	42	24	11
Dwelling units in duplexes & triplexes	*72*	*71*	*97*	*94*	*54*	*24*
Apartments building of > 3 units	16	14	14	12	4	8
Dwelling units in apt buildings	*248*	*345*	*285*	*247*	*19*	*117*
Condominiums	698	633	653	495	402	322
Townhouses	163	155	170	158	114	69
TOTAL Dwelling Units	**2145**	**2073**	**1982**	**1682**	**1161**	**997**
TOTAL Buildings	**1874**	**1705**	**1659**	**1395**	**1116**	**875**

Note that in the last three years, sales have trended upwards only slightly, about 4% per year. In 2007, only 49 multifamily buildings were sold, representing 15% of the total dwelling units sold in that year.

Rental licenses must be renewed every four years and there are about 24,467 rental units in Boulder. If the licenses are evenly renewed over time about 6100 units are licensed each year. So a RECO triggered by rental licenses has the opportunity to address almost three times the number of housing units that a sales-triggered RECO would cover.

Energy-Relevant Circumstances of Boulder's Housing: The Boulder Energy Project

Public policy is often made without fully adequate information about the subject of the policy. Some descriptive information and generalizations about energy consumption are available, as shown above. However, housing stock is quite varied in its construction and energy behavior, making it difficult to know what specific tactics are likely to be effective on particular homes or classes of similar dwellings. More success in lowering the carbon footprint of housing in Boulder will occur if more is known about the real residential energy picture.

The Boulder Energy Project is a nonprofit study to support the goals of Boulder's Climate Action Plan by cataloging housing types and energy usage. It is being conducted as a community service by Jim Logan Architects, in collaboration with the City of Boulder, the Center for Resource Conservation, the National Renewable Energy Laboratory, and the Boulder Green Building Guild. The objectives of the study are to evaluate the carbon emissions of Boulder's existing housing and determine what combination of deep energy retrofit and renewable energy supply would be required to bring these emissions to net-zero by 2030—and how much this would cost.

Database

The Boulder Energy Project is building a database to house energy-related building characteristics and Xcel Energy records for a representative sample of homes throughout the city. In addition to energy bills, the research team is collecting the following information:

1. Demographic Information: location, type (single-family detached, single-family attached, multifamily, and mobile home), occupancy (rented or owner-occupied), number of bedrooms, bathrooms, market value, and year built;
2. House Design: above-grade floor area, number of floors above grade, garage area and relationship to house, foundation type, basement area, and roof solar potential;
3. Building Envelope: wall insulation, ceiling insulation, blower door test results (if available), primary window type, direction, and area;
4. Mechanical Systems: space heating system type and condition, water heating system type, cooling type, and ventilation; and
5. Lights and Appliances: lighting efficiency, refrigerators, clothes washers, hot tubs/pools.

Project data sources include participating homeowners and renters who agree to release their Xcel energy use data. These data are supplemented through the Assessor's records and visual inspection; recipients of energy audits through the Center for Resource Conservation; participants in the Long's Peak Energy Conservation weatherization programs; residents of Boulder Housing Partners properties; and Home Energy Makeover Contest participants.

Participants can elect to be case studies, in which their energy use will be followed before and after energy retrofits and added renewable energy supply. Information from case studies will inform cost analyses.

Building Archetypes

The initial phase of the Project is a rough assessment of the various types of existing homes in each of the nine sub-communities of the city. This rough profile will act as a hypothesis to be tested by the actual energy use and building data coming into the Project database. The archetypes, once refined through comparison with the data in the database, will be the basis for the "solutions" modeling schemes described below.

Net-zero Solutions: Each house archetype will be entered in several energy modeling programs developed by Jim Logan Architects and by our collaborators. The team will use the programs to generate several net-zero solutions for each house type, using a combination of energy-efficiency and renewable energy supply. Recent cost data from case studies in the database will help us identify the most cost-effective strategies for each type.

Scope and Timeframe: This study is limited to the city of Boulder. Present plans are to present results at several points over the next two years, as data comes in and solutions are developed. The aim is to share the database with the city of Boulder and other interested jurisdictions, where it will be a resource and repository for the wealth of knowledge that is generated by citizens' green building efforts. Ideally, the data base will be expanded to reflect details of retrofit work and consequent energy and GHG savings.

Relevance to Boulder's Potential Residential Energy Conservation Ordinance (RECO): The database will provide a sample of the city's actual energy use and carbon emissions, and enable continual re-evaluation of progress both towards the city's Kyoto goal and a future goal of net-zero GHG by 2030. The retrofit cost data will be critical in tracking the cost-effectiveness of various strategies, and will provide a basis for developing both public and private funding mechanisms to address energy efficiency and renewable supply for low- and middle-income citizens.

This is a crucial point in Boulder's residential development: many of the older, inefficient homes in the city are being remodeled, and many multifamily complexes built in the 60's and 70's are in need of substantial exterior and interior retrofits. It is more cost-effective to undertake energy-efficient building envelope retrofit when it is coordinated with maintenance work. Implementing an energy conservation ordinance will help capture many of these opportunities practical in the coming years. The ability to contact HOA's and homeowners by building type and age will be made possible by the archetype mapping. Project estimates of cost effectiveness of various combinations of efficiency and renewable measures will help the city target those efforts by matching investments with likely energy savings.

Conservation Activities Germane to the Housing Sector

The city of Boulder has adopted aggressive energy performance standards for new residential buildings through its Green Points program. Green Points helps ensure that only comfortable, safe, low-energy-cost, and low carbon footprint new housing units are built for city residents. Of significance, the program applies to remodels and additions of more than 500 square feet. However, in any given year, less than 1% of the residences are new—more than 99% of residential buildings already exist.

What can be done to improve the energy use and reduce GHGs from existing residences?

The city supports a wide range of programs that offer opportunities to home-owners, renters, landlords including multifamily owners and managers, and mobile home owners to improve the energy efficiency and comfort of residences. The current suite of residential sector energy efficiency programs is estimated to contribute about 4% to the GHG reduction goal, based on people's choice to take advantage of the opportunities. (Bruno *et al*, 2008)

The following is a summary of current activities that relate directly to the design of a RECO.

Boulder's Residential Energy Audit Program (REAP) is administered by the Center for Resource Conservation. REAP provides co-funding and follow ups on audits of home energy use. The CRC list of auditors and home energy contractors is being expanded with the formation of a trade ally network which will help the program to grow, as well as help homeowner's locate experienced workers to follow up on audit recommendations. Two hundred and twenty four homes were audited in 2007.

Boulder also supplements funding for innovations in the local weatherization services with Long Peaks Energy Conservation (LPEC), a division of Boulder County which has been retrofitting the dwellings of lower-income home owners and renters in Boulder, Gilpin, and Larimer counties for over three decades. The city's Office of Environmental Affairs co-funds the Energy Efficiency Program; twenty city homes were energy retrofitted in 2007. Boulder also provides loan programs for home rehab for health, safety, and energy conservation through LPEC, including forgivable loans for 20 qualifying mobile home owners and low interest loans qualifying homeowners in 2007.

Of great importance, the annual gross income guidelines for qualifying for free weatherization services in the City of Boulder has been recently increased so that many more citizens can be served by the program (Table 2-3).

Table 2-3. Income Limits for Qualifying for Weatherization Services in Boulder 2008

Household Size	1	2	3	4	5	6
Income Limits FY 2008 ($)	49,100	56,300	63,200	70,200	75,900	81,500

This will allow many more renters and homeowners to qualify for weatherization services and may well swamp the program's ability to deliver to all who may be expected to apply under these new guidelines. In the current fiscal year, the agency is expects to provide some level of weatherization services to 1500 dwelling units in its three county service area.

The city has supported efforts to develop a network of building professionals through the Home Performance with Energy Star program. In 2007, the second round of training was attended by 34 contractors from the Front Range, 12 from Boulder. Continued support of the program will lead to increased availability of quality energy retrofit services for Boulder residents.

Xcel is planning to undertake an ambitious multi-tiered energy audit program which will require assembling and training a work force to conduct it. If Boulder undertakes a RECO program to retrofit a number of dwelling units, the need for an enhanced work force of talented and dedicated energy conservation professionals will multiply. Assuring good training, along with certification and quality control will be a matter of great importance to the CAP-related programs the city undertakes.

Section 3
RECOs, Audits, and DSM

Residential Energy Conservation Ordinances

With a view to studying options that may be usefully embraced—or assiduously avoided—by Boulder policy makers and program implementers, it is useful to review efforts by other cities and states that have passed RECOs. Toward this end, the text of the RECO legislation passed by the city council of Burlington, Vermont is reproduced in Appendix A.

The Southwest Energy Efficiency Project (SWEEP, a Boulder-based organization that promotes energy efficiency policies in six southwestern states) recently documented most of the RECO programs in the country. Appendix B of this report is a copy of "Residential and Commercial Energy Conservation Ordinances," dated April 2008.

Accordingly, in this section, we summarize salient findings from SWEEP's work that may relate to forming a RECO for Boulder, adding several findings from follow up work conducted for the present report. The following remarks make the assumption that the reader has either read the SWEEP report or are familiar with RECOs in other jurisdictions.

Point of Sale Compliance. Each of the four RECOs still in operation requires compliance associated with the time of sale. Two (Berkeley and San Francisco) apply to almost all dwelling units, whether rental or not; the other two (Wisconsin and Burlington) apply only to rental properties.

Advantages of enforcement at ownership change include:

- No current obligation to incur expenses placed on existing owners.
- Retrofit expenses for compliance can be negotiated as part of the sale.
- Retrofit expenses for compliance can be included in the buyer's mortgage, and amortized over the period of the loan.

This has increased demand for energy-efficiency mortgages. On the other hand, in the case of rental properties, enforcement only at time of sale does little to encourage tenant participation in energy efficiency.

Berkeley is of special interest both because of a long tradition of progressive leadership and the presence of a major university (and thereby substantial rental housing), properties shared by the city of Boulder.

Now that Berkeley's RECO is about 25 years old, most appear to be pleased with the program:

> "...Berkeley's **Residential Energy Conservation Ordinance** (RECO), which requires that existing houses be given an energy upgrade when they are sold. The upgrades include insulation, fireplace dampers, water heater blankets and toilet-flow regulators. When the ordinance was enacted in the 1980s, it was unpopular with some real estate agents and homeowners who thought it would inhibit sales. Berkeley's housing market has remained solid, however. And in today's market, houses with RECO upgrades are

> more attractive to buyers because of their green features. The ordinance has saved energy while adding value to housing. However, houses turn over slowly. In 25 years, only about 23 percent of Berkeley's houses have had RECO upgrades." (Wenz 2008)

Opportunity for Boulder. Boulder has an active rental licensing program through which rental properties not occupied by members of the landlord's family must be inspected for structural integrity and safety when initially rented, and for safety and related matters each four years thereafter. Net administrative costs to the city for conducting this program are quite modest, and there appears to be general agreement that Boulder's rental housing stock is the better for it. Elements of the current inspection include checking on the safety of hot water heaters and furnaces, so according to Sarah Conover in Boulder's planning office who handles the rental licensing program, adding inspections of energy-efficiency related retrofits would not be unduly burdensome. For rental properties, Boulder may be able to implement RECO energy retrofits much more frequently than just when the properties are sold. Indeed, Boulder may consider using the rental licensing four year inspection to trigger undertaking RECO-related energy efficiency measures and undertaking a measure of inspection for compliance and quality control.

Evaluation. Although all four extant RECO programs are 10 to 25 years old, there is a notable lack of evaluation of energy saved by any of them. Each program director cited cost as the principal reason for lack of energy evaluation—although each claimed to have an interest in knowing what saving are indeed being achieved. Boulder should do better, both in the interests of tracking savings as an overall part of the CAP and to gather information useful in managing a RECO program and in making adjustments in policies and procedures as more is learned from current operations.

Free Ridership Issues. On January 1, 2009, Xcel Energy is scheduled to implement a demand side management (DSM) program aimed at saving natural gas in the residential sector. The plan will integrate the new natural gas DSM program with enhancements to the residential electric DSM program (Xcel, August 2008). The plan covers a number of retrofit measures that would also be covered by a RECO addressed to Boulder's housing stock. Table 3-1 shows retrofit measures addressed to residential customers proposed by Xcel under its new DSM programs.

Table 3-1. Proposed Measures in Residential Sector for Xcel's 2009 and 2010 DSM Programs

Program Name	**Fuel**	**Relevant Details**
Energy Efficient Showerheads	Gas	Free, gas only
ENERGY STAR New Homes	El/Gas	$200 rebate plus $10 per HERS rating point below threshold
ENERGY STAR Retailer Incentive	El	Writes down CFL costs to $1 + appliance rebates at retail outlet
Evaporative Cooling Rebates	El	$200 to $500 depending on evap cooler rating and capacity
Heating System Rebates	Gas	$80 rebate for AFUE > 92; $120 for AFUE of > 94
Home Lighting & Recycling	El	Mail order sales of specialized energy efficiency lighting fixtures
Home Performance with ENERGY STAR	El/Gas	Many rebates from $10 for thermostats to $250 for wall insulation
Insulation Rebates	Gas	20% of cost to $300 maximum
Refrigerator Recycling	El	Removes & de-manufactures second functional frig, $35 incentive

Water Heater Rebate	Gas	$40 to $80 for EF of .62 to .67; $100 for tankless with EF of .82
Saver's Switch	El	Central A/C users; $40 discount from Oct energy bill

The Xcel DSM plan must meet cost-effectiveness criteria established by the Public Utility Commission (PUC). In fact the utility will be incentivized (receive greater profits by way of direct charges to customers on gas and electric bills) to achieve the greatest savings possible per unit of program cost. Of course, this is a matter which will be carefully evaluated, with results made public.

One of the concerns of both the utility and the PUC that regulates it is to keep “free ridership” at a minimum. A “free rider” is a customer who would undertake a given conservation measure whether or not the utility provides an incentive. Under these circumstances, the incentive payment does not buy any extra energy savings beyond those that would take place in its absence.

A Boulder RECO that would specify *prescriptive* measures (air seal, insulate attic, install an evaporative cooler) would *require* these measures. From the point of view of Xcel’s DSM program, customers undertaking these measures would be free riders and thereby be ineligible for Xcel's incentive payments.

This would be unhappy for all parties. Boulder residential rate payers would be paying the rate-based charges for those outside of the city to enjoy the fruits of Xcel’s gas and electric DSM programs, while being unable to benefit from them because of a Boulder RECO requirements. Further, Xcel would likely be disenchanted because Boulder’s generally progressive customers tend to be more likely to retrofit their homes for energy efficiency than are most other customers on Xcel’s grid, thereby increasing Xcel's profit from DSM measures. Since the company is regulated to make more money by achieving cost effective DSM work than it makes selling electricity and gas, Xcel would almost certainly prefer to avoid the free ridership dilemma a RECO that prescribed measures covered by their DSM programs might involve.

The RECO program in Burlington, VT faced this issue with regard to the gas utility that serves the area, Vermont Gas. Their DSM program is quite aggressive. Vermont Gas provides incentives of one third of the cost of energy efficiency measures that meet cost effectiveness criteria and also supplies low-interest loans for remaining costs. For a period of three years, the interest rate is 0%. (Vermont Gas 2008) For the first two years of its operation in the late 1990’s the RECO program in Burlington, which is conducted by the Burlington Electric Department, a municipal utility that serves 16,000 residential customers, did not take advantage of the Vermont Gas DSM program. However, it became clear to all parties that it would be useful to disregard the free ridership issue, a circumstance that has continued through the present. The Burlington RECO applies to about 8,000 dwelling units where tenants pay for heat and is triggered by the sale of buildings. Annual sales over the last decade have ranged from 50 to 150 dwelling units and currently average about 70.

For Boulder, the optimal circumstance would be for Xcel, with the approval of the Colorado Public Utility Commission, to simply ignore the free ridership issue. This is certainly worth pursuing.

However, should this not prove feasible, it may resolve the dilemma for Boulder to enact a RECO that omits prescriptive measures but specifies the meeting of *performance* goals in their stead. In addition to resolving the free ridership problem, there may be other advantages to focusing on performance:

- Peace and freedom (the government does not tell me what to do, just that my property must meet specified levels of efficiency within a certain time period)
- Results oriented (owners can match measures to housing circumstances, which can include the net of occupant actions and technical retrofits.)
- Evaluation is built-in (analyzing bills in useful ways—including results from Smart Grid, which needs to be expanded to include gas—allows for plotting an intelligent retrofit strategy, assessing its success, and allowing all parties—owners, retrofitters, utility DSM evaluators, and CAP staff to benefit from quantified results.)
- Education intensive (will redouble the effectiveness of energy education efforts by CAP staff and others since there will be increased emphasis on how-to-do-it-right retrofits aimed at achieving as much energy savings as possible per dollar spent.)

In order for a performance program to be successful, it will be important to know how much energy is presently being used (both electricity and gas), as a function of housing types prevalent in the city. This will enable practical and fair targets to be set, as well as supply grist for formative evaluation that will be useful to policy makers and program implementers in making mid-course corrections and assessing the achievements of the Climate Action Plan.

There is an unanswered question about the legality of the city requiring the release of electricity and gas billing data. This information appears to be protected by state privacy laws (although we have not yet found the exact language in the Colorado Statutes). In order to work around these privacy issues, a RECO could be structured to present a choice--either accept prescriptive measures, or release utility bills and be allowed to use performance based measures. Allowing those who receive Xcel bills to process them on their own via simple software available on a local web site may alleviate the problem, while enabling Xcel's customers to have a tool that will allow them to become more enlightened users of the utility's energy products.

Interestingly, there is precedent in both Wisconsin and Burlington RECO programs. Wisconsin's program is set up to allow performance measures by lowering the canonical weather-and-size adjusted index of energy used for space conditioning, Btu/square foot/heating degree day derived from billing data. More informally, in Burlington, when energy bills reflect low energy per square foot of heated area, owners are simply assumed to have met the prescriptive requirements of the RECO or their engineering equivalent.

Models of Residential Energy Reduction

There are three elements necessary to any Residential Energy Conservation Ordinance ("RECO") program attempting to quantitatively improve the efficiency of a given house or set of houses. These are the ability to: (1) Establish a universally applicable baseline efficiency level;

(2) Establish measurement units that will consistently illustrate performance above or below that baseline; and (3) Create or select the scheme by which the house or houses are measured with fair and replicable results. Of course, in order to be widely accepted, these elements must be provided in an affordable and timely manner and with particular attention to health and safety.

The current variety of programs attempt to affect home energy efficiency improvements while using one or more of the criteria listed above. These include home energy retrofits, energy audits and HERS rating programs. Energy retrofit programs, being primarily concerned with achieving improvements and less concerned with baselines and measurement, do not directly correspond to the needs of a RECO protocol. Audit programs, being primarily concerned with identifying major inefficiencies within a building system, are largely forensic in nature – providing measurement but lacking a baseline, a consistent set of units, and any **requirements** to pursue improvement. Finally, HERS ratings, being primarily concerned with predicting the future efficiency of an existing or proposed home, shows improvements relative to an established baseline (typically a building code) utilizing a software-based energy model. HERS ratings ignore historic consumption data that could illuminate issues not represented in the theoretical model.

Audits

As noted above, the Center for Resource Conservation currently operates the Residential Energy Audit Program ("REAP") with support from the city and other local governments. These subsidized audits cost homeowners from $100 to $200 (depending on house size) and consist of an energy audit and report containing a prioritized list of recommended improvements. The audit portion typically consists of a visual inspection of all accessible areas of the home's thermal envelope, a tabulation of electric "end-use" devices (i.e., appliances, light fixtures, televisions, computers, etc), an evaluation of the heating and cooling equipment and distribution systems, and an air leakage analysis conducted via a blower door test. Additionally, some auditors provide a variety of other analyses including combustion analysis to determine actual furnace performance and thermographic imaging to identify insulation failures or air leakage areas not visible to the naked eye.

While the REAP program is affordable and has been growing substantially there is no requirement that the audited homes implement the recommended measures. However, since the program does use the analysis of utility bills in the energy education and auditing process, these could be put to use in establishing baselines for establishing savings goals and evaluating savings resulting from the implementing recommended efficiency measures.

Home Energy Rating System

Of the variety of home energy rating systems that have been introduced over the past few decades, the program most widely recognized and adopted is the Residential Energy Services Network's ("RESNET") Home Energy Rating System ("HERS"). Created by the mortgage industry in an effort to promote a fair and universally applicable system by which to measure the energy efficiency of residential structures, the HERS Index method of quantifying efficiency was meant to be a tool used in the delivery of energy efficient mortgages ("EEM"). While the EEM program never became widely utilized, RESNET's HERS rating tool has since been adopted by the US EPA's ENERGY STAR for New Homes program, the USGBC's LEED for Homes program, the City of Boulder's Green Points and Boulder County's BuildSmart programs. In addition, HERS is widely accepted by municipalities throughout the country as a means of illustrating compliance with the "performance path" of the 2006 International Energy Conservation Code. In addition to the air leakage testing provided in a typical energy audit, HERS rating requires the creation of a computer simulated energy model as well as the performance of a duct leakage test and insulation grading procedure. As such, a HERS rating provides a fairly detailed picture of the nature of a building's energy consumption. The energy model can also be used to identify the most cost-effective efficiency improvements.

HERS rating applied to an existing structure is, however, intrinsically fallible largely due to its dependence on a theoretical, software-based representation of the home rather than an observation of the home itself with the historic consumption data from energy bills in hand. Because HERS is intended to be a fair and replicable modeling tool for every home in the country, it bases nearly all electric consumption predictions on a blanket watts-per-square-foot calculation that is meant to replicate the "average" consumer. For this reason, HERS is poorly suited for evaluating the impact of consumer behavior, widely viewed as having a substantial effect on a home's energy consumption. Finally, because energy modeling and field testing can be time intensive, the cost of a HERS rating can range from $350 to more than $1000 depending on the complexity and size of the building and the amount of associated consulting required.

Imagine that HERS ratings were used in a performance-based residential retrofit program requiring a decrease in household energy use of a given fixed percentage. By way of illustration, imagine a requirement to lower a home's HERS rating by 20 percent. Accordingly, a home of HERS rating of 120 (well worse than code) would have a target of 96; one of 100 (just equal to current code requirement) would have to implement measures that would bring its HERS rating down to 80; one of 60 to 48. Note with this scheme that homes with high initial HERS ratings will have to decrease their scores by a greater *absolute* amount than those with lower scores. However, in general higher scores are associated with more energy waste, which is generally more cost effective to diminish than is the case with homes whose before-retrofit energy waste is more moderate.

A second option would be to specify that all stock must achieve a HERS rating of at most 80. With this, quite wasteful homes with HERS ratings above 100 would have to be retrofitted at potentially substantial cost (depending on degree of waste and how best to attack it), whereas those already 20 percent better than code would not be required to undertake any retrofits at all. However, although a HERS score of 80 may appear ambitious for owners of quite wasteful dwellings, it is nonetheless only 20 better than current energy codes which merely express the basement, as it were, of energy efficiency requirements. It is a long way from the HERS 0 score (net zero energy consumption) that is ultimately desirable.

A third option when expressing energy performance with a HERS-style rating would be to define a stair step function wherein houses of a given range of HERS scores would have to bring their ratings down to a target score, perhaps 10 percent below the lowest score in the range of the given stair, etc. This appears to have little to recommend it since it is more crude than the first option and arguably more complicated, therefore, more likely to be less just and more complicated to implement and to administer.

The depravity of each of the HERS approaches is that they leave out the role played by the occupants of the home and assign neither virtue nor depravity to changes in behavior. However, since dwellings and their occupants are inexorably connected, sound energy education needs to be implemented and its presence be rewarded and its absence at least taken into account if not penalized. Finally, it takes real money to produce a HERS rating of any real credibility, and these schemes may require before and after ratings

Better Measure

An ideal approach would blend the analytic power of an energy model with the forensic scrutiny of an energy audit, and would provide both in a quick and cost-effective method. A less sophisticated modeling apparatus than that currently used for HERS rating could provide a consistent means of measurement and reduce costs significantly. This same apparatus, if designed to account for historic energy consumption data from Xcel billing records, would allow users to predict the effects of physical improvement measures such as increased insulation as well as behavior modifications such as setting back thermostats, turning off lights, or hanging clothes on a clothes line instead of using a dryer.

RESNET has endeavored to create a set of parameters that would govern the creation of such a program. There are also a number of local companies attempting to create software that would satisfy these demands. In addition, some of these developing software packages utilize search technology that will perform hundreds of combinations of potential improvements, ultimately identifying the most cost-effective or environmentally sensitive improvement measures depending on the search parameters entered by the user. Perhaps the existing energy audit program run by the CRC and substantially supported by the city will embrace something along these lines when it is ready for prime time. In addition, Xcel's 2009-2010 of the gas and electric DSM programs aimed at residential customers promises to put a multi-tier energy audit program on line, where the upper tier audit is slated to include both blower door and infrared scanning diagnostic procedures.

The nature of the output of these audits is important. A package of recommended retrofit measures along with estimates of costs and paybacks would be very helpful. A score reflecting current performance versus other homes in general would be of use; one that relates to specific homes of similar type would be even more so. Finally, an analysis that disaggregates electric and gas energy used for space heating, space cooling, and other uses would be most helpful.

Of central importance to this report, it is possible to produce such an analysis remarkably inexpensively from the following information: monthly energy bills for 13 months, historic temperature data over the same period, size of the dwelling's conditioned envelope, and number of persons in the household. With ten minutes of labor to enter this data, the output of the analysis includes:

- A weather and dwelling-unit-size-adjusted index of gas and electric use for space heating, Btu/ft2/heating degree day.
- A weather and dwelling-unit-size-adjusted index of gas and electric use for space cooling, Btu/ft2/cooling degree day.
- Annual consumption of gas for non-space conditioning uses (baseload).

- Annual consumption of electric for non-space conditioning uses (baseload).

Since baseload energy use is usually a strong function of the number of members of the household, it is easy to express them on a per-capita basis.

Such measures of performance substantially facilitates developing strategies for retrofitting, a dwelling, setting targets, and evaluating results. If supplemented by an audit, so much the better. Inserting findings from blower door tests, for example, will allow for estimating the portion of space conditioning energy that is used to overcome convective losses rather than conductive ones, thereby suggesting the magnitude of air sealing work that should be undertaken versus insulation work—and relative cost effectiveness of each. However blower door data is not essential for setting goals, evaluating savings from retrofits—and adopting policies that will lower consumption and judiciously and cost effectively.

Continuing to track information from energy bills (and from Xcel's Smart Grid information system, perhaps expanding it to include gas as well as electricity) will be most helpful in evaluating the success of a RECO program and enabling the informed taking of mid-course corrections if deemed appropriate. Such information can also provide detailed consumption information useful in continuing to achieve efficiency or in identifying problems inhibiting it, an observation that applies at both from the perspective of individual dwellings as well as from that of the CAP program.

Section 4
Policy Recommendations

Boulder is a special place whose leaders and citizens understand the critical importance of ensuring the success of the Climate Action Plan voters overwhelmingly passed in November of 2006. An intelligently designed and implemented Residential Energy Conservation Ordinance can contribute substantially to the goal of a city whose carbon footprint is modest—and quality of life high.

Boulder grew especially quickly in the decades around the 70's. Over sixty percent of the city's housing stock dates from 1950-1979, an era when producing housing for a fast-growing population was much more important than energy efficiency in construction. Indeed, leaky, poorly-insulated construction is the rule in a great portion of Boulder's housing stock, both owner-occupied and rental. However, as with many crises, there is opportunity. In the world of energy efficiency, there is a rule that has few exceptions: the greater the waste the greater the opportunity to achieve cost-effective savings.

The details are critical, but in general air sealing and insulating improves comfort, enhances dwelling life and value, and saves energy and money. Toward minimizing carbon footprints cost effectively, energy efficiency needs to precede adding renewable generation sources. It is possible to supply electricity from a photo voltaic array to a home lit by incandescent lamps whose refrigerator and freezer consume 3,000 kWh per year, but it makes much better sense (and saves many more dollars) to lower demand prior to attempting to meet it with renewables. Analogous remarks apply to space conditioning and heating hot water which typically consume natural gas. Air sealing, insulating, installing low flow devices, and adjusting thermostats should precede the sizing of solar thermal systems.

That said, a home, for whatever reason, that is a net zero electricity user, and that does not have unreasonably high gas bills, should by definition meet the RECO. This means that an electricity-inefficient home, with enough solar panels, is as good from a GHG standpoint as an efficient home with fewer solar panels. It will be less cost-effective, but that is a legitimate choice for a homeowner. Of course, it is to the advantage of all parties to also adopt energy efficiency measures, allowing the sale of more PV generated electricity to the utility. This is particularly the case on sunny mid summer weekday afternoons when Xcel's marginal cost to provide adequate electricity to the grid it quite high. Indeed, with the advent of the Smart Grid and its associated flexible time-of-use rate structure, Xcel may be interested in paying a premium for PV generated electricity during periods of peak demand on the grid.

Remove barriers, demonstrate and encourage creative approaches

Energy audits of town houses (plus mobile homes and some other housing types) often reveal deep-running energy problems whose solutions could quite possibly halve energy consumption. In such structures, there is a strong likelihood that closely-similar problems affect all other buildings in the complex. In short, there are many opportunities for achieving strong economies of scale in both the auditing and retrofitting processes, thereby achieving cost-effective retrofits that could benefit all.

In some cases, a district heating (and perhaps cooling) system fueled by an active solar front end (with efficient gas boiler back up) could solve a number of problems in elegantly simple ways. Achieving several somewhat ambitious projects along these lines may stimulate a snowball effect to the net benefit the Climate Action Plan and the energy efficiency infrastructure—as well as to the homeowners involved. The city could play key roles in organizing such win/win projects, ensuring that code or ordinance-related barriers are lowered and results evaluated with a view to building on the strengths of what works—and promoting effective energy saving strategies with great vigor.

Education and Training The state of currently-available why-and-how-to-do-it information, format, and delivery mechanisms needs to be examined with a view to supplying well-crafted training to home owners, landlords, tenants, retrofitters, and suppliers. The aim should be to make best practices known and continuing to improve on them while moving well beyond installing shower heads and CFLs (though these are important, of course.) Boulder could co-sponsor demonstration projects that combine routinely-used technologies with promising new ones than can be implemented by local retrofitters. Ideally, training and workshops should focus on dwellings typical of those prevalent in the neighborhoods where workshops are held.

Some landlords have been contractors; other are just plain handy. They can legally insulate homes they live in, but not those they own that others live in. Instead of insisting that they hire contractors to air seal attics and ducts and blow cellulose insulation, the city could co-sponsor weekend workshops to get people up to speed. Those who pass the course could be authorized to work on their own properties. Of course, inspecting the results should be built in as part of the four year rental license renewal process.

Understanding one's own patterns of energy use as a function of relevant circumstances is very helpful in minimizing waste, a fact Prius drivers and owners of dwellings already connected to the Smart Grid know firsthand. Boulder should make it easy for all citizens to get their billing records (just consumption, not money), fill in info on a web site, and receive feedback that normalizes space conditioning use of gas and electricity to dwelling size and weather—and baseload energy use adjusted to household size. This can both raise consciousness and allow for tracking of past (pre-retrofit) and future (post-retrofit) energy use and savings.

As part of the education process, Boulder should also make it easy for all citizens to measure the consumption of their refrigerator (and other 117 Vac plug-in devices) by lending electric energy meters, just as books are lent by libraries. Excellent quality meters cost $17 in bulk. They could be made available through libraries, workshops, the Center for Resource Conservation, and other outlets like the Boulder Area Rental Housing Association and Thistle Community Housing.

Such widespread use of simple metering equipment will reveal whether it is cost effective to replace a refrigerator with a modern ENERGY STAR unit.

For refrigerators of 20 cubic feet or less, a refrigerator that uses 800 kWh per year or more is usually cost effective to replace with an ENERGY STAR unit; for larger refrigerators, 1000 kWh/yr is a cost-effective threshold for replacement decisions. In addition, measuring other appliances can reveal how much energy it takes to wash a load of clothes (close to a kWh for many older top loaders; 0.25 kWh/load for modern side loaders that are ENERGY STAR rated.) The meter can also reveal phantom loads, such as electronic equipment and printers which use electric energy even turned off. Such waste can be largely eliminated by using power strips whose switches can turn of a number of such offending devices at once.

Infrastructure Development If the council passes a RECO whose requirements are triggered by both the sale of residential buildings and by renewing rental licenses, more than 7,000 retrofit jobs will be undertaken per year. Depending on the circumstances of dwellings and how high bars are set, this would almost certainly overwhelm the ability of the existing contractor base to meet. Of course, it is desirable to stimulate new job development, but it could get wild out there, particularly at the onset of passage of the ordinance. Accordingly, an incremental approach comes to mind in which for the first two year period of the program will avoid requiring retrofits that only professionals can implement.

Financing Being able to borrow money at modest interest rates and minimal hassle will make it easier to do the right things right in the world of retrofitting residences for energy efficiency and renewables.

That's the premise of Boulder County's initiative 1A. The initiative has been embraced by the city council and voters approved it on November 4. This will make available low interest loans to undertake energy efficiency and renewable work on residential buildings, with payments being integrated into tax bills, the debt remaining with the property (paid through the new owner's tax bill) upon sale.

There is a great deal to be said in favor of this initiative. As details of the program are worked out, it will be important to coordinate with Boulder's CAP for residential structures in general and with any emerging RECO initiatives in particular. It may be that the cost of energy retrofits could be matched to diminished energy bills by the judicious juggling of the terms of the 1A loan. Factors that work to the advantage of this circumstance are state and federal incentives, DSM rebates, increases in electricity and natural gas prices virtually sure to outstrip inflation, low interest loans, and a simple mechanism for payment. Keeping administrative costs low and minimizing hassle will be to the interest of a successful program that wins broad acceptance.

Each of these points should be thematic to the effective marketing of the 1A program.

The city might consider something along the same lines as 1A, perhaps as a supplementary measure. Since the CAP carbon tax is paid directly through Xcel electric bills, it may be possible to allow payments for energy efficiency loans to be made through monthly Xcel bills. Again, juggling the terms of the loan with likely energy savings could yield little net effect on the size of the monthly bill until the loan is paid off, at which point a welcome diminution of the bill would occur. Indeed, in ways similar to 1A, it may be feasible to set up a program with Xcel so that the energy retrofit bill is transferred to a new owner's energy bill in the case of property sale.

Finally, it is likely that initial emphasis of 1A will be on the residential sector. However, it is also applicable in the commercial sector, which is far and away the greatest producer of green house gases. This could be attractive to both Boulder's CAP and to Xcel, whose DSM program directed to the business sector is quite aggressive.

Option 1 RECO

This applies to all dwelling units on the occasion of a change of ownership, with a negotiation between present and the future owner concerning who pays, with compliance being complete within one year of sale. The dwelling unit must have at least 80% of its lighting supplied by fixtures (lamps plus ballasts where applicable) whose luminous efficacy is at least 50 lumens/watt, showers whose maximum water deliver rates do not exceed 2.0 gallons per minute, refrigerator(s) that use no more than 800 kWh/yr, attic sealing and insulation of R >30 (if there is an attic) and duct sealing and insulation of R-8 or more in unconditioned areas. (No duct insulation required in semi-conditioned areas such as crawl spaces or basements.)

The advantages of this approach are that it applies to all housing, is not difficult to implement, will increase awareness of all citizens of the importance of diminishing housing-related carbon footprints, and minimizes the problem of free ridership for Xcel rebates save perhaps for attic insulation.

Option 2 RECO

Includes the provisions of Option 1 for all dwelling units, but in addition, adds trigger mechanisms that apply to all rental properties subject to the city's rental license program.

All rental property owners are provided with a notification apprising them of the importance of upgrading the energy efficiency of their dwellings in support of the Climate Action Plan. This notification is accompanied by information on how to evaluate energy conserving options for their buildings through:

- Participating in the automated analysis of energy bills via the Office of Environmental Affairs web site;

- Borrowing an energy meter that enables assessing the electric consumption of a number of plug loads in dwellings and determining cost-effective tactics such as appliance replacement and enhanced controls to diminish waste;

- Undertaking a subsidized energy audit from the Center of Resource Conservation or an audit sponsored by Xcel Energy.

The notification also includes detailed information about opportunities for participating in the weatherization program, federal and state tax and direct incentives for undertaking conservation measures and adding renewables, and details of Xcel's gas and electric DSM programs that apply to residential properties. How to apply for financing via Boulder County's new program resulting from the passage of Proposition 1A is also highlighted.

The Residential Energy Conservation Ordinance is implemented incrementally by taking a hybrid approach consisting of several prescriptive measures that will not suffer free ridership problems with Xcel's DSM program combined with a performance approach that will be voluntary (though monitored via the city's rental licensing program) through the end of 2010 and thereafter be mandatory. (This is that date when Xcel's current DSM programs will likely be replaced by others.)

Rental properties falling under the licensing program will be required to have at least 80% of lighting supplied by fixtures (lamps plus ballasts where applicable) whose luminous efficacy is at least 50 lumens/watt, showers whose maximum water deliver rates do not exceed 2.0 gallons per minute, and refrigerator(s) that use more than 800 kWh/yr. In addition, owners of rental properties will be strongly urged (not required) to implement a range of other retrofit measures depending on the circumstances of the buildings and dwelling units in question. These include:

- Installation of multi-setback thermostat(s) that control set points for heating and cooling; adjusting this thermostat for frugal comfort reflective of periods of occupancy; adjusting thermostats that control HVAC fans, the domestic hot water heater, freezers and refrigerators (both fresh food and freezer compartments).

- Installation of wind-up timers on bathroom fans, ad-hoc space heaters, whole house fans, battery chargers, and entertainment centers.

- Installation of power strips with on/off switches to control devices that continue to use energy even when switched to "off."
- Installation and use of clothes lines.
- Attic sealing and insulation to R >30 (if there is an attic and it will accommodate this much insulation, otherwise air seal thoroughly and insulate as much as possible.)
- Air sealing of the duct system plus duct insulation of R-8 or more in unconditioned areas. (Duct insulation added as desired to improve delivery temperatures when ducts traverse semi-conditioned areas such as crawl spaces or basements.)
- Air sealing and insulating of un-insulated or poorly insulated walls.
- Installation of a whole house fan controlled by a multi-speed switch and thermostat or wind-up timer, with provision for air sealing and insulating the opening to the outside of the conditioned envelope during the heating season.
- Installation of an efficient evaporative cooler with provision for air sealing and insulating the opening to the outside of the conditioned envelope during the heating season.
- Repairing or retrofitting existing windows, adding moveable insulation and/or shading devices as appropriate.
- Replacing existing furnaces or boilers (water and space conditioning) with high efficiency models.
- Replacing energy and water wasteful washing machines with horizontal axis ENERGY STAR models.

Note that many of the items on this list are eligible for rebates under Xcel's DSM programs, but since none are *required* by the RECO program, there will be no free rider issue. Landlords should be urged to take advantage of these rebate opportunities while they are still viable.

Monitoring of the energy-related aspects of rental properties will be implemented shortly after the adoption of Boulder's RECO ordinance. This will include developing a checklist which notes the prescriptive items that are required (as of December 31, 2010), as well as the measures in the above list that are suggested as ways to enhance complying with performance measures that will also kick in at that time. Properties which already meet the prescriptive measures and whose energy bills include heating energy use of below 5 Btu/sq ft/heating degree day and electric base load use of less than 200 kWh per occupant will be deemed "Green Star" dwelling units, with an associated certificate.

Within three months of the effective date of the RECO, landlords will be required to submit a statement of energy consumption based on the analysis of bills using the procedure on the city's website or another reasonable method approved by the Office of Environmental Affairs that does not run afoul of state utility bill privacy laws. This information—annual gas and electricity used for space conditioning adjusted to dwelling unit size and heating/cooling degree days, and gas and electric use for base load—will be used in the Boulder Energy Project data base and in deciding on energy use patterns for determining reasonable thresholds of compliance for the performance-based elements of the city's RECO.

The same energy consumption data (based on use) will be sought on the occasion of renewing rental licenses. The information should be instructive to landlords in tracking their progress in making their properties more efficient (and thereby more rentable). It will also be useful to administrators and policy makers of the Climate Action Plan in evaluating the effectiveness of the RECO and other programs in lowering carbon footprints in the residential sector. It will also be critical in adjusting thresholds to ensure that fairness and equity accompany due diligence in achieving environmental goals.

Savings potential
Appendix A which follows this section examines the potential costs and savings associated with the retrofitting of four dwelling types commonly found in Boulder. Table 4-1 on the following page shows potential aggregate savings of gas and electric energy as well as GHG emissions for both RECO energy efficiency retrofits and "beyond RECO" energy efficiency retrofits that are cost effective. Estimates are weighted according to the percent of each dwelling type in Boulder, based on the information presented in Section 2, Table 2-1. Dollar costs and savings are included.

Results are shown with increasing levels of penetration until year six, at which point full penetration will have been reached, because some home are assumed to have already met or exceeded RECO requirements and the key aim of the table is to illustrate a plausible scenario owing to RECO initiatives undertaken in the near future. Nonetheless, cumulative costs and benefits are extended through year ten, where dollar savings and environmental benefits well exceed costs even under the conservative assumption that electricity and gas energy costs will track inflation.

Table 4-1. Estimates of savings, costs, and benefits of RECO and beyond RECO energy efficiency measures with estimated penetration over the first six years of the program

		RECO Energy Efficiency Retrofits					Beyond RECO Energy Efficiency Retrofits					Total Energy Efficiency Retrofits				
Dwelling Type		Save (trm/yr)	Save (kWh/yr)	Save GHG (M tons CO2/yr)	Save ($/yr)	Cost ($)	Save (trm/yr)	Save (kWh/yr)	Save GHG (M tons CO2/yr)	Save ($/yr)	Cost ($)	Save (trm/yr)	Save (kWh/yr)	Save GHG (M tons CO2/yr)	Save ($/yr)	Cost ($)
4500 ft^2 Detached		516	5046	7.16	$ 1,123	$ 3,755	734	1582	5.26	$ 981	$3,599	1250	6627	12.4	$2,104	$7,354
2000 ft^2 Detached		751	1300	5.10	$969	$ 3,378	608	704	3.82	$746	$ 7,062	1359	2003	8.9	$1,715	$10,440
850 ft^2 MF Apt		371	3305	4.86	$771	$ 2,569	388	0	2.05	$ 427	$4,116	759	3305	6.9	$1,198	$6,685
980 ft^2 Mobile		489	4227	6.30	$ 1,003	$ 4,564	355	433	2.25	$ 438	$ 4,080	845	4660	8.6	$1,442	$8,644
Weighted Average		611	2632	5.54	$961	$3,339	577	729	3.69	$715	$5,591	1188	3361	9.22	$1,677	$8,930
End of year	Cumu-lative Pene-tarion (HH)	Cumu-lative save (10^3 trm)	Cumu-lative save (MWh)	Cumu-lative save GHG (10^3 M tons CO2/yr)	Cumu-lative save (10^6 $)	Cumu-lative cost (10^6 $)	Cumu-lative save (10^3 trm)	Cumu-lative save (MWh)	Cumu-lative save GHG (10^3 M tons CO2/yr)	Cumu-lative save (10^6 $)	Cumu-lative cost (10^6 $)	Cumu-lative save (10^3 trm)	Cumu-lative save (MWh)	Cumu-lative save GHG (10^3 M tons CO2/yr)	Cumu-lative save (10^6 $)	Cumu-lative cost (10^6 $)
1	2000	611	2,632	1.7	$1.0	$6.7	577	729	3.7	$0.7	$11.2	1,188	3,361	5	$ 1.7	$ 17.9
2	5000	2,749	11,842	21.1	$4.3	$16.7	2,599	3,282	16.6	$3.2	$28.0	5,348	15,123	38	$ 7.5	$ 44.6
3	11000	7,636	32,894	65.3	$12.0	$36.7	7,218	9,115	46.1	$8.9	$61.5	14,854	42,009	111	$ 21.0	$ 98.2
4	18000	16,494	71,051	145.6	$26.0	$60.1	15,592	19,689	99.5	$19.3	$100.6	32,086	90,740	245	$ 45.3	$ 160.7
5	25000	29,628	127,629	264.6	$46.6	$83.5	28,008	35,368	178.7	$34.7	$139.8	57,635	162,996	443	$ 81.3	$ 223.2
6	31000	46,732	201,311	419.6	$73.5	$103.5	44,177	55,786	281.9	$54.7	$173.3	90,909	257,097	701	$128.3	$ 276.8
7	31000	65,670	282,889	591.2	$103.4	$103.5	62,079	78,392	396.1	$76.9	$173.3	127,748	361,281	987	$180.3	$ 276.8
8	31000	84,607	364,466	762.8	$133.2	$103.5	79,981	100,998	510.4	$99.1	$173.3	164,588	465,464	1,273	$232.2	$ 276.8
9	31000	103,544	446,043	934.4	$163.0	$103.5	97,882	123,604	624.6	$121.3	$173.3	201,427	569,647	1,559	$284.2	$ 276.8
10	31000	122,482	527,620	1,105.9	$192.8	$103.5	115,784	146,210	738.8	$143.4	$173.3	238,266	673,830	1,845	$336.2	$ 276.8

Appendix A

Costs and Benefits of Energy Retrofit Measures

This appendix consists of an energy retrofit analysis of a sample of four structures that between them are representative of the range of dwelling units that are found in Boulder. In principle, any of them could be rentals or owner-occupied dwellings. The aim of this appendix is to illustrate the energy-related circumstances of each building examined with a view to understanding what retrofit measures might be practical to undertake to meet minimal requirements of an imagined RECO. In addition, further retrofit measures are explored that could be undertaken to make them sufficiently efficient that both solar thermal and solar PV retrofits might become practical considerations toward achieving the goal of net zero energy use featuring tiny carbon footprints in Boulder's residential sector.

Buildings chosen are:

- A 4500 square foot two-story home with five occupants;
- A 2000 square foot home with three occupants;
- An 850 square foot apartment with two occupants; and
- A 980 square foot mobile home with four occupants.

Description of 4500 square foot home with five occupants

The large home was built in the 1970's as a single-family dwelling with four bedrooms and a library, but is now home to a middle-age couple who rent rooms to three somewhat studious graduate students. Its walls have never been insulated, but the attic has six inch fiberglass batts. The un-insulated crawl space has leaky ducts in it from a large (160,000 Btu/hour) gas furnace that replaced the original furnace in 1992, the same time an 80 gallon hot water heater was installed. As part of the work done then, a split system air conditioning unit was installed, with the compressor outdoors and A/C evaporator coil inserted in the supply plenum of the furnace. The original mechanical thermostat still controls the heating and A/C system. The windows are wood frame double hung units with single glazing, half covered by aluminum storm windows, the others by wood storm windows. Glazing areas total 530 square feet, 14% of the wall space. About 160 square feet of the glazing area is south-facing with modest shading from neighboring deciduous trees.

An energy auditor who used both a blower door and an infrared scanner found a number of air leakage areas both at the bottom and top of the home's envelope, as well as substantial leakage in the return air system which pulls air from outside via the attic vents and a large bypass that connects the attic to the basement. Other major leaks come from recessed lighting fixtures in three second-floor bedrooms and the upstairs hall. The blower door measured a flow of 3800 cubic feet per minutes of flow at a 50 pascal pressure difference, indicating that convective air leakage accounts for about 274 therms per year of energy loss each winter. The three showers in the home have flow rates ranging from 3 to 4.2 gallons per minute and the hot water tank delivers water at 152 degrees F. The homeowner agreed to replace the shower heads with 2 gpm units and the auditor showed him how to lower the temperate of the hot water tank to 120F. With permission of the homeowner, the auditor also reset the furnace distribution fan to come on at 115F on temperature rise, and stay on until the temperature in the heat exchanger drops below 100F at the end of the firing cycle. Of the 38 incandescent lights in the home, the homeowner agreed to replace 27 with compact fluorescents; the chandelier and several other lights were on dimmers. The auditor also left behind two digital watt hour meters, placing one on the refrigerator, the other on the freezer. The homeowner read them the following afternoon and found that the refrigerator is using about 1150 kWh/yr and the freezer 480 kWh/yr.

The energy bill on this large, energy wasteful dwelling runs $4672 per year; it consumes 3220 therms per year of gas and 12,500 kWh of electricity.

RECO retrofit work on 4500 square foot home

The homeowner undertook retrofit work in stages. In the first, he decided on a number of low and medium-cost retrofit measures that would exceed the requirements of the RECO legislation. These are: three shower head replacements; 27 lighting replacements; a multi-setback electronic thermostat; three power strips and four timers to control lighting loads; comprehensive air sealing of the attic, ducts, and recessed lights; additional cellulose insulation in the attic to achieve an R-value of 40, a new ENERGY STAR refrigerator, and a through-the-wall energy-efficient evaporative cooler on the second floor. See Table A-1.

Table A-1. Retrofit measures in 4500 square foot home retrofit undertaken in response to an imagined RECO; consumption and savings per year.

Energy Element	Retrofit Measure	As is (trm)	As is (kWh)	Retro-fit (trm)	Retro-fit (kWh)	Savings (trm)	Savings (kWh)	Savings ($)	Cost ($)	Pay-back (yr)	GHG Saved (m tons)
Convective Losses	Seal, ins ducts (80% to 92% dist eff)	2463	1550	2142	981	321	568	$416	$360	0.9	2.19
Convective Losses	Seal envelope 3800 to 2000 cfm50	417	791	220	417	197	373	$258	$450	1.7	1.37
Attic Conductive	Insulate R 19 to R 40	241	457	114	216	127	241	$166	$1418	8.5	0.88
Cooling	Evap Cooler		3900		1155	0	2745	$302	$650	2.2	2.42
Space Cond Control	Set back stat 2F winter & summer	2463	4670	2315	4390	148	280	$193	$120	0.6	1.03
Thermal Retrofit Package	Includes interaction between measures	2463	4670	2042	1793	421	2877	$780	$ 2998	3.8	4.75
DHW	Lo flow, thermostat	215	0	120	0	95	0	$105	$30	0.3	0.50
Lighting	27 CFLs, 5% duty		1049		505	0	544	$60	$27	0.5	0.48
Frig	New 22 ft3 EN STAR		1150		425	0	725	$80	$645	8.1	0.64
Plug Load	Timers & Strip SW		1500		1200		300	$33	$35	1.1	0.26

Clothes drying	Clothes Line 75%		800		200		600	$66	$20	0.3	0.53
Baseload Retrofit Package	Ignores tiny interaction	215	4499	120	2330	95	2169	$343	$757	2.2	2.41
Total Retrofit	Thermal + Baseload	2678	9169	2162	4123	516	5046	$ 1,123	$ 3755	3.3	7.16

Assumptions:
Boulder base 60F heating degree days = 5554
Ducts 80% efficient before, 92% after, cost $30/unit % improvement
CFM 50 before = 3800, after 2000, cost $0.25/cfm50
Attic insulation cost $0.03 per R per ft^2
Wall insulation cost $0.10 per R per ft^2
Crawl space and basement insulation cost $0.05 per R per ft^2
Present cooling system 5 tons, COP = 2.5, duct eff = 80% 400 hours/cooling season before retrofit.
Retrofit: Evap cooler 600 hours at average of 0.3 kW, AC 100 hours
Lighting original 38 incandescent average 63 connected watts, 5% duty cycle. Retrofit 27 with 17 watts average, same duty cycle.
Three shower heads averaging 3.6 gpm replaced by 2.0 gpm models, five showers per day at 6 minutes/shower, gas heater recovery efficiency of 78%, cost $10 each.
Greenhouse gases at 0.00527 metric tons per therm of natural gas; 0.00088 metric tons per kWh of electricity.

Notice that calculations of thermal losses are made of individual measures along with their paybacks *as if each measure were taken independently of the others*. However, when a package of measures is taken, interactions between measures are computed together to produce a comprehensive analysis of savings and payback. Note that the investment in attic insulation by itself has relatively long payback (because its before-retrofit R-value is 19), but when bundled with other measures the group of measures has a simple payback of less than four years.

Beyond RECO retrofit work

A second round of retrofit measures that would go well beyond an imagined RECO set of requirements would also be a worthwhile investment. Insulating the crawl space insulation will allow the home to run warmer in the winter, thereby lowering both duct losses and losses through the floor. Both will improve comfort and save both energy and money. Insulating the walls by blowing high density cellulose will lower wall conductive losses as well as lower overall convective losses. This will not only decrease energy bills summer and winter but also improve comfort and likely extend the lifetime of the home by lessening the flow of moisture-laden air through building materials. Baseload measures for the second round of retrofit measures might include:

- Add 5 more CFLs for $5, replace incandescents
- Install Energy Star dishwasher for $370

- Sell Plasma TV to someone who does not watch much, buy non-plasma Energy Star TV, move from having TV on for 2800 hours/yr to 2200 (primarily by turning it off when no one is paying attention anyway); net cost $400.

Table A-2. Beyond RECO retrofit measures in 4500 square foot home retrofit undertaken beyond an imagined RECO; consumption and savings per year

Energy Element	Retrofit Measure	As is (trm)	As is (kWh)	Retrofit (trm)	Retro-fit (kWh)	Savings (trm)	Savings (kWh)	Savings ($)	Cost ($)	Pay-back (yr)	GHG saved (m tons/yr)
Sidewall conductive	Insulate R-5 to R-13	1376	1075	530	465	846	610	$998	$2,539	2.5	5.00
Crawl conductive	Insulate R-8 to R-18	129	101	57	50	72	51	$85	$285	3.4	0.42
Thermal Retrofit Package	Includes interaction between measures	2042	1793	1334	1327	708	467	$830	$2,824	3.4	4.14
Dish-washer	Energy Star washer	52	744	26	410	26	334	$65	$370	5.7	0.43
TV	600 fewer hrs, no plasma		1120		440		680	$75	$400	5.3	0.60
Lighting	5 CFLs, 5% duty		138		37	0	101	$11	$5	0.5	0.09
Baseload Retrofit Package	Ignores tiny interaction	52	2002	26	887	26	1115	$151	$775	5.1	1.12
Total second retrofit	Thermal + Baseload	2094	3795	1360	2214	734	1582	$ 981	$3,599	3.7	5.26
Total both retrofits	All	2678	9169	1360	2214	1318	6955	$2,214	$7,354	3.3	13.06

Description of 2000 square foot home with three occupants

This home is typical of 30 year old single story or split ranch homes with modest insulation in the ceiling, none in the walls, and about 12 percent glazing, all of which is single glazed with aluminum frames. In this case, four years ago the old furnace was replaced by a condensing unit rated at 95% steady state efficiency, but the distribution system was left as is. The conditioned envelopes of brick homes of this kind are usually only moderately leaky, but frequently they have leaks into the attached garage, which is sometimes intentionally heated. If leaks are on the return air side (or there is an intentional return air duct in the garage), there is danger of bringing carbon monoxide into the home on cold winter mornings when the car is started. Duct work in such homes is typically both leaky and poorly insulated, if insulated at all. In this case, the auditor estimates the distribution system has an efficiency of only 75%. Sometimes these homes have been retrofitted with a “pop up” second floor consisting of a master bedroom, bath, and modest size office. Energy auditors frequently note air leakage in the interstices between the new and old parts of the home, or wherever different building materials meet. Frequently, the addition is heated by electric resistance heaters because the builder did not want to bother with installing proper duct work. Since electricity costs three times as much as gas, this presents an opportunity for substantial saving.

This home is occupied by three graduate students from the CU engineering school. The annual energy bill of this 2,000 square foot home is $3245, of which $2320 is for 2120 therms of natural gas and $913 is for 8300 kWh of electricity.

RECO retrofit work on 2,000 square foot home with three occupants
Air sealing work showed a lowering of the blower door reading from 2500cfm50 to 1200cfm50, with fully 500 cfm50 being associated with air sealing the ducts in the attic alone. Plumbing and wiring penetrations were also prevalent, as was an area between the attic and garage which was sealed as part of the attic insulation job by blowing cellulose to high density. The blower door also found that the porch at the entry way of the home was open to the space above the living room ceiling, so the porch ceiling was blown with ten bags of cellulose to stop that major convective leakage. Finally, the auditor found a large opening at the top of the interior wall separating the living room from the kitchen, allowing thermo-siphoning of cold air from the vented attic all the way to the bottom of the interior wall. Although this opening was closed from the interior envelope space, thus making it undetectable by the blower door, it nonetheless had been a major source of convective losses over the lifetime of the home. Accordingly, in preparing the attic for insulation, the top of the interior wall was sealed at the level of the attic floor by caulk, aluminum flashing attached by a hammer stapler, then urethane foam at the edges. The duct work itself was fitted with "Ultimate R," an insulation containment system that allows for fully insulating ducts during the process of blowing cellulose into attics. The attic was insulated to R38, up from the auditor's before-retrofit estimate of R-10.

The two ton room air conditioner was removed and a through-the-wall efficient evaporative cooler was installed in its place. Twenty CFLs were installed, a 1.5 gpm shower head replaced a 3 gpm model, the hot water heater turned down from 140F to 120F, and pipe insulation was installed on all the hot water pipes easy to access plus 6 feet of the cold water pipe into the heater to prevent thermo-siphoning. The refrigerator was ten years old, but measured 689 kWh/year, so was not cost effectively replaceable. The 20 cubic foot freezer in the garage measured 780 kWh/yr so merited replacement soon, a job relegated to the "Beyond RECO" round of retrofits. A clothes line was installed in the back yard and the tenants agreed to put it to use instead of the electric dryer whenever weather permitted. Table A-3 shows savings, costs, and benefits.

Table A-3. Retrofit measures in 2000 square foot home retrofit undertaken in response to an imagined RECO; consumption and savings per year

Energy Element	Retrofit Measure	As is (trm)	As is (kWh)	Retrofit (trm)	Retrofit (kWh)	Savings (trm)	Savings (kWh)	Savings ($)	Cost ($)	Pay-back (yr)	GHG Saved (m tons/yr)
Convective Losses	Seal, ins ducts (75% to 92% dist eff)	1567	533	1278	435	289	98	$329	$510	1.6	1.61

Convective Losses	Seal envelope 2500 to 1250 cfm50	255	87	128	44	127	43	$144	$313	2.2	0.71
Attic Conductive	Insulate R 10 to R 38	379	129	99	34	280	95	$318	$1,680	5.3	1.56
Cooling	Evap Cooler		1125		175	0	950	$105	$650	6.2	0.84
Space Cond Control	Set back stat 3F winter	1567	533	1437	501	130	32	$147	$120	0.8	0.71
Thermal Retrofit Package	Includes interaction between measures	1567	533	870	296	697	237	$793	$ 3,273	4.1	3.88
DHW	Lo flow, thermostat	108	0	54	0	54	0	$59	$30	0.5	0.28
Lighting	20 CFLs, 5% duty		552		149	0	403	$44	$20	0.5	0.35
Plug Load	Timers & Strip SW		1200		900		300	$33	$35	1.1	0.26
Clothes drying	Clothes Line 75%		480		120		360	$40	$20	0.5	0.32
Baseload Retrofit Package	Ignores tiny interaction	108	2232	54	1169	54	1063	$176	$105	0.6	1.22
Total first retrofit	Thermal + Baseload	1675	2765	924	1465	751	1300	$969	$ 3,378	3.5	5.10

Beyond RECO retrofit work on 2,000 square foot home

The tenants installed two inches of rigid board insulation in the crawl space (R = 13), then sealed the joints with urethane foam. This helped in air sealing and made the floors more comfortable. If the distribution system had been in the crawl space instead of the attic, this retrofit would have also improved its efficiency as well. The crawl space insulation job was accomplished by four graduate students on a Saturday afternoon. They made a party out of it and the landlord supplied materials, a case of dark beer, and lowered the rent by $100 for the next month.

Wall insulation was installed by professionals, who blew cellulose to high density from the inside. They used the tube method, which requires drilling only a single hole per stud bay. This preserved the brick façade and contributed to air sealing as well as insulation. The uninsulated wall with brick façade was estimated to have an initial R-value of 5; post-retrofit was R-13.

Since the original windows were aluminum single-glazed units that have U values of 1.16 and solar heat gain coefficients (SHGC) of 0.76, all but the south-facing windows were retrofitted. There were 228 square feet of windows in all, distributed as shown in Table A-4 below.

Table A-4. Window replacement retrofit details

Facade	Window	Heating	Retrofit	Retrofit	Savings	Savings	Cost

	area (square feet)	Season Energy (trm)	Window	heating season energy (trm)	(trm/yr)	($/yr)	
North	66	122	.11U; .53 SHGC	6	116	$128	$2640
East	50	54	.37 U; .57 SHGC	5	49	$54	$1200
South	70	17	Same; 1.16 U; 0.76 SHGC	17	0	0	0
West	42	55	.37 U; .57 SHGC	14	41	$45	$1008
Total	228	248		42	206	$227	$4848

Note that in spite of choosing appropriate windows for each façade, simple payback for the windows retrofit work is fully 21 years.

Finally, the freezer was replaced by a more energy efficient ENERGY STAR model. Estimates of savings and costs associated with the beyond RECO retrofit work are shown in Table A-5.

Table A-5. Beyond RECO retrofit measures in 2000 square foot home retrofit undertaken beyond an imagined RECO; consumption and savings per year

Energy Element	Retrofit Measure	As is (trm)	As is (kWh)	Retrofit (trm)	Retrofit (kWh)	Savings (trm)	Savings (kWh)	Savings ($)	Cost ($)	Payback (yr)	GHG Saved (m tons/yr)
Sidewall conduct-ive	Insulate R-5 to R-13	583	247	224	115	359	132	$409	$1,294	3.2	2.01
Crawl conduct-ive	Insulate R-4 to R-18	146	62	32	16	114	45	$130	$550	4.2	0.64
Win-dows	Replace 158 ft2	248	105	42	22	206	84	$236	$4,848	20.6	1.16
Thermal Retrofit Package	Includes interaction between measures	870	296	262	97	608	199	$690	$6,692	9.7	3.38
Freezer	Energy Star freezer	0	780	0	275	0	505	$56	$370	6.7	0.44
Base-load Retrofit Package	Ignores tiny interaction	0	780	0	275	0	505	$56	$370	6.7	0.44
Total second retrofit	Thermal + Baseload	870	1076	262	372	608	704	$746	$7,062	9.5	3.82
Total both retrofits	All	1675	2765	262	372	1413	2392	$1,817	$10,440	5.7	9.55

Description of 850 square foot apartment with two occupants

This apartment is on the second floor (top) of a four building complex, each building of which has 20 apartments. It is occupied by a 30's something couple; he was injured in the Iraq war and is largely confined to a wheel chair but nonetheless does part time work on the internet; she is a waitress in a local restaurant. Theirs is an end unit on the north of the building and they have three windows on the north façade and a pair each on the east and west facades, all of which have double pane clear glass enclosed in aluminum frames which have badly worn weather stripping. There is also an eight square foot skylight in a well in the master bedroom that faces west; it is a single-glazed plastic bubble. The entry is on the east, so the porch overhang shades the east-facing windows. The west windows are not shaded and one of them houses a 2.5 ton air conditioner. The couple pays the electricity bill directly to Xcel, but heat and hot water are supplied from large gas-fired boilers in a boiler room on the first floor of each building. Each of the four rooms plus the bath in their apartment has baseboard radiant heaters installed that are heated by hot water from the boilers that supply both them and their neighbors. When their thermostat calls for heat, a solenoid valve opens, allowing water to flow from the boiler. There is a thermal switch on the incoming pipe that closes when the pipe gets hot, opening when it cools to 120F. The thermal switch actuates an elapsed timer in the boiler room. A maintenance staff person at the complex reads elapsed timers once a month, sending the information to a company that computes the heating bill for each resident. The bill for heating and hot water is tacked onto the rent along with charges for water and garbage pick up. The heating bill in cold months is $110 in spite of frugal thermostat settings.

Over 67% of the tenants met income requirements for being served by the Weatherization Assistance Program, so the landlord applied for weatherization services for the whole complex. A dedicated energy auditor interviewed the couple who indicated that their apartment was not very comfortable, especially on windy winter nights, and that their energy bill for heat was twice that of their neighbors whose apartments were slightly larger than theirs. Being intrigued by the mini-utility service for hydronic heat and hot water, the auditor measured supply temperatures from the boiler at the entry to the apartment five minutes after the thermostat called for heat and found them to be 8 degrees cooler than the temperature of neighboring apartments after the same time interval. With digital thermometer in hand, the auditor also measured supply temperatures of hot water at the kitchen sink; it was 157F. The couple indicated that the water is always that hot, even at 3 am.

The auditor also found that the attic that is common to all ten apartment units on the top of the couple's building had 3.5 inch fiberglass batts installed on the floor between trusses on 24 inch centers. The installation was sloppily done, with gaps quite common, particularly toward the edges of the attic. Further, the well housing the skylight had never been insulated, with 20 square feet of ½ inch dry wall exposed directly to the attic which was vented according to code. The ceiling also had 8 recessed light fixtures with 60 to 100 watt incandescent bulbs installed; there were 14 other incandescent bulbs in the apartment, six 40 watt bulbs above the bathroom mirror. The blower door reading was 1910 cfm50, with leakage from the can lights, plumbing penetrations, the main entry door, and all seven windows predominating. The 1980's vintage refrigerator, an avocado-colored side-by-side 22 cubic model whose ice maker had failed years ago, measured 1845 kWh/year.

The annual gas bill from the landlord is $1300, corresponding to 1180 therms of gas at $1.10 per therm. The electric bill is $683 for 6205 kWh/year.

Retrofit work on 850 square foot apartment

Under the new gas and electric DSM program, the utility kicked in $120,000 to supplement weatherization funds to accomplish a thorough weatherization job on the four-building complex. At the building level, all of the old boilers were replaced with low-mass condensing units with turn-down ratios of 15:1. When fully turned down, the new boilers are rated at 97% efficiency, up from 78% for the old clunkers they replaced. DHW temperatures were set at 120F and modern circulation pumps turned off between 11 pm and 6 am. All shower heads in the complex, which averaged 3.2 gallons per minute, were replaced by 2.0 gpm units. Modern urethane pipe insulation replaced old insulation on supply piping for both DWH and heating, and Btu meters that sense both temperature and flows to apartments were installed and hooked up to Xcel's Smart Grid data loggers. Attics in the complex were prepared for insulation by sealing all penetrations, including plumbing, wiring, and can lights. Then two inch rigid insulation was used to form boxes over the can lights and to cover sky light wells. Finally, 10 inches of cellulose insulation was carefully installed over the existing fiberglass batts, bringing the overall R value of the attic to approximately R-45 from an estimated initial R-7. Properly insulated (R-13) and weather stripped attic hatches replaced the flimsy sheet rock hatches that were initially installed.

At the apartment level, detailed air sealing on the inside of the envelope was accomplished, and all seven windows were replaced with double glazed low-e vinyl windows, low end products that nonetheless have U values of 0.37 and are generally quite tight when closed. Exterior shading devices were installed on the two west-facing windows. The window-mounted A/C unit was removed and instead a through-the-wall evaporative cooler was installed in the master bedroom. It was equipped with a moveable insulator to cover it in the winter. The couple was impressed by the insulator, so designed one that would friction fit in the skylight well. They now use it to raise the R value of their skylight from 1 to 12 on winter nights, and to form a shade on hot summer afternoons. They store it under the bed when not in use.

The weatherization program also supplied the couple with a new 18 cubic foot ENERY STAR refrigerator rated at 350 kWh hours per year. It has a top freezer. All bulbs including the porch light were replaced with CFL's, 22 in all. The couple uses two power strips equipped with switches to turn off computer equipment and printers on the one hand and their entertainment center on the other. These phantom loads thus turned off amount to 32 watts. Keeping off 18 hours per day saves over 200 kWh per year!

As Table A-6 indicates, very substantial savings resulted from this retrofit.

Table A-6. Retrofit measures in 850 square foot apartment retrofit undertaken in response to an imagined RECO; consumption and savings per year

Energy Element	Retrofit Measure	As is (trm)	As is (kWh)	Retrofit (trm)	Retrofit (kWh)	Savings (trm)	Savings (kWh)	Savings ($)	Cost ($)	Pay-back (yr)	GHG Saved (m tons/yr)
Convective Losses	Seal envelope 1910 to 1020 cfm50	800	2	707	1	93	0	$102	$223	2.2	0.49
Attic Conductive	Insulate R 7 to R 45	236	0	36	0	200	0	$220	$969	4.4	1.05
Cooling	Evap Cooler		1658		491	0	1167	$128	$650	5.1	1.03
Space Cond Control	Set back stat 2F winter & summer	800	2	752	2	48	0	$53	$120	2.3	0.25
Thermal Retrofit Package	Includes interaction between measures	800	1661	477	494	323	1167	$484	$ 1,962	4.1	2.73
DHW	Lo flow, Ins pipes, temp lower 37F, adj circ controls	105	0	58	0	47	0	$52	$30	0.6	0.25
Lighting	22 CFLs, 5% duty		607		164	0	443	$49	$22	0.5	0.39
Frig	New 18 ft3 EN STAR		1845		350	0	1495	$164	$520	3.2	1.32
Plug Load	Timers & Strip SW		1000		800		200	$22	$35	1.6	0.18
Baseload Retrofit Package	Ignores tiny interaction	105	3452	58	1314	47	2138	$287	$607	2.1	2.13
Total first retrofit	Thermal + Baseload	905	5113	534	1808	371	3305	$771	$ 2,569	3.3	4.86

Other increments toward zeroing out the footprint could include somewhat heroic work on insulating the walls, perhaps with a combination of blown cellulose as possible over the batts the auditor’s IR scan indicated as being largely collapsed plus two inches of rigid insulation (like polyisocyanurate) covered with ½ inch dry wall. This would raise the R value from 7 to 19. Table A-7 shows the beyond RECO work on improving energy efficiency.

Table A-7. Beyond RECO retrofit measures in 850 square foot apartment retrofit undertaken beyond an imagined RECO; consumption and savings per year

Energy Element	Retrofit Measure	As is (trms)	As is (kWh)	Retrofit (trms)	Retrofit (kWh)	Savings (trms)	Savings (kWh)	Savings ($)	Cost ($)	Payback (yr)	GHG Saved (m tons/yr)
Sidewall conductive	Insulate R-7 to R-19	230	0	84	0	146	0	$161	$1,575	9.8	0.77
Windows	Replace 7 windows (84 ft2), insulate skylight	169	0	39	0	130	0	$143	$2,016	14.1	0.69

Heating Boiler	Replace 78% eff boilers w 95% eff	477	1	391	1	85	0	$94	$425	4.5	0.45
Thermal Retrofit Package	Includes interaction between measures	477	494	101	494	376	0	$413	$4,016	9.7	1.98
DHW Boiler	Replace 78% eff boilers w 95% eff	72	0	59	0	13	0	$14	$100	7.1	0.07
Baseload Retrofit Package		72	0	59	0	13	0	$14	$100	7	0.07
Total second retrofit	Thermal + Baseload	548	494	160	494	388	0	$ 427	$4,116	9.6	2.05
											0.00
Total both retrofits	All	905	5113	160	494	745	4619	$1,327	$6,685	5.0	7.99

Note that the two sets of retrofits have lowered this couple's energy bill from $1983 to $656, a savings of two thirds. If similar savings in energy are achieved throughout the apartment complex, installing solar systems will be substantially more cost effective. An active solar front end feeding large insulated tanks could be the source of both heat and DHW for the complex, using the new boilers as solar back up to occasionally feed the tanks during particularly cold periods with no sun. Finally, PV could be installed to net zero out net electric energy use in the complex.

Description of 980 square foot mobile home with four occupants

Mobile homes—manufactured housing equipped with wheels, electric brakes, and a yoke with a trailer hitch—are the only housing type currently governed by a single national building code, that of the Department of Housing and Urban Development (HUD). By in large, this has resulted in better quality homes, but that fact that they have to be sufficiently road worthy to be pulled by trucks from the factory to a site where they are set up means that they must be sturdy enough to survive the occasional pot hole, yet cannot weigh too much. The former means that a good deal of the key structure is made of steel I beams that are anything but insulators, and that there's not very much thermal mass in the homes. Further, just as refrigerator walls have become thinner to enable packing more food and drink into a given cubic footage, mobile home manufacturers routinely sacrifice wall thickness for living space. In the case of refrigerators, high-quality urethane insulation at close to R-10 per inch has saved the day. However, for mobile homes, R-3 per inch fiberglass batts are still the routine in the walls of most units, and even that can sag into much less effective insulation by the combination of road trips and warm moist air traversing the walls. The combination of low mass and poor insulation means that the time constant of mobile homes is much shorter than is the time constant of site-built homes. The analogy is the hot rod with poor shock absorbers; mobile homes heat up fast on hot summer days and cool down fast on cold winter nights; it's a decidedly bumpy ride that's far from comfortable—or efficient. Finally, low mass and poor insulation are routinely coupled with inefficient furnaces whose distribution systems are frequently quite leaky and poorly insulated.

Yet mobile homes are home-sweet-home for many people and properly retrofitted can become remarkably green, much more comfortable, and enjoy longer lifetimes with modest energy bills.

The home selected for illustration is a 70 foot long unit that is 14 feet wide. There are three bedrooms and two baths for the couple with a pair of children, a girl in high school and a boy in grammar school. They live in a mobile home park with a playground, friendly neighbors, and quite a few deciduous trees. The long axis of their home runs approximately east and west, leaving the south side with about 60% of un-shaded solar exposure. There is 110 square feet of glazing on the home, 40 square feet each on the north and south sides and 15 square feet on the two ends. All of the windows are single glazed units with aluminum frames; those on the ends are jalousie windows consisting of overlapping six inch wide glass louvers that can be cranked out to supply ventilation. Unhappily, they also tend to be leaky even when closed tightly for the winter, the primary reason those in the mobile home retrofit trade term them “jay lousy” windows.

The auditor funded from Xcel’s new gas DSM program examined the home and found that most of the usual places are leaky: the electric circuit breaker box, most plumbing penetrations, the jalousie windows, the space that is hard to get to behind the washer and dryer, and especially the supply ducts. A pressure pan reveals that leaks associated with the registers closest to the furnace are leakier than the others, strongly indicating that the supply plenum from the downdraft furnace itself is not fully connected to the middle of the duct work that runs the length of the mobile home. The auditor has seen this before. However, leakage from the register farthest from the furnace in the master bedroom is also quite substantial. A flashlight and a 45 degree angled mirror reveal that the end of the duct run was not properly sealed at the factory.

There are two air conditioners in the home, a 1.5 ton unit at each end.

There is not a CFL in the place, but there are 24 incandescents. The thermostat is a flimsy model that has no provision for automatic setback. Further, the hot water tank in the utility closet looks like it is on its last legs and is set to deliver water at 148F. The auditor is successful in suggesting that replacing the 3.2 gpm shower heads with 1.5 gpm models will enable the DHW system to be reset for 120F, particularly if shower time is limited to ten minutes or so. The parents agree to discuss the point of shower duration with their teen age daughter.

The mobile home has been in place for 25 years and the tires were sold 15 years ago. There is little likelihood that it will ever be moved ever again. (The average lifetime traveled of a mobile home from manufacturing plant to final destination is 300 miles.) Yet the skirting (sometimes called “underpinning”) of the home is thin, leaky, and largely useless at impeding the flow of winter winds. In the case of this mobile home, a sixty foot long heat tape is needed to keep pipes from freezing, and there is evidence that the home sometimes suffers frost heaving, a malady that contorts the mobile homes, shortens their lives, and makes doors hard to open.

Given these circumstances, the energy auditor suggests something rarely done with mobile homes; to couple the home to deep earth and to decouple it from the surrounding surface earth. Instead of flimsy skirting that stretches between the side of the home and the surface of the earth beneath it, the idea is to dig a trench around the home 3 to 4 feet deep and wide enough to accommodate 4 inches thick of a rigid board insulation rated for being buried in the earth (e.g. Styrofoam blue board). The board is placed all around the home, with care in sealing the joints, both between boards and between the top of the insulation and the bottom of the mobile home's wall. After back filling, the exposed portion of the insulation is covered with a rigid coating to protect it from the elements, ideally a material like grailcoat. (Note that after this treatment, the home will be air tight underneath, so combustion air to the furnace should come from the top of the home (as with more modern mobile home furnaces) instead of from the bottom.

What will be the result? Much better energy performance and comfort year around. Deep earth temperature in the city Boulder is about 52F. So instead of the bottom portion of the home, over 20% of its total area, being exposed directly to outside air temperature, it will "see" 52F or higher. Indeed, with this arrangement a thermal bubble will build up under the dwelling that will likely climb into the 60's after a year or so. This will not only limit convective losses, but also create much-needed thermal mass, thereby lengthening the time constant of the home. In addition, ducts under the floor of the home will function in a much more benign environment, thereby raising the system efficiency of the heating system and increasing the temperature of delivery air from the furnace, particularly at the ends of the supply duct run. Further, the home will never again frost heave or need heat tape to keep pipes from freezing. Indeed, even with no heat at all, the home will likely never get close to freezing, particularly in Boulder's climate where adequate sunshine for at least a modicum of passive solar heating is the rule for much of the winter.

Retrofit work on 980 square foot mobile home with four occupants

The home is air sealed as is the duct system. To accomplish the latter, the furnace is temporarily lifted from its place and the supply plenum is modified to accept a vee-shaped diverter to direct flow from the furnace down the two main trunks. The system is put in place and sealed with urethane foam. All risers are also sealed, and the open trunk is fitted with sheet metal, pop riveted in place, and caulked. Both shower heads are replaced with 1.5 gpm units, the hot water tank and pipes are insulated, and the thermostat is set at 120F. All 24 incandescents are replaced by CFLs and a new multi-setback space conditioning thermostat is installed. The four jalousie windows on the ends of the unit are fitted with insider storm windows made of 3/16 inch plexiglass. The units are secured by magnetic strips which seal completely, yet facilitate removing of the storms during summer months; they are stored under a bed. Both A/C units are removed. One space is insulated and sealed inside and out; the other is modified to accommodate a through-the-wall evaporative cooler. The mobile home's existing skirting is carefully removed and a trenching tool is used to dig a four foot deep, 5 inch trench all around the perimeter. Four inches thick of Blue board is installed. Finally, the roof is partially pealed to allow for blowing cellulose into the ceiling area to an average of 10 inches deep. The roof is rolled back into place and securely and sealed. A post-retrofit blower door reading is 1100 CFM50, down from 2450CFM50 before retrofit work. The electrical connection to the pipe heater is permanently disabled.

Table A-8. Retrofit measures in 980 square foot mobile home retrofit undertaken in response to an imagined RECO; consumption and savings per year

Energy Element	Retrofit Measure	As is (trm)	As is (kWh)	Retro-fit (trm)	Retro-fit (kWh)	Save (trm)	Save (kWh)	Save ($)	Cost ($)	Pay-back (yr)	GHG Saved (m tons/yr)
Convective Losses	Seal, ins ducts (80% to 94% dist eff)	1257	471	1069	401	188	71	$215	$1,456	6.8	1.05
Convective Losses	Seal envelope 2450 to 1020 cfm50	268	101	111	42	157	59	$179	$1,406	7.8	0.88
Attic Conductive	Insulate R-10 to R-38	200	75	52	20	148	56	$169	$823	4.9	0.83
Cooling	Evap Cooler		3900		1155	0	2745	$302	$650	2.2	2.42
Space Cond Control	Set back stat 2F winter	1257	471	1207	453	50	19	$57	$120	2.1	0.28
Thermal Retrofit Package	Includes interaction between measures	1257	4371	863	1479	394	2893	$752	$ 4,455	5.9	4.62
DHW	Lo flow, thermostat	215	0	120	0	95	0	$105	$30	0.3	0.50
Lighting	24 CFLs, 5% duty		663		179	0	484	$53	$24	0.5	0.43
Plug Load	Timers & Strip SW		1200		950		250	$28	$35	1.3	0.22
Clothes drying	Clothes Line 75%		800		200		600	$66	$20	0.3	0.53
Baseload Retrofit Package	Ignores tiny interaction	215	2663	120	1329	95	1334	$251	$109	0.4	1.67
Total first retrofit	Thermal + Baseload	1472	7034	983	2808	489	4227	$1,003	$ 4,564	4.5	6.30

Beyond RECO second phase retrofit work involves pealing the side walls and installing polyisocyanurate rigid board insulation in place of the old and mostly fallen fiberglass, raising the effective insulating value of the wall from R-8 to R-20. The windows on the north and south sides are fitted with exterior insulating shutters that may be opened or shut to optimize energy efficiency in all seasons. (In summer, they provide shade from direct beam sun; in winter, they turn R-1 windows into R-12 windows on cold nights.) In addition to diminishing conductive losses and improving comfort, the blower door reading indicated that when shutters are closed, the air leakage dropped to 830 CFM50.

Table A-9. Beyond RECO retrofit measures in 980 square foot mobile home retrofit undertaken beyond an imagined RECO; consumption and savings per year

Energy Element	Retrofit Measure	As is (trms)	As is (kWh)	Retro-fit (trms)	Retro-fit (kWh)	Save (trms)	Save (kWh)	Save ($)	Cost ($)	Pay-back (yr)	GHG Saved (m tons/yr)
Sidewall conductive	Insulate R-8 to R-20	327	123	131	49	196	74	$224	$1,630	7.3	1.10
Windows	Shutters plus Jalousie storms	134	1205	-11	689	145	516	$216	$2,450	11.3	1.22
Thermal Retrofit Package	Includes interaction between measures	863	1479	507	1046	355	433	$438	$4,080	9.3	2.25
Total both retrofits	All	1472	7034	507	1046	965	5989	$1,720	$8,644	5.0	10.35

Finally, in coordination with two dozen nearby neighbors in the mobile home park, the family participated in an experiment for a “Boulder Solar Front End Project” (BoSoFEP). In order to qualify, each of the participants had retrofit work akin that that on the home described, so that the demand for both electricity and gas was well less than half of that of the average mobile home in the park. A 75 kW PV array was installed, along with a solar thermal system consisting of 3000 square feet of collectors feeding a pair of super insulated 10,000 gallon tanks buried two feet underground. These fed a district heating system that supplied a heat exchanger to heat cold water showering and other hot water needs and a second heat exchanger that replaced the air-to-air heat exchanger in the furnace. This enabled turning off gas to these two appliances. With a clothes line used instead of the gas-fired clothes dryer for 75% of the time, gas usage became relegated to cooking only. A single gas-fired very efficient boiler served as back up to the solar front end whenever an extended cold period was associated with an extended period without sunshine. Meanwhile Xcel’s grid served as the back up to the PV system, resulting in better than net zero carbon footprint for the 25 mobile homes participating in the first Boulder Solar Front End Project.

Hopefully, there will be a number of others, both for mobile homes and a range of other housing stock in Boulder’s neighborhoods.

Appendix B

Sample RECO Legislation from Burlington, Vermont

This appendix is a reprint of the Minimum Energy Efficiency Standards Ordinance passed by the City of Burlington, Vermont in 1996. It is available on the web at www.burlingtonelectric.com/EnergyEfficiency/tos3.htm and is hereby reprinted with permission of Chris Burns, Director of Energy Services, Burlington Electric Department, City of Burlington, Vermont.

A simplified explanation about the workings of the energy ordinance from the property owner's perspective in "Q and A" form is available at www.burlingtonelectric.com/EnergyEfficiency/tos2.htm

That the Code of Ordinances of the City of Burlington be and hereby is amended by amending Chapter 18 to add Article VII thereto to read as follows:

ARTICLE VII

MINIMUM ENERGY EFFICIENCY STANDARDS ORDINANCE

Sec. 18-500. Title.

This article shall be known as the Minimum Rental Housing Energy Efficiency Standards Ordinance.

Sec. 18-501. Statement of findings and purpose.

A. There exist in the City of Burlington numerous dwellings which are substandard due to the lack of adequate insulation and other thermal performance defects that cause the inefficient use of energy to heat the dwellings. Such substandard dwellings may compromise public health, safety and welfare.

B. The efficient use of energy is essential to the economic security and well being of the people of the City of Burlington. Significant opportunities do exist to reduce energy consumption which will result in the lowering of housing costs, stimulation of the local economy and creation of local jobs. Buildings which require improvements to meet these minimum energy efficiency standards may require investments by buyers or sellers. This ordinance is designed to allow property owners to pass on the cost of energy improvements to tenants through increases in rents and any increase in rent that may result from such investment is expected to be offset over time by reductions in energy bills.

C. The purpose of this ordinance is to promote the wise and efficient use of energy through cost effective minimum energy efficiency standards for rental dwellings where physically possible.

Sec. 18-502. Applicability.

A. This article shall be applicable to all rental properties subject to the Minimum Housing Code. In mixed commercial/residential buildings this article shall apply only to the residential portion of the building. This article shall not apply to owner-occupied portions of a multi-unit building.

B. The following properties shall be exempt from meeting the requirements of this article:

1. Rental properties not rented between November 1 and March 31 of each year.
2. New construction subject to and in compliance with the Energy Conservation Ordinance, B.C.O. Sections 8-100 to 8-104.
3. Hotels, motels, tourist rooming houses, dormitories, hospitals, hospices and nursing homes.
4. Buildings or apartments where heating costs are paid by owners of the rental properties.

Sec. 18-503. Certificate of Minimum Energy Efficiency Standards compliance required.

A. Upon transfer of a rental property where there is a deed recorded, an inspection report signed by a Vermont licensed mechanical engineer, or an inspector certified by the program administrator, must be filed with the city clerk when the deed is recorded in the land records. The inspection report shall either include a certificate of energy efficiency compliance, if the standards of this article are met, or list the standards not met and inform the property owner that the required energy improvements must be made within one year of the date of transfer. An inspection report and certificate shall not be required for the following transfers:

1. transfer of property for no or nominal consideration, including inheritance;
2. transfer of property as part of a divorce settlement;
3. involuntary transfers of property including foreclosures, bankruptcies, condemnations and tax sales.

B. Extension Stipulation. An extension stipulation to extend the time for the filing of a certificate for a period of time not to exceed two years may be granted by the program administrator where the cost of making energy improvements needs to be spread over more time due to financing constraints.

C. Cost Effectiveness Limitation. Notwithstanding the above, no property owner shall be required to make any specific energy improvement where the cost of making the improvement is greater than seven times the calculated first year savings in energy costs attributable to the improvement. All such calculations must be verified by a Vermont licensed mechanical engineer or an inspector certified by the program administrator.

D. Total Cost Cap. The total cost of energy improvements required under this article shall not exceed 3% of the sale price of the property listed on the property transfer tax return or $1,300 per rental unit, whichever is less.

E. Not withstanding the above, no property owners shall be required to make any specific energy improvement when the specific energy improvement would compromise building integrity or otherwise adversely affect the health or safety of the building occupants. Such a determination shall be made by the program administrator and the city engineer.

F. Waiver.

1. The program administrator shall grant a waiver for rental properties to be demolished or converted to a non-residential use within one year of the date of transfer.
2. The program administrator shall grant a waiver to the owner of a rental property that cannot obtain financing for energy improvements required under this Article. In order to secure such a waiver, the owner must document and prove that good faith efforts to obtain financing have been unsuccessful, including following up on assistance from the program administrator.

G. All forms necessary for administration of the program shall be provided by the program administrator.

Sec. 18-504. Inspection and certification of rental properties.

A. Inspectors.

1. Energy inspections required pursuant to this ordinance must be conducted by Vermont licensed mechanical engineers or inspectors certified by the program administrator and the city engineer. Fees for such inspections shall not be regulated by the program administrator.
2. The program administrator shall promulgate rules and standards for certification and decertification of inspectors, provide periodic training and administer testing to qualify prospective inspectors.

B. Certification of Rental Properties.

1. The inspector shall complete an inspection report on a form provided by the program administrator which shall indicate compliance or noncompliance with the minimum energy efficiency standards of this article. The original inspection report shall be given to the property owner, with a copy to the program administrator.
2. If the minimum energy efficiency standards are not all met, the inspection report shall list the standards not met and inform the property owner that the required energy improvements must be made within one year of transfer of the property.
3. When all the minimum energy efficiency standards are met, the inspector shall prepare and sign a certificate of energy efficiency compliance and provide the original to the property owner, with a copy to the program administrator. The program administrator shall file a copy of the certificate with the city clerk.

Sec. 18-505. Administration of energy efficiency ordinance.

The general manager of the Burlington Electric Department shall be the program administrator for the Minimum Rental Housing Energy Efficiency Standards Ordinance. The program administrator may take such measures as are necessary for the proper administration of this ordinance. The program administrator may delegate his/her powers and duties under this ordinance to an appropriate administrator within the department. The program administrator may charge an administrative fee of $15 per building payable at the time of recording a deed transferring a rental property except in situations where no inspection report is required.

Sec. 18-506. Appeal.

A party aggrieved by an action of an inspector or the program administrator may request a hearing before the Housing Board of Review pursuant to Division 2, Article II of Chapter 18 by writing the program administrator within sixty (60) days from the action from which relief is sought. The request shall specify the grounds for the appeal and the relief which is requested. The program administrator shall notify the chair of the Housing Board of Review of the receipt of the notice of appeal forthwith.

Sec. 18-507. Enforcement and penalties.

Any violation of this article shall be subject to civil penalties as set forth in Section 1-9(b). Prior to filing a municipal complaint, the program administrator shall send a notice of violation to the property owner. Each day's failure to comply with the minimum energy efficiency standards as required by this article shall constitute a separate offense. The general manager of the Burlington Electric Department and designated administrators within the department are authorized to issue a municipal complaint for a violation of this article.

Sec. 18-508. Minimum energy efficiency standards.

A. Definitions. For the purposes of this section, the following terms, phrases, words and their derivations shall have the meanings given herein:

1. A "heated space" means any living space within the exterior boundaries defining the building into which heat is intentionally introduced during the heating season.
2. "Attic" means the volume, if any, between the roof and the ceiling over the interior finished space nearest the roof.
3. "Box sills" shall be defined as the cavity created by the floor joists resting on the foundation, and the outer band joist.
4. "Roof" means the surface on the top of a building which separates the building from the outdoors.
5. "Exterior walls" means all walls separating the heated space of the building from the outdoors, or from spaces typically having temperatures during the heating season which approximate outdoor temperatures.

B. Standards. These minimum energy efficiency standards shall apply where physically possible and cost effective as provided in Sec. 18-503C. and Sec. 18-503D:

1. Insulation of Exterior Walls. All exterior walls with an existing overall effective insulation value of less than R-11 and enclosing an empty cavity of over 2" in depth shall have insulation added to achieve an R-11 overall effective insulation value. In cases where there is insufficient space to add insulation to the R-11 level, as much insulation shall be added as will fit.
2. Insulation of Open Attics/Ceilings/Roofs.

    a. If existing insulation in open attics (an attic which is unfloored) provides less than an average effective value of R-15, insulation shall be added to bring the average effective insulation value to an R-40 level. In cases where there is insufficient space to add insulation to the R-40 level, as much insulation shall be added as will fit.
    b. The space under the flooring of an unheated floored attic shall be filled with insulation, not to exceed R-40. (See Section 1. above.)
    c. Horizontal attic access panels shall be insulated to an R-20 level.
    d. Vertical attic access panels shall be insulated to an R-10 level.
    e. "Sloped roof cavities" (including "cathedral" ceilings) and knee walls shall be treated as exterior walls. (See Section 1. above.)

3. Insulation of Other Areas.

    a. Box sills shall be insulated on either the inside or the outside of the band joist to an overall effective R-10 level.
    b. Floors over basements, crawl spaces, outdoor spaces or spaces typically approximating outdoor temperatures during the heating season, shall be insulated to an overall effective R-19 level unless:

        i. they are already insulated to an overall effective R-11 level or greater, in which case no additional insulation is required;
        ii. the basement contains equipment used for space heating, in which case no insulation is required;
        iii. the floor assembly encloses a space, in which case the floor shall be treated as an exterior wall (see Section B above); or
        iv. the basement or crawl space is not vented to the outdoors, in which case an alternative method of compliance is to insulate the perimeter of the foundation above grade, and at least two (2) feet below grade, to an overall effective R-10 level.

    c. Electric water heaters shall be insulated to an R-10 level.

4. Heating/Cooling Ducts and Piping, and Domestic Hot Water Piping

    a. All accessible space heating/cooling ducts in basements or crawl spaces with insulated ceilings, or in attics, shall be insulated to an overall effective R-10 level if less than an effective R-5 level currently exists. Ducts in unheated attics shall have any visible leaks sealed with proper duct mastic prior to insulation.

b. All accessible space heating/cooling piping in basements or crawl spaces with insulated ceilings, or in attics, shall be insulated to an overall effective R-4 level if less than an effective R-2 level currently exists.
c. All accessible domestic hot water piping which is part of a pumped circulating loop in basements or crawl spaces with insulated ceilings, or in attics, shall be insulated to an overall effective R-4 level if less than an effective R-2 level currently exists.
d. All accessible domestic water piping (both hot and cold) within nine feet of the domestic hot water tank shall be insulated to an overall effective R-4 level if less than an effective R-2 level currently exists.
e. Operation of the heating or cooling air distribution system shall not induce a pressure differential of more than 2 pascals between the conditioned space and the outdoors, as measured after any other energy improvements are completed.

5. Windows and Doors.

a. All windows in exterior walls shall be double-glazed or provided with storm windows during the heating season.
b. All operable windows in exterior walls shall have functioning latches which close windows tightly.
c. All doors and access hatches opening to the outdoors, or to spaces which typically approximate outdoor temperatures during the heating season, shall have functioning weatherstripping and latches which close doors tightly.

6. Air Leakage. All residential buildings shall have

a. a leakage rate no greater than 1,500 cubic feet per minute at a pressure differential of 50 pascals as tested with calibrated pressurization (or depressurization) air flow measurement equipment; or
b. a projected natural air leakage rate which is no greater than .6 average annual air changes per hour as calculated by accepted professional practice approved by the program administrator.

Application of this standard shall not require more than that large gaps and holes be sealed to achieve a reasonable airtightness level.

7. Combustion Appliances and Equipment.

a. All combustion appliances and equipment shall have been tested for operational safety within 12 months, before or after the title transfer date. All health and safety deficiencies identified during such tests shall have been corrected.
b. All components of a heating system including any pumps, motors, and controls shall be in good operating condition.
c. The heating system shall be adequate to heat all living spaces as required and defined by the City of Burlington's minimum housing code.

Sec. 18-509. Implementation.

The effective date of the requirements under this article shall be six (6) months after city council passage of the ordinance, provided that this article shall not become effective unless the program administrator certifies that there are financing sources available for energy improvements required under this article.

Sec. 18-510. Report.

Reports on the impact of the ordinance shall be prepared by the program administrator six (6) months and eighteen (18) months after implementation of the ordinance. The report shall be presented to the board of electric light commissioners, the public works commission and the City Council.

Sec. 18-511. Phase-in.

The requirements of this article shall be phased in with the requirements initially applicable only in the Enterprise Community as designated by the U.S. Department of Housing & Urban Development. A phase-in approach will provide an opportunity to study the impact of the article. The initial applicability will be in the Enterprise Community as that is the area of greatest need with the largest concentration of low-income tenants and where heating costs are the most burdensome on tenants.

The applicability of the requirements of this article shall be expanded to the rest of the City one month after the City Council receives the 18-month report. During the intervening month, the City Council may do nothing, repeal, halt or postpone expansion or consider amendment of this article.

* Material in brackets deleted.
** Material underlined added.

Appendix C

Residential and Commercial Energy Conservation Ordinances

This appendix a reprint of a report prepared by the Southwest Energy Efficiency Project (SWEEP) in April 2008; permission to reprint was granted by SWEEP's Executive Director, Howard Geller. It gives a brief history of the both residential and commercial energy conservation ordinances in the cities and states where RECOs have been passed, both programs that are presently functional and those which have been abandoned for one reason for another. It contains a helpful reference section at the end. This is followed by tables showing prescriptive measures required by RECO legislation in Berkeley, Burlington, San Francisco, and Wisconsin. These are reproduced from a draft of "Consideration of a Residential Energy Conservation Ordinance (RECO) for Boulder, Colorado" by Rachel Reiss, June 20, 2007. (Reiss, 2007)

Southwest Energy Efficiency Project

Saving Money and Reducing Pollution through Energy Conservation

Residential and Commercial Energy Conservation Ordinances

Overview

Common policy tools used by many state and local governments to reap energy savings include energy codes that specify minimal level of energy efficiency in new residential and commercial construction and major renovations of existing structures. However, other existing homes and buildings outside the reach of adopted energy codes continue to be less efficient than they otherwise could be through the utilization of widely-available and cost effective
energy efficient technologies.

Another concern is rental housing, where landlords typically don't have an incentive to invest in energy efficiency improvements because their tenants pay for the heating and cooling costs. As a result, these properties tend to become the most inefficient in a community. Finally, many communities are looking for effective policies and programs to become better environmental stewards and curb global warming, reduce greenhouse gas emissions and improve local air quality.

To address these issues, a few state and local governments have passed residential energy conservation ordinances (RECO), while one city adopted a commercial energy conservation ordinance (CECO).

RECOs and CECOs are policies designed to improve the level of energy efficiency in existing homes and buildings to minimum standards. Traditionally, these ordinances require home and building owners to comply with prescriptive energy efficiency measures at time-of-sale or during an inspection process. Most include spending limits to lessen financial obligations and allow a year for compliance. Recently, a trend is forming towards a performance-based approach to capture energy savings data, which is not currently tracked with the prescriptive-based approach.

Status of RECOs and CECOs

Analysis included a review of policies passed in five cities and two states:

- Ann Arbor, MI
- Burlington, VT
- Berkeley, CA
- Davis, CA
- San Francisco, CA
- Minnesota
- Wisconsin

Berkeley, CA is the only known city who has adopted both a RECO and CECO.
Only four ordinances are active - Burlington, Berkeley, San Francisco and Wisconsin, while others have been repealed, nullified because of state policies, or simply not enforced. The details of each program are described below.

Berkeley, California
The city of Berkeley, California adopted a RECO in 1987 and a CECO in 1994. The RECO applies to all residential properties sold or undergoing renovations of a value more than $50,000. Meanwhile, the CECO applies all non-residential buildings that is either sold or renovated with a value more than $50,000 or addition more than 10% of conditioned space. In both cases, the seller must comply before the title transfer of the property, but responsibility can be transferred to a buyer (but only for one time). Then compliance must be met in one year for the RECO and 15 months for the CECO.

The Energy Office oversees the program, but has contracted with a non-profit organization, the Community Energy Services Corporation (CESC), to serve as the only authorized inspector of the properties for compliance. However, commercial properties owners can opt to complete a "self-audit" with knowledgeable experts on staff or other contractors. Inspection costs and filing fees are outlined in the table below:

Table 1: Filing and Inspection Fees for Berkeley, CA

	RECO	CECO
Filing fees		
Certificate of Compliance	$15	
Audit Fees *(applies to commercial property only)*		
Less than 30,000 sq ft		$180.00 - $250
Greater than 30,000 sq ft		$0.01 - $0.02/ sq ft
Inspection Fees		
Renovations	Included in cost of construction permit fees	
Sale or ownership transfer	$100, plus $50 for each additional unit	$90
Re-inspections	$50, plus $25 for each additional unit	$70
Appeals Fee		
First Measure		$50
Each additional Measure		$15

The prescriptive measures are described in Attachments A and B and include requirements for insulation, weather-stripping, lighting and water efficiency. The spending limits for RECO is:

0.75% of the sale price of a single structure, or
0.75% of the sale price of each building when property with more than one structure with 2 or less housing units, or
$0.50 per square foot for any one structure with 3 or more housing units, or
1% of renovation costs of a renovation with a value more than $50,000.

The spending limit for the CECO when applied to the sale of property is the lesser of $150,000 or 1% of the property's sale price or assessed value prior to sale. For a renovation, the limit is the lesser of $150,000, or 5% of the total construction cost of the addition, or 1% of the assessed value of the entire building before renovation.

The Energy Office enforces the ordinances by tracking the weekly listings of properties for sale and preventing owners in willful non-compliance from transferring the property to the buyer. A lien may be placed on the property to stop the sale, but it has never happened (as of March 31, 2008).

Alice LaPierre, Building Science Specialist with the Energy Office, reports that 10 hours per week of staff time are allocated to the energy ordinances, and income from filing fees offset the expense. Audits and inspections are contracted to the third party (CESC), who collects their fees directly from the clients.

The city focused training on real estate agents and title companies, so they can pass the information on to sellers and buyers. Information was sent to agents, one-on-one meetings were organized at individual offices, and speaking engagements were conducted at association's meetings. Initially, the real estate community was a challenge in accepting the energy ordinances, but they are no longer a problem after 20 years of implementation. There were also no major objections from landlords because fewer complaints were received from tenants.

To date, more than 44,000 housing units have participated. Energy and cost saving data has not been collected because no direct comparison can be made between the seller, who usually completes the prescriptive measures, and buyer, who has different living habits, appliances, and number of household members.

Currently, the city is looking into revising the ordinances with requirements for performance-based measures to include duct testing and blower door testing. Measureable data would be recorded and an energy-related rating could be linked to the home or building. However, the real estate community is voicing their concerns. The city is also working with the cities of Oakland and San Francisco on a regional program.

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Burlington, VT
In 1997, the city of Burlington, Vermont adopted the "Time of Sale Energy Ordinance," which applies during the sale of rental housing built before August 1, 1991 and where tenants pay for the heating bills. Responsibility is negotiated between the seller and buyer. One year is allowed for compliance.

The Burlington Electric Department, the city's municipal utility, administers the program and the income received from filing fees offset staff time and other expenses. Inspections are provided by private inspectors certified by the city or a Vermont licensed mechanical engineer. The city does not regulate inspection fees, but they have averaged $75 - $100 per unit. A filing fee with the department is $30 per building.

The prescriptive measures are described in Attachment A and include measures for insulation, weather-stripping, windows, and combustion equipment. The spending limit is the lesser of $1,300 per residential unit or 3% of the sales price.

The Burlington Electric Department also enforces the ordinance by following the sale of properties and maintaining a database that tracks the homes in the various stages towards compliance. Letters are sent to owners to notify them of the ordinance requirements. A civil approach is preferred by providing flexibility for owners to comply if he/she communicates and works with the city. Otherwise, penalties are applied for delinquents and liens may be placed on the property.

The Burlington Electric Department general manager or program administer has some flexibility in managing the program based on how the ordinance was written. For example, the department may use a building's energy performance data to determine compliance. The city found that 60% of buildings subjected to the ordinance are already performing at or above the minimum level of energy efficiency, even though all the prescriptive measures may not exist in the building. Determination is made by calculating the space heating use per square foot from the annual utility bills.

Chris Burns at the Burlington Electric Department made the point that a strong relationship with the local utility is important. Nearly 98% of the buildings affected by the ordinance use natural gas as a primary heating fuel, and initially, since they are required by the city to perform energy efficiency, these homes did not qualify for any of the demand-side management programs offered by Vermont Gas. And to reduce costs, many owners tried to install the required energy efficiency measures themselves without using a professional, but ended up not meeting the minimum standards and were in non-compliance. Thus, the city mandated the use of experts for installing the energy efficiency measures, which increased costs to owners.

To overcome the financial issues, the city worked with the local utility, Vermont Gas, to develop an agreement that allows buildings, which must comply with the ordinance, to be eligible for the utility's incentive and financing programs. Then homeowners can either opt to install the prescribed measures with a professional, or participate in the utility's gas weatherization program that includes a free audit. Even though the recommended energy efficiency improvements by the utility may exceed the level in the ordinance, owners have found it more cost-effective to work with Vermont Gas because they provide rebates representing a third of the installed cost of recommended measures and a reduced interest loan through a local bank on the remaining balance.

No formal training was conducted for realtors, inspectors or other professionals. Informational meetings were held to provide program details and respond to questions and "reminder" packets are mailed out each year. The real estate community was slow to accept, but are agreeable now since the ordinance is a part of what they must work with in selling property.

In the next year or so, the city will consider revising the ordinance by increasing the level of energy efficiency required. Energy costs are rising and stricter standards for insulation and HVAC improvements may become more cost-effective (still meeting the ordinance's stipulation for all measures to have a 7-year payback).

For more information:
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San Francisco, California
In 1982, the city of San Francisco, California adopted a RECO. It applies before the sale of single and duplex homes, apartment buildings, individual condominium units, residential hotels, but also triggered for any major renovations with a greater value of $20,000 for single and duplex homes, $6,000 for apartments and condominiums, and $1,300 per unit in residential hotels. Compliance must be met by the owner before the title is transferred to the buyer, or if an agreement is made between the seller and buyer, then the buyer has 180 days after date of title transfer to comply.

The Department of Inspection manages the program and handles inspections. A private inspector, who is certified by the city, may also perform inspections. Filing and inspection fees are described in the table below.

Table 2: Filing and Inspection Fees for San Francisco, CA

	Single & Duplex Homes	Apartments & Condominiums
Filing fees		
Compliance Energy Reports & Certificates	$10	
Appeals	$43.05	
Certification for Inspectors	$20.50	
Inspection Fees		
Initial Inspection	$52	$58.30-$116.55
Compliance Inspection	$26	$28.60 - $58.30

Prescriptive measures are described in Attachment A and include requirements for insulation, weather-stripping, combustion equipment and water efficiency. The spending limits is $1,300 for single and duplex homes, condominiums, apartments, and 1% of the assessed value or sale price for buildings with 3 or more units.
The department of inspection is also responsible for enforcement, but the ordinance has been primarily self-policing, requiring no official action by the city. The local real estate community is requiring the RECO inspection to be disclosed in terms of sale to buyers. If not done, then the seller and buyers work out a civil agreement. Since 1989, the city reported 71,103 residential properties have been inspected and complied with the ordinance.

The costs have been minimal to the city in managing this program. The income from fees cover the expense for a clerk to receive and process inspection and compliance reports and also time for management information system experts in developing and maintaining an electronic database. The majority of inspections have been handled by private inspectors, who cover costs from their own fees charged to customers. So there has been little impact on department resources in administering the ordinance, but it has been a challenge to ensure all private inspectors perform standardized RECO inspections.

Overall, reactions to the ordinance have been positive with few complaints received by the Department of Inspections, but this may be due to the less stringent measures required by San Francisco when compared to other jurisdictions.

Patrick McKenzie commented that "in light of the present day concerns over global warming, sky rocketing energy costs coupled with a more cultural acceptance to the green movement, property owners are more receptive to energy cost savings and a cleaner environment." The RECO is considered a cost-effective strategy to tackle these issues. Unfortunately, no performance data has been collected for analysis since the ordinance never required it. Moving forward, the city is reviewing it and planning revisions, including an increase in the spending limits for energy conservation measures.

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Wisconsin

In 1985, the state of Wisconsin passed their version of the RECO called the "Rental Weatherization Program." It applies to any residential property when its ownership is transferred and when its use, after the sale, will be rental. Specifically, single and two family homes are affected if built before December 1, 1978 and also residential buildings with 3 or more dwelling units built before April 15, 1976. Exempted properties include the primary residences of owners, condominium buildings with three or more units, mobile and manufactured homes, hotels, and any rental units and second homes which are unoccupied between November 1 and March 31. The seller must comply, unless responsibility is transferred to the buyers and then one year is allowed for compliance.

The Department of Commerce manages the program with a full-time staff person to receive and process the compliance reports. Private inspectors who are certified by the state perform the inspections for compliance and recoup their costs through the fees charged directly to customers. However, the state establishes a ceiling on the maximum amount charged for inspection fees. Costs are covered through inspection and filing fees as listed in the table below.

Table 3: Filing and Inspection Fees for Wisconsin

Buildings with number of	1 – 8 rental units	More than 8 units
Filing fees		
Certificate of Compliance	$50	
Inspection Fees		
Compliance Inspection	$200, plus $50 per each additional unit over two	$500, plus $25 for each additional unit

On February 21, 2008, the state adopted changes to the Rental Weatherization Code, with May 1, 2008 as the effective date. A stipulation and waiver fees were eliminated. The fee for Certification Stamp used by inspectors to validate certificates of compliance was increased from $20 to $30. The state feels that the fees now collected more closely equal the cost of providing the services outlined in the code. Another change is a reduction in the number of departmental reports required to show compliance.

Prescriptive measures are described in Attachment A. There is no spending limit, so owners must meet all required measures. However, an owner may get an exemption from a specific weatherization measure if the payback takes more than 5 years. However, this stipulation may be eliminated in the proposed revisions because the minimum technical requirements are already based on achieving a 5-year cost payback and compliance is based on the lifetime of the building. The exemption is not within the code's intent.

A significant revision to the existing ordinance is the inclusion of performance-based energy efficiency requirements as an alternative option to prescriptive measures. Owners can comply with the code by choosing to meet the standards of space heating energy use as described in Attachment A. Thus, an owner may elect to utilize other measures not specified in the code. The determination of annual space heating energy use per square foot will be performed and verified by a state-certified inspector.

In late 2007 as part of the review of the code, the Department of Commerce requested public input and received mailed-in comments on proposed changes. Home inspectors associations wanted the ceiling limit on inspection fees to be raised and encouraged more education and outreach with the real estate community. Several comments addressed enforcement, since many believed there are thousands of delinquent properties because owners can easily pay a small fee to get a stipulation where the buyer takes responsibility to meet compliance within a year. Many voiced concerns over the proposed change to eliminate this fee, fearing more people will opt to obtain a stipulation; thus, avoiding compliance by completing a simple form and never planning to complete the energy efficiency requirements. Instead, they felt the fee should be raised to encourage added pressure to the sellers, mainly from buyers, to complete the requirements. The department responded that they are continuing "to work on eliminating the unsatisfied stipulations" including eliminating the transfer of responsibility on outstanding stipulations to future buyers.

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Inactive RECOS

Three jurisdictions have RECOS that have been repealed, nullified or no longer being enforced. Below is a description on these inactive programs in Ann Arbor, MI, Davis, CA and Minnesota.

Ann Arbor, Michigan

In 1985, the city of Ann Arbor adopted the "Basic Winterization in Rental Housing" ordinance that applied to all rental housing built before 1977 and where tenants pay the heating and cooling costs. Prescriptive measures included sealing of all cracks and gaps in the building envelope, insulation in attic of R-30 (unless R-19 currently exists and satisfies the code). Penalties for non-compliance were charged for $1 - $100 at the discretion of the court, but the maximum fine for first offense was $50.

The city also passed an ordinance on notification of utility bills to potential tenants. The landlord is required to provide a 'budget plan' that consists of a projection of monthly utility costs for the primary heating fuel as prepared by the utility.

Although thess ordinances still exists in the municipal code, they are not being enforced. Andrew Brix with the Ann Arbor Energy Office originally stated that the RECO ordinance was nullified by the statewide energy code, but he is investigating the limits of the state energy code and how it impacts the RECO. He also stated that the ordinance which mandated the notification of utility information to tenants is not being enforced. No results or performance data was recorded.

Davis, California

In 1990, the city of Davis, California adopted the "Energy Conservation Retrofit Regulations" for residential property built October 15, 1975. The seller was to comply, but may transfer responsibility to the buyer, who then had 90 days from date of sale.

The above information was provided by the DOE's ***Sustainable Buildings Network,*** but did not include specific energy efficiency measures covered in the ordinance. Furthermore, the city of Davis municipal code no longer includes the ordinance. The city staff had no knowledge of the ordinance and believed the state energy code may have nullified it.

Minnesota

In 1980, the state of Minnesota adopted the "Energy Standards for Rental Properties," which applied to all renter-occupied property constructed before January 1, 1976.
Prescriptive measures included weather-stripping, caulking or sealing exterior joints, installation of storm windows and doors, and insulation of accessible attics (R-19) and walls and floors (R-11). The statute included the flexibility for owners to select between two options, depending on the type of building, for either installing specified prescriptive measures or a combination of installing prescriptive and performance based measures. The performance-based measures had to achieve a cumulative energy consumption savings of

25 – 30% and determined by a certified auditor, engineer or architect.

The Minnesota Energy Office administered the program. Enforcement was made in the courts with judgments made by administrative judges on the demonstration of “good cause” by owners in complying with the statute. Fines could be assessed for 1-4 unit buildings between $100 plus $200 each month after 120 days of ruling, or for building owners of 5 or more units, a maximum fine of $500.

The statute included funding for 1.5 years, but the legislature cut the funding due to budget constraints. In 1983, funding was reinstated to provide for 4 employee positions, including a supervisor. The plan was to adopt administrative rules to operate the program followed by implementation. However, the state faced additional budget deficits, funding was once again cut, and never reinstated for 20 years since.

The statute was revised to allow municipalities to adopt the rules, but it effectively repealed the program statewide. Phil Smith, energy specialist with the Energy Office, commented that the program was a “dismal failure.” He stated that staffing to deliver the program by a state agency is “most impractical” and the “least efficient use of resources.” He felt enforcement is key and in order to be most effective, this policy should be incorporated into state building codes or statutory incorporation into local building codes, or placement in the “Covenants of Habi tability” addressing rental of dwellings. Municipalities are often more aware to prevent inhabitable living conditions and in the best position to incorporate and enforce RECOs into their building codes.

This paper was researched and written by Christina Panoska at SWEEP.

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The following are four tables of prescriptive measures by city from a draft of “Consideration of a Residential Energy Conservation Ordinance (RECO) for Boulder, Colorado” by Rachel Reiss, June 20, 2007.

Berkeley	
Toilets	1.6 gal./flush toilet, or flow reduction devices
Showerheads	3.0 gal./min. flow rate
Faucets	2.75 gal./min. flow rate for kitchen and bathrooms
Water Heaters	Insulation wrap of R-12 value
Hot & Cold Water Piping	Insulate first two feet from water heater to R-3 value
Hot Water Piping in Pumped, Recirculating Heating Systems	Insulate all piping to R-3 value
Exterior Door Weather-Stripping	Permanently affixed weather-stripping, and door sweeps or door shoes
Furnace Duct Work	Seal duct joints, add insulation wrap to R-3 value
Fireplace Chimneys	Dampers, doors, or closures
Attic Insulation	Insulate to a minimum of R-30 value
Common Area Lighting (multi-unit buildings only)	Replace incandescent with compact fluorescent lamps (CFL) of at least 25 lumens per watt

Burlington	
Exterior wall insulation and sloped roof cavities	R-11 or as much as will fit
Attic insulation	R-40 or as much as will fit
Horizontal attic access panels	R-20
Vertical attic access panels	R-10
Box sills insulation	R-10
Electric water heater insulation	R-10
Floors over basements, crawl spaces, outdoor spaces insulation	R-19*
Ducts in attics insulation	R-10 if less than R-5 exists
Ducts in unheated attics	sealed with proper duct mastic
Space heating and domestic hot water piping insulation	R-4 if less than R-2 exists
HVAC distribution system pressure differential	less than 2 pascals between conditioned space and outdoors
Windows	Double-glazed or storm windows
Operable windows	Functioning latches which close windows tightly
Doors and hatches to outside	Functioning weatherstripping and latches which close doors tightly
Air leakage rate	No greater than 1,500 cfm at 50 pascals or less than 0.6 average air changes per hour
Combustion appliances and equipment	Tested for operational safety and corrected deficiencies within 12 months of the title transfer date
Heating system components	In good working order
*unless already has R-11, the basement contains no equipment used for space heating, or the basement or crawl space isn't vented to the outdoors	

San Francisco	
Attic insulation	R-19; existing R-11 is deemed acceptable
Weatherstrip	All doors leading from heated to unheated areas
Insulate hot water heaters	R-6 jacket on heater and the first 4 feet of hot water line insulated to R-4
Low-flow showerhead	Maximum 2.5 gallons per minute
Reduce infiltration	Caulk and seal cracks in building exterior greater than 1/4 inch wide
Insulate ducts	R-3 insulation for all heating and cooling ducts and not sealed with duct tape
Faucet aerator	Sinks designed to accept aerators are to be equiped with a flow restrictor
Low-flush toilets	3.5 gallons per flush or less, or retrofitted to use less gallons per flush
Clean and tune boilers	Repair boiler leaks and time clock control on the burner

Wisconsin	
Building Element	**Amount of Insulation**
Attics:	
If currently R-0 to R-10.9	bring to R-38 level
" " R-11 to R-18.9	add R-19
" " R-19 or more	no action needed
Box sills:	
If currently R-0 to R-2.5	bring to R-19
" " R-2.6 to R-10.9	then
" " R-11 or more,	no action needed
Heating supply ducts located in vented spaces	R-5
Steam heating pipes in vented space	R-4

Appendix D

References

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