ENVIRONMENTAL BENEFITS OF ENERGY EFFICIENCY: IMPACT OF WASHINGTON STATE RESIDENTIAL ENERGY CODES ON GREENHOUSE GAS EMISSIONS

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Scientific evidence developed over the past decade strongly suggests that the concentration of carbon dioxide in the earth's atmosphere is increasing, quite probably as a consequence of our ever increasing reliance on fossil fuels. Climate models predict that increasing concentrations of carbon dioxide may contribute significantly to future disruptions in the earth's climates, with possible disastrous implications. To respond to this environmental threat, national and international scientific and policy making bodies have called for efforts to reduce the rate carbon dioxide is added to the atmosphere.

Among the strategies available to achieve this goal, improvements in energy efficiency offer unique advantages. Many investments in energy efficiency are justified on conventional economic grounds, even before environmental costs and benefits are considered.

This paper examines the environmental benefits and the consumer economics of residential building energy codes in Washington State. Since 1978 Washington State has enforced insulation standards for new homes. These standards have improved space heating efficiency by up to 60 percent. Performance monitoring and collection of incremental construction costs demonstrate that the standards are consumer cost-effective for both electric and natural gas heated homes. In addition, projection of housing starts through 2005 indicate that by that year the standards will have reduced annual carbon dioxide emissions from Washington State by 3.3 million short tons (2000 lbs.) per year. This represents approximately 4 percent of the annual energy related carbon dioxide emissions currently made by the state.

INTRODUCTION

The relationship between energy policy and environmental quality has become increasingly apparent over the last decade. A growing body of information and scientific consensus links our reliance on fossil fuel energy with both the acidification of rainfall and the increased concentration of atmospheric greenhouse gases. A similar consensus exists concerning damage to the earth's upper atmosphere and our reliance on man-made chlorofluorocarbons (CFCs) in a variety of energy related processes including refrigeration and insulation (for example, see DOE 1989 and Krause 1989).

In response to the widespread and global implications of these connections between energy use and environmental quality, national and international initiatives have been proposed to reduce the environmental risks. In the fall of 1987, 43 members of the United Nations signed the Montreal Protocol for the control of chemicals that deplete the stratospheric ozone layer. Also in 1987, the U.S. Congress passed the Global Climate Protection Act directing the EPA, Office of Technology Assessment, and USDOE to study and prepare reports concerning policy actions necessary to control global warming. In the following year, the Toronto World Conference on the Changing Atmosphere established a 20 percent reduction in fossil carbon dioxide releases target to be achieved by the year 2005. Finally, national legislation dealing with various aspects of the energy and environment connection have been introduced and debated over the past two congressional sessions. Examples include the National Energy Policy Act introduced in 1988 by Senator Wirth and the current debate over the reauthorization of the Clean Air Act.

The United States has made major contributions to the research and scientific consensus concerning the significance and reality of the environmental threats posed by current energy policy. However, progressive decisions to implement policies and allocate budget resources to address these threats comprehensively have either been slow in coming (acid rain), or have yet to be made at all (greenhouse gas reduction). The reluctance to act has been largely driven by concern over the impacts such policies might have on the U.S. economy. To the degree that policies aimed at reducing greenhouse gas emissions, acid gas emissions, other air pollutants, or non-air-related environmental threats (for example, oil spills) are expensive, they are perceived to place a burden on the economy and lead to reduced productivity and competitiveness. Consequently, the last two administrations have taken the position that until a threat can be scientifically proven beyond controversy, the principal action taken should be further study.

Many policy analysts have been quick to point out, however, that even if a cautious "wait and see" strategy is taken, those actions that achieve the environmental objectives while at the same time providing other economic benefits should be implemented now. Energy conservation and efficiency measures offer such an opportunity. Because these measures improve the efficiency, both thermodynamic and economic, with which an energy service is delivered, they are often justified on conventional economic grounds, even before environmental costs and benefits are considered. In light of the fact that many of our energy resources are finite and that a sizable portion of our gross national product is devoted to energy costs, these are efficiencies that should be pursued anyway--even if they offered no environmental benefits.

The purpose of this paper is to provide a real world example of such a "no regrets" energy efficiency policy action. The State of Washington enforces a residential building code that sets minimum levels of insulation for new buildings. This paper discusses the cost of these insulation levels, their energy savings, their economics from the perspectives of the individual homebuyer and the state as a whole, and the magnitude of the environmental benefits achieved. Assessment of environmental benefits focuses on reduction in annual emissions of greenhouse gases.

THE WASHINGTON STATE RESIDENTIAL BUILDING ENERGY CODE

The Washington State Legislature enacted the State's first energy code covering residential construction in 1977 (effective 1978). This code established basic insulation requirements for ceilings, walls, and floors in new residential buildings. Before enactment of the 1978 code, Washington had no minimum specific insulation standards for residential structures.

The 1978 Washington State Energy Code (WSEC) was upgraded in 1980 and 1986 and was revised again by the Legislature in 1990 to be upgraded effective in 1991. This analysis evaluates the cost, savings, and reductions in greenhouse gas emissions associated with the 1980, 1986, and 1991 codes, taking the 1978 code levels as a base case.

Both climate severity and heating fuel are considered in the insulation specifications of the 1986 and 1991 codes. The 1980 code was "fuel-blind" and nearly uniform across the state's climate zones. Tables 1 and 2 present the insulation levels called for by the current code (1991), as well as previous code levels in the two Washington climate zones. The levels for the 1986 and 1991 codes were established on the basis of consumer cost-effectiveness. The code is structured such that these insulation

Table 1. Washington State Residential Energy Codes. Insulation levels, Western Washington climate zone. (<6000 HDD 65 F). (Electric Heat/Natural Gas, or other Heat)

	Ceiling (R-value)	Walls (R-value)	Floors (R-value)	Windows[a] (U-value)	Doors (U-value)	Infil. (type)
1978	19/19	11/11	11/11	single/single	NR	NR
1980	30/30	11/11	11/11	double/double	NR	clk/wthrstrp
1986	38/30	19/19	19/19	.60/.75	NR	clk/wthrstrp
1991	38/30	19/19	30/19	.40/.65	.19/NR	clk/wthrstrp

[a] window requirements by basic description in 1978 and 1980 codes. Tested U-value maximums (AAMA 1503.1) required by 1986 and 1991 codes.
NR - no requirement

Table 2. Washington State Residential Energy Codes. Insulation levels, Eastern Washington climate zone. (>6000 HDD 65). (Electric Heat/Natural Gas, or other Heat)

	Ceiling (R-value)	Walls (R-value)	Floors (R-value)	Windows[a] (U-value)	Doors (U-value)	Infil. (type)
1978	19/19	11/11	11/11	single/single	NR	NR
1980	30/30	11/11	11/11	double/double	NR	clk/wthrstrp
1986	38/30	19/19	25/19	.60/.75	NR	clk/wthrstrp
1991	38/38	24/19	30/25	.40/.60	.19/NR	clk/wthrstrp

[a] window requirements by basic description in 1978 and 1980 codes. Tested U-value maximums (AAMA 1503.1) required by 1986 and 1991 codes.
NR - no requirement

"prescriptions" establish a target space heat performance level. Flexibility is permitted in actual building component insulation levels, so long as whole house performance equivalent to the prescription levels is maintained.

For comparison, the current draft American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) Standard 90.2 recommends insulation levels for Washington State that fall between the 1980 and 1986 WSEC levels.

COST AND ENERGY SAVINGS FOR ENERGY CODE INSULATION LEVELS

The additional construction costs for new residences incorporating the insulation levels required by the energy codes have been documented in two ways. First, incremental construction costs were collected from the builders of 226 energy efficient demonstration homes as a part of the Residential Standards Demonstration Project (RSDP) in Washington State (Tangora et al. 1986). Data were collected in 1985. Second, incremental construction costs were estimated by standard construction cost estimation procedures as a part of the University of Washington's (UW) Component Testing Project (Ossinger et al. 1989). The agreement between these two data sources is quite close (Byers 1989). Because of their more extensive documentation, costs from the UW project have been used in this analysis. Stated in 1989 dollars, Table 3 presents the added costs (as $/square foot of building component) for insulation components included in the Washington energy codes. These costs include a 40% markup for builder overhead and profit.

Energy savings have been both directly measured and estimated through use of computer models. As a part of the RSDP and a later demonstration

Table 3. Component Level Insulation Costs

Ceilings	Walls (net sf)	Floors	Windows	Doors
R19:Base	R11:Base	R11:Base	Single:Base	Wood:Base
R30:$.17	R19:$.56	R19:$.20	.75:$1.75	R5:$1.12
R38:$.30	R24:$1.24	R25:$.29	.65:$2.54	-
-	-	R30:$.46	.60:$3.99	-
-	-	-	.40:$6.87	-

Note: Costs are cumulative from indicated base. 1989$/SF including 40% builder overhead and profit.

project, the Residential Construction Demonstration Project (RCDP), some 350 electrically heated homes were end-use monitored. The results of the space heat monitoring for these homes were compared with predictions from a simple thermal simulation model, SUNDAY (Ecotope 1984). An analysis of the agreement between model predictions and actual use indicated that, on average, the model's predictions agree to within 7 to 10 percent of actual space heat use (Byers and Palmiter 1988; Downey 1989). In addition, the University of Washington compared SUNDAY predictions with those of other models (including DOE-2 and CALPAS), and with the monitored space heat use of four extensively instrumented test homes. In this test, SUNDAY actually under predicted the energy savings from a package of insulation measures by 16 percent (Emery et al. 1989). As a consequence of these two tests, the Washington State Energy Office (WSEO) has concluded that the computer model SUNDAY is sufficiently accurate to estimate the typical savings to be expected, on average, from packages of insulation measures.

The energy savings calculations derived from SUNDAY assume that future household operating conditions will remain similar to current conditions (for example, internal temperatures of 67 to 68 degrees, internal heat gains from appliances and occupants of 3000 Btu/hour). This is a conservative assumption. As appliances become more efficient, the availability of internal heat gains will be reduced and space heat requirements will increase. This means that the savings due to improved insulation will increase as well. Computer runs made with SUNDAY to check the sensitivity of savings to this assumption indicate that a reduction of 1000 BTU/hr in available internal gains yields an increase in space heat of about 2050 kWh/yr for a home insulated to the 1978 code base case and only 1600 kWh/yr for the 1991 code home. This means that space heat savings is increased by 450 kWh/yr.

While no homes using natural gas heat have been monitored, it is assumed in this analysis that insulation performance will be similar to performance in electrically heated homes and that assumptions need only be made concerning heating system efficiency. An annual fuel utilization index (AFUE) of 78 percent is assumed (minimum set by National Appliance Efficiency Act) with a distribution system efficiency of 70.5 percent (derived from engineering estimation of conductive and convective heat-loss from ducts and forced air differential pressurization of building envelope). This leads to a total natural gas heat delivery efficiency of 55 percent (Harris and Maloney 1989).

Figure 1 compares the estimated typical annual space heat for each of the heating fuel types and energy codes. Implementation of insulation standards has reduced typical space heating energy by approximately 60 percent in electric resistance heated homes and 43 percent in homes heated with natural gas. The wide disparity in performance levels between electric and natural gas heated homes reflects the difference in consumer cost for these two fuels. Natural gas costs only about 30 percent as much as electricity on a Btu basis (53 percent adjusted for end-use efficiency). Consequently, the insulation levels required in natural gas heated homes are less stringent than those in electrically heated homes.

Recent analysis of space heat end-use monitored data indicate that, for electrically heated homes, peak load or peak system capacity savings may be as much as five to eight times annual average capacity savings (Foley 1989). These figures are based on

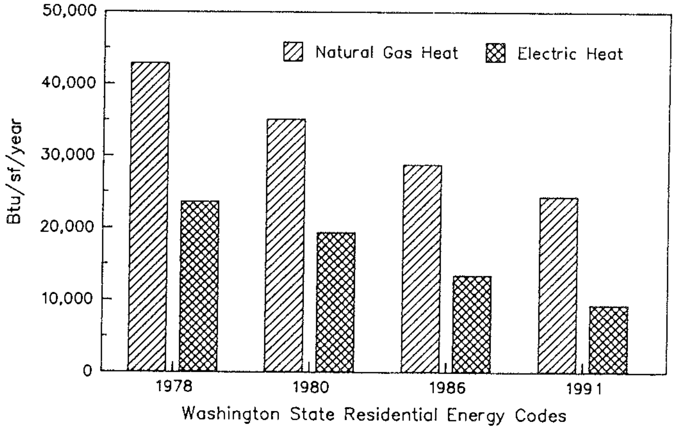

Figure 1. Annual Space Heat for Typical 1650 Square Foot Washington Home

preliminary analysis of hourly end-use data and the observation that electrical system load factors for residential space heating are typically in the neighborhood of 20 percent [see Sands and Gillman (1990) for a more detailed analysis of this issue].

The additional construction costs and energy savings attributable to the Washington State Energy Codes are summarized in Table 4. Figures are based on a typical 1650-square-foot home. Costs are stated in 1989 dollars. Both costs and energy savings are cumulative from the 1978 code base case.

ESTIMATION OF GREENHOUSE GAS REDUCTIONS

The energy savings achieved by the energy codes displace greenhouse gas emissions of both carbon dioxide (CO_2) and methane (CH_4). These two gases are considered to contribute about 80 percent of the human caused warming potential due to atmospheric radiative absorption (Lashof and Ahuja 1989).

Reduction of gas emissions due to energy savings in natural gas heated homes assumes 118 pounds of CO_2 per million Btus of natural gas and methane loss from pipeline distributions systems of .5 percent of volume (the lower end of the .5 to 1.6 percent range for lost/unaccounted for gas reported by natural gas utilities in Washington). Current estimates indicate that methane is approximately 10 times (on a weight basis) more potent than CO_2 for greenhouse warming (Lashof and Ahuja 1989). Assuming 1000 cubic feet per million Btus and a weight of .0424 lb per cubic foot of natural gas, the methane leaks contribute another 2.1 pounds of CO_2 equivalent per million Btus of gas.

Reduction of greenhouse gas emissions due to energy savings in electrically heated homes is more difficult to estimate. The calculation depends on the kind and fuel source of electricity generation. Electricity savings attributable to improved efficiency in new residential loads can be considered to displace the kind of electricity generation that is growing the fastest to serve increased electricity loads (that is, the marginal resource). Because Washington is part of an electricity distribution grid that encompasses a large portion of the western United States and Canada, the full range of electricity generation that supplies this grid must be considered in identification of this marginal resource. Fully 30 percent of the electricity that serves the Pacific Northwest region comes from outside the region (as defined by the Pacific Northwest Electric Power Planning and Conservation Act 1980) (PNUCC 1987). To reflect this, Figure 2 plots the generation mix as a proportion of total generation in the states of Washington, Oregon, Idaho, Montana, Wyoming, and Nevada (EIA 1982-1988). Electricity generation owned by Washington utilities is confined to these six states. The figure plots the mix over the decade of the 1980s.

In 1980, 72 percent of generation was hydroelectric. By 1988, this percentage had declined to 56 percent. Over the same period, the proportion of coal-fired

Table 4. Cost and Annual Energy Savings for Washington State Residential Energy Codes

	Western Washington				Eastern Washington			
	Savings		Cost		Savings		Cost	
Code	Elect (kWh/yr)	Gas (thms/yr)	Elect	Gas	Elect (kWh/yr)	Gas (thms/yr)	Elect	Gas
1980	1980	123	$973	$973	3052	198	$973	$973
1986	4785	225	$2491	$1864	6995	330	$2573	$1864
1991	6715	293	$3662	$2326	10031	483	$4503	$2920

Note: Based on average 1,650 SF. home. Base case equals 1978 WSEC. Costs and savings are cumulative from 1978 base case.

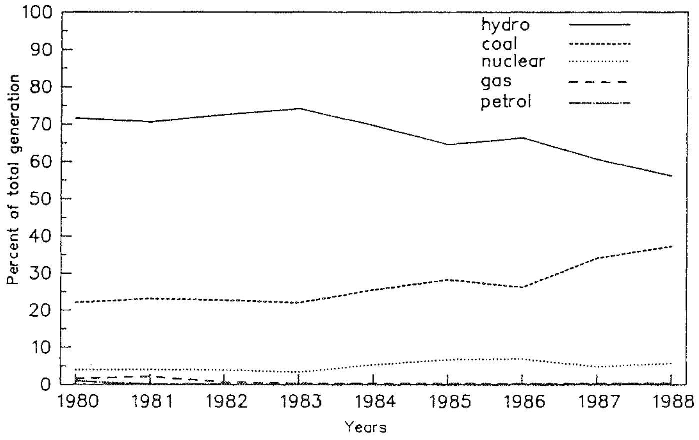

Figure 2. Northwest U.S. Electricity Generation Types as Percent of Total

generation increased from 22 to 37 percent. Because the share of regional generation provided by coal is growing, this analysis assumes that efficiency improvements in new loads are saving coal-fired electricity.

The large coal-fired plants in Washington, Oregon, Montana, Wyoming, and Nevada have an average heat-rate of 10,685 Btu/kWh (PNUCC 1987). Considering this heat-rate and an average CO_2 emission rate of 204 lbs./mmBTU of coal (Marland and Rotty 1983), the plants produce an average of 2.18 pounds of CO_2 per kWh of electricity generated. Including the effect of electricity transmission losses averaging 8.9 percent (Edison 1989), each kilowatt hour of end-use electricity saved reduces carbon dioxide emissions by 2.38 pounds.

Current electricity planning in the Northwest appears to be leaning toward reliance on combined cycle gas combustion turbines for new electricity supplies. Consequently, the marginal electricity resource in the future may be a combined cycle, gas-fired facility operating at a higher efficiency than the coal-fired resource assumed in this analysis. Carbon dioxide emissions from these facilities would be lowered by approximately one-half while methane emissions would increase by approximately 10 fold (Rosen 1990). It does not appear likely that these new generating facilities will be constructed before the late 1990s. Because of the uncertainty in this timing and the excess coal-fired capacity currently available in the PNW (i.e., the Boardman Plant is not being utilized to capacity), this analysis assumes that coal-fired electricity will continue to make up the margin over the period evaluated.

Table 5 presents the CO_2, methane, and total CO_2 equivalent emissions per million Btus of natural gas and electricity. These figures reflect only direct use, or generation of the energy sources; they do not reflect fuel life cycle contributions of greenhouse gas (for example, coal mining, natural gas fields). Based on these assumptions the annual greenhouse gas savings for each of the building code levels are presented in Table 6. Again, these figures are reported as cumulative from the 1978 code base case.

ECONOMICS OF ENERGY CODE AND COST OF ENVIRONMENTAL BENEFITS BASED ON INDIVIDUAL HOMES

Based on the cumulative energy savings and cost for all three building codes, the economics for homes built to the 1991 code are presented in Tables 7 and 8 for homes heated with electricity and natural gas, respectively. The net present value (Net PV) of energy savings to the homebuyer assumes an economic life of 30 years and a nominal discount rate equal to a 10.5 percent mortgage rate. Electricity prices are assumed to escalate at a real annual rate of .2 percent and natural gas prices are assumed to escalate at a real annual rate of 1.6 percent (NPPC 1989).

In all cases presented in Tables 7 and 8, the benefit cost ratio exceeds one, indicating that the investment in the building-code-required insulation measures has positive value for the homebuyer under the economic assumptions used. In simple terms, the measures pay for themselves.

Two costs per ton of displaced CO_2 are calculated. Both assume that new homes will last for 70 years. The first calculation ignores the value of saved energy. If the building code was implemented for the sole purpose of saving CO_2, with no consideration of energy dollar savings, this figure would reflect the cost of CO_2 abatement. The costs range from $5.38 to $18.84 per ton. These figures compare favorably with estimates ranging from $4.95 to $33.00 per ton of CO_2 abatement (Bernow and Marron 1990; Nordhaus 1990).

The second CO_2 cost calculated does consider the value of the saved energy. Because all of the cases have benefit cost ratios greater than unity, all of these costs are effectively negative. The CO_2 abatement is more than paid for by the value of the energy savings.

These two calculations provide a sensitivity test for the cost of CO_2 reduction achieved through the building codes. The most extreme economic assumptions might consider that consumer discount rates are so high that energy saved in the future has little, or no value. Even under this case, the cost of CO_2 reduction is very comparable to other methods currently estimated, or being considered in carbon tax proposals (Nordhaus 1990; Flavin 1990).

CHARACTERISTICS OF THE WASHINGTON STATE HOUSING STOCK

To estimate the cumulative impacts of Washington's residential energy codes, the construction cost, consumer benefits, and environmental benefits can be extrapolated to the housing stock. Currently, about 60 percent of the single-family housing stock and 90 percent of the multifamily housing stock in Washington is heated with electricity. While energy prices and the geographic availability of natural gas may influence these proportions in the future, the magnitude and even the direction of these changes are difficult to predict. This analysis assumes that the fuel mix will remain constant through 2005.

A similar assumption has been made concerning the distribution of housing starts between the eastern and western Washington climate zones. Currently, about 94 percent of new houses are built in western Washington. The analysis assumes this split will continue.

Housing start data for 1981 through 1989 were obtained from building permit records. Housing start projections for the period 1990 through 2005 are derived from economic forecasts done by the Bonneville Power Administration (BPA) and the Northwest Power Planning Council (NPPC) (BPA 1988). Projections are drawn from the medium growth scenario in these forecasts.

Table 5. Greenhouse Gas Emission Rates per mmBTU of End-Use Electricity and Natural Gas (Pounds)

	CO_2	CH_4	CO_2 Equiv.
Natural Gas	118	2.1	120.1
Electricity	698	.005	698

Table 6. Greenhouse Gas Savings for Typical-Sized Single-Family Home in Washington State

	Western		Eastern	
	Electric	Nat. Gas	Electric	Nat. Gas
1980	4716	1486	7272	2378
1986	11398	2715	16666	3963
1991	15996	3527	23898	5805

Note: Annual pounds of equivalent carbon dioxide, cumulative from 1978 base code. (lbs./year)

Table 7. Costs and Benefits of Building Energy Code for Typical Electric Resistance Heated Home. Based on 1991 building code and 1978 code base case. 1989$.

	Savings (kWh/yr)	Cost	Net PV	B/C[a]	\$/ton CO_2[b]	\$/ton CO_2[c]
West WA	6715	$3662	$1713	1.47	$6.54	($3.05)
East WA	10031	$4503	$3526	1.78	$5.38	($4.21)

[a] Benefit cost ratio

[b] Cost of lifetime displaced CO_2 before consideration of value of energy savings. Assumes 70 year physical life for average home.

[c] Cost of lifetime displaced CO_2 after consideration of value of energy savings. Assumes 70 year physical life for average home.

Table 8. Costs and Benefits of Building Energy Code for Typical Natural Gas Heated Home. Based on 1991 building code and 1978 code base case. 1989$.

	Savings (thms/yr)	Cost	Net PV	B/C[a]	\$/ton CO_2[b]	\$/ton CO_2[c]
West WA	293	$2326	$18	1.01	$18.84	($0.14)
East WA	483	$2920	$943	1.32	$14.37	($4.64)

[a] Benefit cost ratio

[b] Cost of lifetime displaced CO_2 before consideration of value of energy savings. Assumes 70 year physical life for average home.

[c] Cost of lifetime displaced CO_2 after consideration of value of energy savings. Assumes 70 year physical life for average home.

STATEWIDE ENERGY, PEAK ELECTRICAL LOAD, AND EQUIVALENT CARBON DIOXIDE SAVINGS

Slightly more than 300,000 single-family homes and apartment units were added to the state's housing stock over the period 1981 through 1989. Table 9 presents the annual housing starts, annual rate of electricity savings, estimated peak electricity capacity savings, annual rate of natural gas savings, and annual rate of CO_2 displacement.

Electricity savings from housing starts through 1989 amount to 589 GWh, enough energy to serve the needs of a city the size of Everett, Washington (population 64,170). The total cost to achieve these savings is estimated at 294 million dollars (1989 dollars). The present value of energy savings over the 30-year economic life of these homes is estimated at 462 million dollars (benefit/cost ratio of 1.57). Taking a societal discount rate of 3 percent real and assuming a 70-year physical life for the homes yields a levelized cost of 17 mills/kWh (41 mills in nominal terms if a 5 percent inflation rate is assumed). This is less than half the estimated cost of generating electricity from a new coal-fired plant (NPPC 1990).

Natural gas savings from housing starts through 1989 amount to 13.5 million therms per year, or an average of 3.7 million cubic feet per day. These savings were achieved for a cost of 106 million dollars. The present value of energy savings is estimated to be 124 million dollars (benefit/cost ratio of 1.17). Again, taking a 3 percent social discount rate and considering the 70-year physical life for the structures yields a levelized real cost of $.27 per therm (1989 dollars). This is significantly less than the $.41 to $.44 per therm estimated as a long-term avoided gas cost by two major gas utilities serving Washington State and Oregon (Cascade 1990; Northwest NG 1990).

Carbon dioxide displacement reached 782,000 tons per year for the cohort of homes built between 1981 and 1989 (Table 9). If these tons are valued at the $5.00/ton figure discussed by Nordhaus (1990), the value of the greenhouse gas benefits from the homes built during the decade of the 1980's is 3.9 million dollars per year. Cumulative tons of CO_2 displaced reached 2.8 million tons through 1989, worth 14 million dollars at $5.00 per ton.

These figures only reflect the energy savings and CO_2 benefits through 1989. These homes will

Table 9. Statewide Aggregate Totals for Energy and Carbon Dioxide Savings from Residential Building Codes. Cumulative Annual Rates for Homes Built 1981 - 1989.

Year	Housing (units)	Elec. (10^6 kWh)	Peak MW (MW)[a]	Gas (10^6 thms)	CO_2 (2000 lbs)
1981	23,853	27.6	15.7	.8	37,888
1982	17,586	47.6	27.2	1.5	65,591
1983	27,278	78.8	45.0	2.5	108,885
1984	30,944	113.8	64.9	3.5	156,597
1985	35,475	152.5	87.0	4.5	208,721
1986	36,428	248.2	141.6	6.5	335,321
1987	38,341	348.1	198.7	8.6	465,907
1988	44,553	463.4	264.5	10.9	616,758
1989	47,607	588.7	336.0	13.5	782,046
Forecast through 2005		2526.0	1,442.0	57.9	3,353,889

[a] Estimated at 20 percent load factor

continue to save energy and CO_2 throughout their lifetimes, and additional savings will accrue as new homes are built under the 1991 building code. Table 9 also includes an estimate of energy savings and CO_2 benefits for housing starts forecasted to occur through 2005. By the year 2005, 822,900 homes will have been added to the state's housing stock, 2526 GWh of electricity will have been saved, nearly 58 million therms of natural gas per year will have been saved (an average of 15.8 million cubic feet per day), and CO_2 emissions will have been reduced by 3.3 million tons per year. The annual CO_2 savings amount to about 3.9 percent of the state's total energy related CO_2 emissions (86.7 million tons in 1988) and 14.0 percent of energy related emissions from residential and commercial buildings (WSEO 1990).

CONCLUSIONS

While the original objective of Washington State's residential energy code was to achieve energy efficiency that was cost-effective to the new homebuyer, the state, and the Region--an objective that has been met--this policy of energy efficiency has also netted substantial environmental benefits. Because the energy efficiency measures required by the code are cost-effective to the home buyer and state, the environmental benefits are obtained at no net cost. In simple terms, they are paid for by the value of the energy savings.

By the year 2005, carbon dioxide savings will reach 3.3 million tons per year, an environmental bonus from energy efficiency worth an estimated 16.5 million dollars per year (at $5.00 per ton). Similar policies aimed at achieving energy efficiency throughout the state and U.S. economies can reasonably be expected to achieve similar economic and environmental benefits.

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