CHAPTER 3
RESIDENTIAL SECTOR
CO_2 EMISSION REDUCTION STRATEGY

Key Findings

Figure 3-1

Residential Sector CO_2 Emission Projections Through 2010

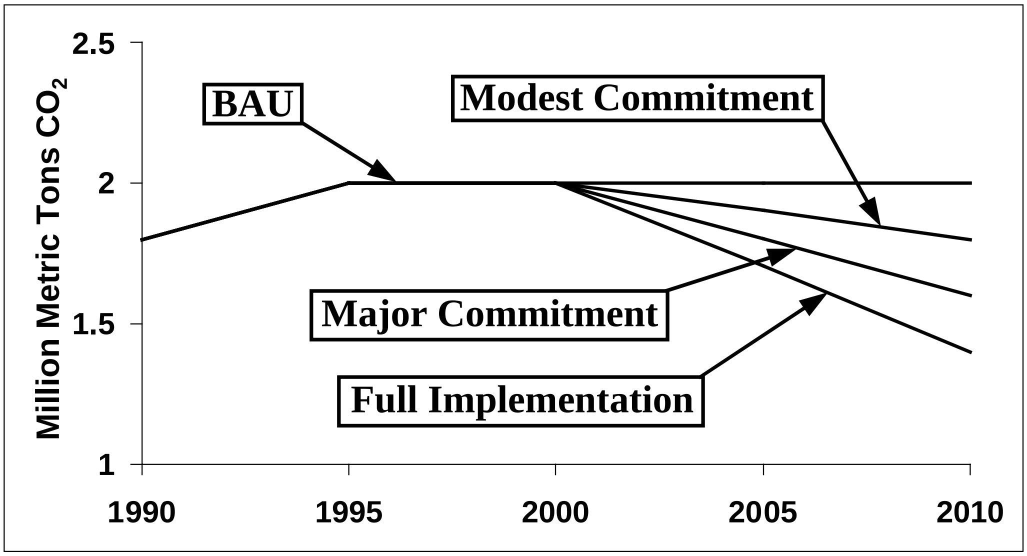

Table 3-1

Summary of Scenario Analyses to Reduce CO_2

in Delaware's Residential Sector

	Energy Use (trillion Btus)	GHG emissions ($mmtCO_2$)*
1990	26.7	1.8
2010 BAU	33.4	2.0
Implementation Scenarios		
Modest Commitment (35%)	31.5	1.8 (10%)
Major Commitment (65%)	30.0	1.6 (18%)
Full Implementation (100%)	28.1	1.4 (28%)

* Percentage reductions from forecast emission level are indicated in parenthesis

Under the BAU scenario, residential energy consumption increases slightly to approximately 2.0 mmtCO_2 in 2010 (Table 3-1). This represents an 11% increase during the forecast period. Implementation of all measures identified in the Action Plan (the Full Implementation Scenario) produces an emission total for the sector of 1.4 mmtCO_2 by 2010, which is a 22% reduction from 1990 levels. The Major Commitment scenario, involving significant state and federal policy support to capture 65% of the savings identified in the Action Plan, would result in an 11% reduction below 1990 emissions. The Modest Commitment scenario (which realizes 35% of identified savings in the Plan) returns this sector's emissions level to 1990 levels. Measured from the emission forecast for 2010 of 2.0 mmtCO_2, the Full Implementation, Major Commitment and Modest Commitment Scenarios would lead to a 28%, 18% and 10% reductions in emissions, respectively. Efficiency upgrades of space and water heating equipment, electric appliances and gas cookers, and lighting are the focus of the Action Plan for the residential sector. Figure 3-1 and Table 3-1 depicts the effects of the three scenarios analyzed for DCCAP.

Background

Delaware had 289,900 housing units in 1990, 45% of which were less than 21 years old (DHSC 1990). The occupancy level for these units was 85% (DHSC 1990). In 1990, total CO_2 emissions were 1.8 mmtCO_2, rising to 2.0 mmtCO_2 in 1996. The *Delaware Greenhouse Gas Inventory* indicates that emissions in this sector accounted for 7% of Delaware's total CO_2 emissions in 1990 (CEEP 1995). Emissions from Delaware's residential sector are proportionally less than the national contribution (the IWG reports in its 1997 study that about 20% of national greenhouse gas emissions originate in the residential sector), but are consistent with its climate.

Most of the state's residential sector emissions are associated with natural gas and electricity for space heating and air conditioning. Energy use in space heating and cooling correlates with the state's climate, which shapes total consumption and affects the seasonal distribution of energy use.

Sources and Trends of Emissions

The main sources of energy consumed in the residential sector are natural gas (about 30%) and the largest energy source, electricity (about 34% - annual consumption by fuel type is listed at Appendix D). Strong growth has characterized residential energy use in recent years. Increasing energy use correlates with growth in total residential buildings in the state and behavioral patterns and decisions that result in greater home energy use, including the trend of increasing numbers and usage of energy-consuming appliances in the home. In 1990 total fuel and end-use electricity consumption was 26.7 trillion Btus with a corresponding 1.8 mmtCO_2 of emissions (CEEP 1995). By 1998 these had increased by 19% and 13% respectively (see Table 3-2). Within this time period, the residential fuel mix changed, with overall declines in coal and kerosene, and increases in natural gas and electricity (both of which are less CO_2-intensive) (see Appendix D).

Table 3-2
Residential Sector Fuel And End-Use Electricity Consumption, 1990, 1998 and 2010

Year	Btus Trillion	Million Metric Tons of CO_2
1990 (actual)	26.7	1.8
1998 (forecast)	31.7	2.0
2010 (forecast)	33.4	2.0

Residential energy use is associated with a wide variety of energy-consuming services within the home, and the relatively broad mix of energy sources applied to these services. Mechanization, automation, and computerization of many domestic services has achieved high levels, and few tasks in the home are without the potential for demand on energy systems through the use of some type of appliance. Examples include televisions, computers, furnace fans, well pumps, spas and an array of kitchen equipment.

Delaware's residential energy use is dominated by its application to space heating, and to a lesser extent, water heating (see Table 3-3). Electricity supplies about 11% of the energy consumed in space heating and slightly less than a quarter of water heating energy (as shown in Table 3-3). Minor energy-consuming devices have a growing collective energy demand (see 'Miscellaneous (electric)' in Table 3-3.)

Table 3-3

Residential Energy Consumption By Major End-Uses, Emissions, 1996

Selected End Use	Percentage	mt of CO_2 Emissions
Space heating (all fuels)	43.0	757,335
Space heating (electric only)	(5.0)	(128,380)
Water heating (all fuels)	13.3	234,075
Water heating (electric only)	(3.2)	(83,795)
Miscellaneous (electric)	10.1	260,696
Space cooling (electric)	4.1	107,071
Refrigerators (electric)	3.7	95,433
Lighting (electric)	3.1	79,140
Clothes dryers (electric)	1.7	44,225
Cooking (gas)	1.7	30,050
Freezers (electric)	1.2	30,259
Miscellaneous (gas)	0.9	15,816

Note: Percentages and tons in parentheses are included in the “all fuels” category of an end use.
Source: Appendix E

Projections

A dominant factor in shaping total residential energy use is the number of households, and accordingly, increasing population size has historically resulted in increased residential energy demand. It is projected that by 2010 total housing units will increase to 311,400. Under the BAU scenario, overall energy consumption is projected to increase by 20% (rising to 33.4 trillion Btus) and emissions to increase by 8% over 1990 levels (see Table 3-1).

Much of the increase in emissions between 1990 and 2010 under the BAU scenario occurs in the first decade of the projection, while the sector's total energy use continues to grow throughout the period. This difference is due to the forecast fuel mix becoming less CO_2-intensive in the future, and as a result, CO_2 emissions become flat after 1995. Because of this factor, emissions fall slightly while energy use continues to increase.

Methodology

The *Delaware Greenhouse Gas Inventory* (CEEP 1995) supplied data on State energy use by fuel type and consumption levels and provided the 1990 baseline from which projections of future trends were made. Breakdowns of residential energy end-uses are not available for Delaware, so national residential statistics were used as the basis for establishing state conditions. Regional data were selected on the basis of Delaware's climatic classification developed on the associations between climate and energy use by the U.S. Department of Energy's Energy Information Administration (EIA 1997).

A recently completed study jointly prepared by five national energy research laboratories for the U.S. Department of Energy (IWG 1997) provided estimates of reduced energy use for major residential sector equipment. A cost-effectiveness test was applied to these potential measures: only those with a cost of conserved energy less than 4.0¢/kWh and whose payback period was less than five years were included in the Action Plan for Delaware. This is consistent with the criterion used by the Interlaboratory Working Group (IWG).

Scenarios were developed by applying measures that met the DCCC's cost-effectiveness criterion to the goal of CO_2 emissions reduction by assuming their introduction on a replacement basis (described below) and calculating the combined effect on emissions and energy use. Appliance introduction rates were taken from published measurements of product 'lives' of existing appliances (most of the appliances analyzed for the Action Plan are used for between 14 and 18 years). More efficient appliances were introduced into the forecasts at existing appliance replacement rates, which represent current residential decision-making.

Estimates of the costs of these upgrades were obtained from the IWG study (1997) and were used to calculate scenario costs. Energy use was calculated on the basis of the overall consumption level and specific type of energy consumed (results are shown in Appendix E). The effects of implementation of these measures are captured in the Full Implementation scenario, while the Modest and Major Commitment scenarios were developed by scaling down the results of the Full Implementation scenario to 35% and 65% of potential, respectively (results are shown in Appendix F). The scaling factors are identical to those used by the IWG and correspond to alternative policy environments: the 35% case is intended to correspond to a case where modest state and federal policy incentives are present and results are largely driven by the pace of market changes; the 65% case would reflect a circumstance where state and federal policy incentives are stronger (higher investment tax credits, for example) and society responds to these policy signals by aggressively pursuing its high-efficiency options.

Analysis of Options

The measures to reduce CO_2 emissions include high-efficiency models of home appliances, such as electric clothes dryers, refrigerators and freezers, gas cookers, electric and gas water heaters, lighting and space conditioning equipment improvements. These measures were grouped together in the scenario analyses for this sector. In addition, the effects of higher efficiency building design and materials, and the choice of fuel base for energy supply to the home were modeled.

Switching to appliances of greater energy efficiency offers a ready means to sectoral energy savings. For example, the average energy consumption for refrigerators was 944 kWh per year in 1997, the average of higher efficiency refrigerators is 647 kWh/year; and the highest efficiency model available on the market is estimated to use 437 kWh/year (IWG 1997). All appliances considered in the analysis are currently available on the market and meet a cost-effectiveness test of 4.0 ¢/kWh and paying back their incremental cost (compared to conventional models) in less than 5 years through reduced household energy bills.

In 1996, the energy consumed by refrigerators in Delaware's residential sector is estimated in the Action Plan to account for 95,433 $mtCO_2$, freezers for 30,259 $mtCO_2$, clothes dryers for 44,225 $mtCO_2$, and gas cookers for 30,050 $mtCO_2$, for a combined total of 199,967 $mtCO_2$. Analyses for the Action Plan show that, under the BAU scenario, the use of standard 1997 technologies for these appliances would reduce CO_2 emissions by some 34% to 132,101 $mtCO_2$ in 2010. Thus, the BAU assumes the upgrade to the typical 1997 appliance. The Modest and Major Commitment and the Full Implementation scenarios analyze efficiency upgrades that are greater than those embodied in the typical 1997 appliance. With full use of cost-effective, high-efficiency technologies (Full Implementation scenario), the emissions from these appliances could be reduced by a further 14,392 $mtCO_2$ or 11% below the projected 2010 levels in the BAU scenario. Details on the energy consumption and CO_2 emissions for specific measures are presented in Appendices E and F.

In 1996, energy consumption by electric water heaters in Delaware accounted for 3.2% of total residential energy consumption, while gas water heaters used 13.3%. Water heaters have an average lifetime of 10 years and consume considerable quantities of electricity on a unit basis: the U.S. annual average energy use in 1997 per electric unit was 4,924 kWh/year (IWG 1997). Current electric water heaters exhibit improved energy efficiency; 1997 models have an annual energy consumption of 3,899 kWh/year (IWG 1997).

Under the BAU scenario, it is estimated that 2010 CO_2 emissions attributable to electric water heaters would decrease from 83,795 $mtCO_2$ in 1996 to 70,819 $mtCO_2$, a decline of 15%. Emissions from gas heaters would only decrease from 234,075 $mtCO_2$ to 230,196 $mtCO_2$, down 1.6% from 1996 levels. This effect will be caused by an increasing proportion of gas heaters, which involves the combustion of natural gas, a more efficient means of heating water than its common alternative, electricity; and because natural gas combustion releases less CO_2 than the combustion of the coal-dominant fuel mix for electricity generation in Delaware, an increase in the proportion of gas water heaters will lower CO_2 emissions. By using cost-effective, high-efficiency models, it is estimated that, under Full Implementation, carbon dioxide emissions would decrease by 20% relative to forecast levels for Delaware.

Studies have shown that, in general, fluorescent lighting is more energy efficient and causes less carbon dioxide to be emitted than incandescent lighting. Conventional lighting has a short equipment lifetime (one year according to the IWG study) and this greatly influences the cost-effectiveness of introducing new technology. There are considerable opportunities to replace traditional incandescent lighting, which is associated with 90% of U.S. residential lighting, with more energy-efficient technologies, such as halogen and compact fluorescent lights.

In Delaware, electric lighting accounted for 3.1% of the energy consumed in the residential sector, and 79,140 $mtCO_2$ emissions in 1996. Under the BAU scenario these emissions are projected to decrease to 72,683 $mtCO_2$ in 2010, down by 8% from 1996. By using high-efficiency, cost-effective lighting technologies, however, it is possible under Full Implementation to reduce emissions in 2010 by 38,522 $mtCO_2$ or 53% below the BAU projections for 2010 (see Appendix F). These measures can be introduced for immediate cost savings, as discussed below.

Space heating and cooling is the largest consumer of energy and emitter of carbon dioxide in the residential sector in Delaware. Energy consumption is largely shaped by the number of days requiring heating and cooling (i.e. climatic conditions), building energy efficiency, and the efficiency of the heating/cooling systems. The cost of conserved energy tends to be lower for new buildings than for existing ones.

As with the case of water heating, gas- fueled space heating is more efficient than electric systems and produces lower emissions of greenhouse gases. Under the BAU scenario, CO_2 emissions from the current proportion of electric heaters will decrease from 128,380 $mtCO_2$ to 116,545 $mtCO_2$ in 2010, or by 9% over 1996 levels. By contrast, emissions from the current proportion of gas fueled space heating will decrease from 757,335 $mtCO_2$ to 671,473 $mtCO_2$ in 2010, down by 11% from 1996 levels. By switching more Delaware households to natural gas, greater CO_2 emissions savings can be realized than from the continued use of electricity for this end use (see Appendix E). By using cost-effective, high-efficiency models for both electric and gas heating/cooling systems, it is estimated that, under Full Implementation, carbon dioxide emissions would decrease by 14% relative to forecast levels for Delaware.

Results

Switching residential technology to those of maximum end-use efficiency (while still meeting the cost-effectiveness tests of 4.0 ¢/kWh and payback periods less than or equal to 5 years) at the rates determined by existing appliance/equipment life, makes considerable energy savings possible by 2010. No additional technological improvements over the best available technologies in the present market are needed to achieve residential energy services at lower CO_2 emissions. The Action Plan's residential sector strategy concentrates on those end uses with a high proportion of sectoral energy use and where applicable technologies offer considerable energy and emissions benefits.

Under the Full Implementation scenario (i.e., all cost-effective measures are implemented), there would be an estimated 28% reduction or 552,729 $mtCO_2$ below BAU at 2010. The Modest Commitment scenario (35% of cost-effective measures implemented) would achieve a 10% reduction and the Major Commitment scenario (65% implementation) would achieve an 18% reduction in emissions from forecast levels for 2010.

Conclusion

Under the BAU scenario, the sector's emissions are forecast to rise from their 1990 level of 1.8 $mmtCO_2$ to 2.0 $mmtCO_2$ by 2010. Emissions under the Modest Commitment scenario are 1.8 $mmtCO_2$ and 1.6 $mmtCO_2$ under the Major Commitment scenario by the target year. Adoption of the Full Implementation scenario will result in emissions of 1.4 mmtCO_2 by 2010. Using the Major Commitment scenario as the benchmark for action, emissions in the residential sector can be reduced by 18% from the forecast level for 2010. This is equivalent to an 11% reduction from the 1990 level for this sector.

Analyses prepared for the Action Plan show that the application of existing high-efficiency, cost-effective measures, can yield substantial reductions in emissions for the sector. These measures are spread across a wide array of residential energy services. Overall, the cost of conserved energy for these measures is low, but the policy challenge is to interest residential consumers in making these upgrades when they replace older equipment. Policy actions to support the adoption of the analyzed measures for CO_2 emission reduction in the residential sector are identified in Chapter 9.

References

Center for Energy and Environmental Policy (CEEP). (1995) *Delaware Greenhouse Gas Inventory*. Newark, Delaware: CEEP, University of Delaware.

Delaware Health Statistics Center (DHSC). (1990) *Census of Population and Housing*.

Energy Information Administration (EIA). (1999) *Emissions of Greenhouse Gases in the United States*, 1997. Washington, DC: National Technical Information Service.. Available at Internet website: http://www.eia.doe.gov/oiaf/1605/gg97rpt/chap2.html.

Interlaboratory Working Group on Energy-Efficient and Low Carbon Technologies (IWG). (1997) *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy-Efficient and Low-Carbon Technologies by 2010 and Beyond.* Washington, DC: U.S. Department of Energy.

U.S. Department of Energy (USDOE). *Rebuild America Info Kit*. Washington, DC: National Technical Information Service.

U.S. Environmental Protection Agency (USEPA). (1999) *Energy Star Buildings Program*. Washington, DC: National Technical Information Service.. Available at Internet website: http://www.epa.gov/appdstar/buildings/.