CHAPTER 2
INDUSTRIAL SECTOR
CO_2 EMISSION REDUCTION STRATEGY

Key Findings

Figure 2-1

Industrial Sector CO_2 Emission Projections Through 2010

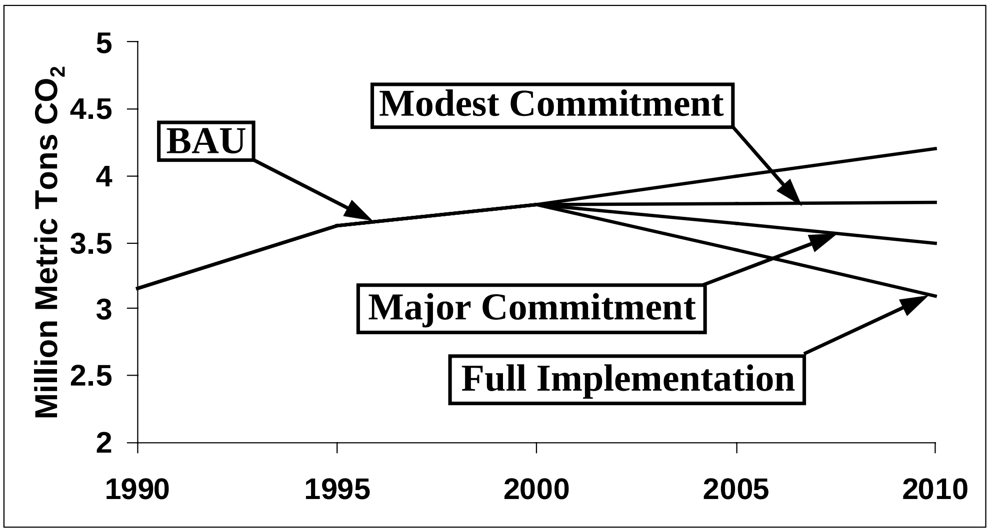

Table 2-1

Summary of Scenario Analyses to Reduce CO_2

in Delaware's Industrial Sector

	Energy Use (trillion Btus)	GHG emissions ($mmtCO_2$)*
1990	75.5	3.2
2010 BAU	105.0	4.2
Implementation Scenarios		
Modest Commitment (35%)	99.3	3.8 (9%)
Major Commitment (65%)	94.4	3.5 (18%)
Full Implementation (100%)	88.6	3.1 (27%)

* Percentage reductions from forecast emission level are indicated in parenthesis

Industrial sector energy use is forecast to grow by 40% between 1990 and 2010 under the BAU scenario, while CO_2 emissions are expected to increase by nearly 35%. This is to be contrasted with the DCCC's goal of a state-wide reduction in CO_2 emissions of 7% below 1990 levels by 2010. To consider alternatives to this growth, energy efficiency measures were evaluated that have a payback period of less than four years. This resulted in a list of 170 technology options (see below for details) with an average payback period of one year. Assuming that only 35% of these low-cost, fast payback emission reduction measures are implemented (Modest Commitment scenario),[1] it is estimated that the sector's emissions would be 9% lower by 2010 (Figure 2-1). Adopting policies consistent with the Major Commitment scenario[2] would yield 18% lower emissions by the target year. Full implementation of the identified measures would result in an emissions reduction of 27%, which exceeds the emission reduction target of 23%, adopted by the Consortium for all end-use sectors.

Background

Based on 1995 census information, Delaware's industrial sector (which includes construction) is comprised of more than 3,300 establishments, employing 20% of Delaware's working population. Of those establishments, almost 1,100 are manufacturers and employ almost 80% of Delaware's industrial employees (approximately 70,000 people), making them the largest source of State income and the third largest employer, following services and trade.

Industrial energy use is typically concentrated in four major manufacturing groups: petroleum and coal products; chemical and allied products; paper and allied products; and the primary metal industry (EIA 1997b: 5). The chemicals and petroleum industries alone account for over half of the energy consumed by US manufacturers (EIA 1997a: 2). Approximately 12% of Delaware's industrial employees are employed in these energy-intensive industries.

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[1] Each scenario is depicted in Figure 2-1. The Modest Commitment Scenario will require some state and federal policy support for its implementation, but less than its Major Commitment counterpart. See Chapter 9 for general outline of policy needs.

[2] Successful implementation of this scenario is expected to require significant state and federal policy support. See Chapter 9 for a general outline of policy needs.

Motor drives, boilers, and air compressors have been identified by a major national study as targets for cost-effective energy use reduction (IWG 1997). Several U.S. studies conclude that electric motors consume approximately two-thirds of electricity across all sectors, with the industrial sector accounting for between 26 and 30% of the total (STAPPA/ALAPCO 1998). The industrial sector also uses a substantial amount of steam. According to the Council of Industrial Boiler Owners, of the 16.55 quadrillion Btus consumed by U.S. manufacturers in 1995 for heat, power, and electricity generation, 9.34 quadrillion Btus of fuel were burned to produce steam, or approximately 56% of energy used by manufacturers (Jones and Jaber 1998). Each year U.S. industry releases over 700 mmtCO_2 while producing steam (EIA 1993).[3] These emissions represent over 40% of all U.S. industrial emissions of carbon dioxide and over 13% of total U.S. emissions. Demand for steam is projected to increase 20% in 5 major industries by 2015 (compared with 1990 levels), with demand in food processing and chemicals being even greater (Gas Research Institute 1996). If all U.S. manufacturers improved the efficiency of their steam systems by 30%, they would reduce CO_2 emissions by approximately 150 mmtCO_2 (EIA 1993). Many of the strategies investigated for reducing Delaware's industrial sector emissions are related to steam production and distribution.

Additionally, space conditioning and lighting are also seen as targets for significant energy savings. Through the development and application of more efficient lighting technologies and design, lighting energy use for industrial lighting could be reduced by over 50% by 2020, with equal or improved health, comfort, and productivity (IWG 1997). These technologies were therefore targeted, as well, in the scenario analyses of Delaware's industrial sector.

Sources and Trends of Emissions

Between 1986 and 1996, Delaware's industrial energy use has grown from 66 trillion Btus to 85 trillion Btus, an increase of 28%. Over the last decade, there is a trend

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[3] EIA calculations of emissions were converted from units of carbon to units of CO_2.

of increasing energy use despite small annual fluctuations. Carbon dioxide emissions have also increased, although in recent years the emission benefits of switching to more efficient and cleaner fuels has become evident. Industrial sector CO_2 emissions grew by only 15% between 1986 and 1996. Electricity use has risen since 1986, extending a long running trend for the sector. There is a long-term trend of declining coal use, but in the period 1986-1996, there is considerable interannual variability. Annual natural gas use is in the range of 15-20 trillion Btus between 1986-1996 (see Appendix A).

Projections

It is projected that by 2010, under the BAU scenario, energy consumption in Delaware's industrial sector will increase from 75.5 trillion Btus in 1990 to 105 trillion Btus, a rise of 39%. This represents an annual average increase of 1.7% in energy consumption. Carbon dioxide emissions are projected to rise to 4.2 mmt by 2010 under the BAU scenario, which is an overall increase of 34%. The slightly slower increase in CO_2 emissions is due to the rising share of natural gas in the industrial sector's fuel mix (see Appendix A).

Based on EIA data, the industrial sector accounted for 31% of Delaware's energy consumption and emitted 20% of its CO_2 emissions in 1990. The BAU forecast for emissions and energy use in 2010 anticipates that the industrial sector will slightly increase to a 32% share of the state's energy use and increase its share of CO_2 emissions to 22%. For comparison, the national average for industrial sector contributions to total greenhouse gas emissions was 27% in 1995.

Methodology

The measures selected to achieve reductions in CO_2 emissions were based on recommendations from industrial assessments sponsored by the U.S. Department of Energy's Office of Industrial Technologies and the university-based Industrial Assessment Center program (IAC). The IAC coordinates assessments throughout the country using established engineering measurement methods as the basis for recommendations to facility managers. These recommendations focus on potential savings from energy efficiency improvements, waste minimization and pollution prevention, and productivity improvements (USDOE 1998).

In conjunction with its industrial assessment work, the IAC maintains a database of more than 8,000 manufacturing plants with almost 58,000 separate technology and maintenance recommendations. The database contains detailed data, available by Standard Industrial Classification (SIC), fuel type, base plant energy consumption, and recommended energy-efficiency improvements. Projected energy savings, cost savings, implementation cost, and simple payback are provided for each recommended measure (USDOE 1998).[1]

For our analysis, data matching the State's industrial profile were selected from the national database. Assessments were screened by state (Delaware, Maryland, Virginia, New Jersey, and Pennsylvania only) and two-digit SIC codes of major Delaware manufacturers (accounting for 58% of Delaware industrial employment) to identify the measures most applicable to Delaware. This initial screening effort resulted in a database containing 1,358 recommendations. These were further screened to include only energy efficiency measures. Within SIC codes, duplicate energy efficiency measures were eliminated by selecting the typical case. Measures with payback periods exceeding 4 years were eliminated because they were regarded as too expensive.

This second screening of the IAC database yielded 170 non-duplicate recommendations for 55 four-digit SIC categories of industrial establishments. This regional database represents plant facilities with 1,000 or fewer employees.[2] Potential

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[1] As the *Industrial Assessment Database* is derived from free audits of industrial enterprises, it does not represent a random sample of firms. However, the sample size is large and covers a wide range of technology upgrades. CEEP researchers, in consultation with the IAC, concluded that the database reasonably characterizes the range of technologies for upgrades of typically sized industrial plants, and provides a plausible basis for estimating the energy efficiency potential for Delaware's industrial sector. While audits in the database do not include plants with 1,000 or more employees, CEEP expects little bias in sector estimates since large-scale facilities have traditionally been more energy efficient than typical plants (due to there need to be more competitive in international markets).

[2] As noted above, large industrial plants are not assessed under the IAC guidelines.

measures, such as cogeneration and fuel switching, were not investigated. However, it is possible to subsequently consider these measures to satisfy the goals of the Action Plan. Detailed information on the methodology used to estimate savings for this sector is provided in Appendix B.

Analysis of Options

The 170 measures selected to achieve reductions in CO_2 emissions in Delaware's industrial sector include improvements in heat recovery and containment, space conditioning, boilers steam, air compressors, motors, and lighting. Table 2-2 lists the number of measures by type that were used in the industrial sector analysis. The energy and CO_2 impacts of selected examples of these measures and their economic payback periods are provided in Tables 2-3 through 2-8.

Table 2-2
Types of Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Types of Measures	Number of Measures	Percentage (%)
Boilers and Steam Systems	50	29
Heat Recovery & Containment	39	23
Space Conditioning	35	20
Air Compressors	20	12
Motors	18	11
Lighting	9	5

Table 2-3

Space Conditioning Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Space Conditioning Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Improve Interior Circulation with Destratification Fans	5,220	5,303	0.98	11,752	618
Use Properly Designed and Sized HVAC Equipment	7,010	5,240	1.34	118,375	10,243
Use Computer Programs to Optimize HVAC Performance	12,000	20,807	0.58	26,026	2,290
Summary Data					
Average Measure	7,631	12,498	0.88	40,800	2,910
Subtotal	267,077	437,444	NA	1,427,993	101,834
Share Of Total	18.9%	21.8%	NA	36.4%	37.0%

Changes in space conditioning can be as inexpensive as insulating air conditioning ducts or as complex as redesigning heating, ventilation and air conditioning systems (HVAC), as indicated in the range of measures shown in Table 2-3. Annual energy savings from all measures in this category have the potential to reduce CO_2 emissions by an amount equal to 37% of the sector's target (See Chapter 1 for the method used to set sector targets). The database included 35 measures to improve energy efficiency. The average payback period for space conditioning is less than one year, even though some measures had high implementation costs.

Table 2-4

Boiler and Steam Systems Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Boiler and Steam Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Repair Leaks in Steam Lines and Valves	325	6,284	0.05	26,803	1,966
Analyze Flue Gas for Proper Air/Fuel Ratio	500	2,009	0.25	1,318	70
Insulate Steam Pipes	8,003	9,848	0.81	1,584	84
Preheat Boiler Intake Air Using Hot Flue Gas	11,600	4,636	2.50	2,240	119
Summary Data					
Average Measure	2,318	8,573	0.46	21,285	1,309
Subtotal	115,915	428,670	NA	1,064,269	65,441
Share Of Total	8.2%	21.3%	NA	27.1%	23.8%

The fifty measures examined in relation to boiler and steam systems account for almost 24% of the reduction in CO_2 emissions identified in the Action Plan for the industrial sector (Table 2-4). Annual energy savings in steam-related systems can have a large impact on CO_2 emission from this sector, as noted earlier. Many of these are comparatively low cost measures. This results in a high ratio of CO_2 mitigated to implementation cost (almost 4:1 - see Table 2-4) and short payback periods (on average, less than 0.5 years for the typical Delaware case).

Table 2-5

Heat Recovery and Containment Measures to Save Energy and Decrease CO_2 Emissions in Delaware's Industrial Sector

Examples of Heat Recovery and Containment Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Use Insulated Doors on Furnace Openings to Reduce Heat Loss	522	6,458	0.08	404	21
Recover Boiler Room Waste Heat	1,360	11,475	0.12	15,920	847
Install Heat Exchangers	5,550	18,070	0.31	72,205	3,843
Insulate Rotating Kilns	16,700	21,127	0.79	1,040	55
Summary Data					
Average Measure	8,895	13,537	0.80	23,574	1,585
Subtotal	337,991	514,417	NA	895,805	60,215
Share of Total	23.9%	25.6%	NA	22.8%	21.9%

Preventing heat loss and improving energy-efficiency involving heat production and use is another important means to reduce industrial energy use and CO_2 emissions. Almost 22% of the reduction in CO_2 emissions identified in the Action Plan for the industrial sector are expected from the 38 measures in this category. While the implementation costs of some measures are high, the average payback period for this category remains attractive – less than one year (Table 2-5).

Table 2-6

Compressed Air System Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Compressed Air Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Repair Leaks in Compressed Air Lines	800	4,909	0.16	69	6
Replace Compressed-Air Wipers with Sponge Rollers	3,000	5,441	0.55	4,502	396
Install Higher Efficiency Compressors	36,000	38,326	0.94	14,822	1,304
Summary Data					
Average Measure	3,364	10,017	0.21	14,768	1,300
Subtotal	67,286	200,335	NA	295,366	25,992
Share Of Total	4.8%	10.0%	NA	7.5%	9.5%

Activities involving compressed air can be found in a vast array of enterprises and therefore comprise a varied number of measures. Twenty energy-saving strategies with an average payback period of less than one year were used in scenario analyses of the industrial sector. Although the total contribution to the industrial sector's overall energy savings is 10%, the relatively low average cost for implementation and average payback period (0.21 years – see Table 2-6) makes improvements in compressed air efficiency a sound investment.

Table 2-7

Motors System Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Motor Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Replace Standard V-Belts with Cogged V-Belts	955	5,663	0.17	12	1
Use Most Efficient Type Of Electric Motors	44,360	35,736	1.24	23,247	2,046
Install Variable Frequency Drives On Evaporative Condenser Fan	66,206	26,349	2.51	28,570	2,514
Summary Data					
Average Measure	17,293	15,105	1.12	9,714	855
Subtotal	293,977	256,792	NA	165,134	14,532
Share Of Total	20.8%	12.8%	NA	4.2%	5.3%

Just over 5% of the reduction in CO_2 emissions identified in the Action Plan for the industrial sector derive from the 17 motor-related measures. Results from our data indicate that improving the efficiency of motors is expensive, as shown by examples in Table 2-7. The Interlaboratory Working Group Study (IWG 1997) focused on motor systems because of the large energy efficiency gains that were possible with improvements. Motors have wide application within the industrial sector and improvements in efficiency would bring benefits to a large number of firms (USDOE 1996). Compared to the national average in the USDOE Industrial Assessment Center database, the energy savings from motor upgrades identified for Delaware are relatively low. Thus, the DCCAP's estimate may be conservative.

Table 2-8

Lighting Equipment Measures to Save Energy and Reduce CO_2 Emissions in Delaware's Industrial Sector

Examples of Lighting Measures	Implement. Cost ($)	Energy Savings ($)	Payback Period (years)	Energy Saved (Btus)	$mtCO_2$ Mitigated
Reduce Lighting Usage	6,120	7,021	0.87	851	75
Install High Efficiency Lighting	48,924	18,336	2.67	19,902	1,751
Install High Pressure Sodium Fixtures	26,726	26,996	0.99	12,846	1,130
Summary Data					
Average Measure	36,123	23,239	1.36	8,429	742
Subtotal	325,103	209,150	NA	75,862	6,676
Share Of Total	2.6%	1.2%	NA	0.2%	0.3%

Of the 170 selected measures used in the Action Plan analysis of the industrial sector, 9 were lighting-related. A relatively small percentage of annual energy conserved and CO_2 emissions mitigated by the Action Plan would derive from this category, but there is a short payback period (less than 1.5 years) justifying the investment. In the case of lighting, use of the screening criterion of including only those measures which decreased energy use for the particular category (in this case, lighting) by 5% or more, led to selection of large-scale upgrade projects with comparatively higher costs. Thus, it is possible that cheaper lighting upgrade options exist in Delaware, which are cost-effective but may require greater management initiative to pursue. Indeed, the 5% savings threshold was used on advice from industry representatives of the DCCC who indicated that smaller savings were unlikely to win management support. This is because few rewards would accrue to managers for achieving low-impact improvements, even though the upgrades are cost-effective.

Results

Table 2-9

Summary of Results: Full Implementation Scenario

Analysis by Measure Category	Energy Saved (%)	CO_2 Mitigated (%)
Space Conditioning	36	37
Boiler and Steam Systems	27	24
Heat Recovery and Containment	23	22
Compressed Air	8	9
Motors	4	5
Lighting	2	2
TOTAL	100	100
Average Payback (all measures)		0.7 years

Note: Average payback = (measure payback) * (CO_2 mitigated by a measure / CO_2 mitigated in the sector).

CO_2 reductions are spread unevenly among the categories of measures, with lighting offering the least reduction and space conditioning offering the greatest (see Table 2-9 above). However, achieving cost-effective energy savings and reductions in CO_2 emissions across the sector requires initiatives employing the full range of equipment upgrades examined for the Action Plan.

Of course, it would be difficult to achieve all savings identified by the Action Plan, even if each meets strict cost-effectiveness standards. For this reason, the Action Plan adopts the approach used in the recent Interlaboratory Working Group Study (IWG 1997) in which scenarios are built for 100%, 65% and 35% implementation rates. The same 170 measures are employed for all three cases. Full implementation would realize a 27% reduction (1,140,100 mtCO_2) from 2010 levels. The Major Commitment scenario (65% implementation rate) would achieve an 18% reduction (741,100 mtCO_2), while the Modest Commitment scenario (35% implementation rate) would achieve a 9% reduction (399,000 mtCO_2) in emissions (Table 2-1). A detailed description of the measures analyzed for the Action Plan is provided in Appendix C.

Conclusion

In 1990, the sector's emissions totaled 3.2 mmtCO_2 and are forecast to increase to 4.2 mmtCO_2 under the BAU scenario by 2010. Under the Major Commitment scenario, emissions would be 3.5 mmtCO_2. Using the Major Commitment scenario as the benchmark for action, emissions in the industrial sector can be reduced by 18% from the forecast level for 2010. This is equivalent to less than 10% above the 1990 level for this sector.

The potential exists to make significant, cost-effective reductions in the energy consumption and carbon dioxide emissions of the industrial sector in Delaware. Although industrial processes entail a myriad of individual energy-consuming activities, our analysis has shown that by concentrating mitigation policy in key areas it is possible to slow industrial sector greenhouse gas emissions at relatively low cost. Implementation of 65% the 170 measures in six categories (air compressors, motors, lighting, space conditioning, boiler/steam, and heat recovery) identified in the Plan would result in annual savings in energy expenditures that would make Delaware's industry more competitive in the future. Specific policy actions to support the adoption of the analyzed measures for CO_2 emission reduction in the industrial 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.

Energy Information Administration (EIA). (1997a) *Annual Energy Outlook 1998: With Projections to 2020*. Washington, DC: National Technical Information Service.

———. (1997b) *Manufacturing Consumption of Energy 1994*. Washington, DC: National Technical Information Service.

———. (1993) *Emissions of Greenhouse Gases in the US, 1985-1990.* Washington, DC: National Technical Information Service.

Gas Research Institute. (1996) *Sector Summary: Industrial Sector*. Washington, DC: GRI.

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: National Technical Information Service.

Jones, T. and D. Jaber. (1998). *Steam Challenge: Improving Steam System Efficiency through Marketplace Partnerships*. Washington, D.C.: Alliance to Save Energy.

State and Territorial Pollution Program Administrators/Association of Local Pollution Control Officials (STAPPA/ALAPCO). (1998). *Reducing Greenhouse Gas Emissions: A Menu of Options*. Washington, D.C.: STAPPA/ALAPCO.

U.S. Department of Energy (USDOE). (1998) *The DOE Industrial Assessment Database User Information*. Washington, DC: National Technical Information Service. Available at Internet website: http://oipea-www.rutgers.edu/database/db_f.html.

———. (USDOE). (1996) *Motor Challenge Sourcebook: A Compendium of Current Activities and Resources in the Industrial Motor Systems Markets*. Washington, DC: National Technical Information Service.