# CHAPTER 1
# ECONOMIC, ENERGY, AND $CO_2$ EMISSION FORECASTS FOR DELAWARE

In this chapter, the method used to derive forecasts for Delaware's economic growth, energy demand, and $CO_2$ emissions to the year 2010 is described. These forecasts quantify the likely growth in the state's economy, energy consumption, and $CO_2$ emissions by 2010 under the assumption that no policy interventions to alter current patterns are adopted. The objective is to forecast emissions under business-as-usual assumptions in order to allow the measurement of possible effects of alternative emission reduction strategies.

The Delaware Econometric Model (DEM), maintained by the College of Business and Economics of the University of Delaware, was used as a reference framework and source for key variables. The DEM is a simulation model that treats the Delaware economy as consisting of 13 sectors and uses 47 variables to forecast state income growth. The DEM was used to project state economic growth and the projected growth was then used as an input to, in turn, forecast energy demand and associated $CO_2$ emissions.

Sector-specific regression equations predicting energy demand were devised for the residential, commercial, industrial, transport and utility sectors. These equations express the relationship between energy demand and key independent variables, including income, average energy price, and energy intensity. Estimates of the number of future households and population in Delaware were provided by the University of Delaware's Center for Applied Demography and Survey Research. The result is a forecast of state energy demand by sector, which was then converted to sector-specific $CO_2$ emission projections using established conversion factors.[1] This forecast is termed the Economic, Energy, and $CO_2$ (or $EECO_2$) forecast.

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[1] The forecast used for this report does not include greenhouse gas emissions from agricultural sources, e.g., bovine methane emissions.

Data for most economic variables derive from the DEM database and cover the period 1975-1995 (although in some cases a shorter span of records had to be used). An exponential smoothing technique was applied to regressions used for the $EECO_2$ forecast to project sector values through 2010.

Analysis of historical fuel mix trends for each sector was used as the basis to forecast future fuel mixes by sector. These fuel mix forecasts were, in turn, employed to project $CO_2$ emissions for the period 1996-2010 using standard conversion factors.[1] Summation across individual sectors produced the total forecast energy consumption and $CO_2$ emissions for the state.

**Delaware Energy Demand Model**

$$Y = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_n X_n$$

**Residential Sector**

$$\ell nD = 2.43 - 0.11\ell nP + 0.17\ell nY + 5462I$$
(14.7) (-2.7) (32.7) (21.7)

$R^2 = .99$

**Commercial Sector**

$$\ell nD = 6.35 - 0.45\ell nP + 0.49\ell nY + 0.82\ell nI$$
(9.32) (-7.21) (10.79) (15.32)

$R^2 = .95$

**Industrial Sector**

$$\ell nD = 2.10 - 0.24\ell nP(-1) + 1.37\ell nN + 0.69\ell nI$$
(1.52) (-2.76) (9.31) (6.96)

$R^2 = .95$

**Transportation Sector**

$$\ell nD = 3.74 - 0.27\ell nP + 0.34\ell nI$$
(17.2) (-6.62) (-5.94)

$R^2 = .89$

Note: D = Energy demand, P = Energy price, I = Energy intensity,
Y = Delaware state income, and N = GDP of U.S.

In the residential sector, annual energy demand between 1996 and 2010 was forecast with an equation derived from historical trands among the combined variables of energy price, income, and energy intensity. Data from 1980 to 1995 were used to

[1] Specifically, conversion factors established by the Energy Information Administration of the U.S. DOE (see www.eia.doe.gov) were applied in the $EECO_2$ model

establish the historical relationships. For the commercial energy sector, energy demand was forecast by an equation using comparable variables to those for the residential sector forecast. Data for this sector were gathered for the period 1978-1995. In the industrial sector, energy demand was forecast by an equation involving the comparable variables of energy price, energy intensity, and state GDP that were applicable to this sector. Data from 1975-1995 were used to build the industrial sector forecast. For the transportation sector, energy demand was forecast by an equation with the independent variables of energy price and energy intensity. Data from 1975-1995 were used to anchor this sector's forecast.

**Electric Utility Sector**

Residential

$$\ell nD_{res} = -34.59 - 0.34\ell nP_{res} + 3.49\ell nH_{res} + 0.38\ell nI_{res}$$

(-4.67) (-1.77) (5.44) (4.55)

$R^2 = .98$

Industrial

$$\ell nD_{ind} = 2.29 - 0.31\ell nP_{ind} + 0.39\ell nI_{ind} + 0.6\ell nRGDP_{ind} + 0.32\ell nD_{ind}(-1)$$

(1.33) (-4.14) (3.69) (3.32) (2.47)

$R^2 = .97$

Commercial

$$\ell nD_{com} = 3.57 - 0.21\ell nP_{com} + 0.05\ell nPI_{com} + 0.24\ell nI_{com} + 0.74\ell nD_{com}(-1)$$

(0.58) (-0.98) (2.35) (2.55) (1.47)

$R^2 = .98$

Total Electrical Consumption

$$Total_{elec} = D_{res} + D_{ind} + D_{com}$$

Electricity Losses

$$Loss_{elec} = Total_{fuel} - Total_{elec}$$

Note: H = number of households, D = electricity demand, P = electricity price, I = electricity intensity, Y = income, GDP = national GDP, RGDP = state GDP, and PI = Delaware Personal Income

Two special features must be taken into account when modeling the electricity sector: (1.) the existence of energy losses in the conversion of a fuel to end-use electricity; and (2.) the impact of end-use demand on the sector's energy losses. As to the first, the electric utility sector both consumes energy as fuel and produces energy as electricity. The difference between its fuel consumption and the generation, transmission, and distribution of electricity by the sector equals the losses within the system. Forecasts of energy consumption and energy supply by the electricity sector must account for these losses. With respect to the sector's second special feature, electricity savings made in other sectors impact total electricity demand, which, in turn affects energy losses by the sector. It is necessary for the methodology used to estimate $CO_2$ reductions to take account of this fact. The factors influencing end-use electricity demand are indicated by the regression equations above. The sum of the projected electricity demands of residential, industrial and commercial users provides the forecast of electricity demand in Delaware. Multiplying this forecast of state electricity demand by the loss rate associated with the electricity generation, transmission and distribution facilities in Delaware provides the net energy demand of the sector, which can then be used to forecast its $CO_2$ emissions (in conjunction with the forecasted fuel mix for the sector).

Electricity consumption to 2010 was estimated for each sector based on 1985-1995 data. Electricity losses were attributed to the electric utility sector based on sector demand. Because Delaware's expected generation capacity through 2010 is sufficient to meet forecast demand, no net electricity imports or exports are foreseen.[2] Energy consumption within the electric utility sector was converted to $CO_2$ emissions on the

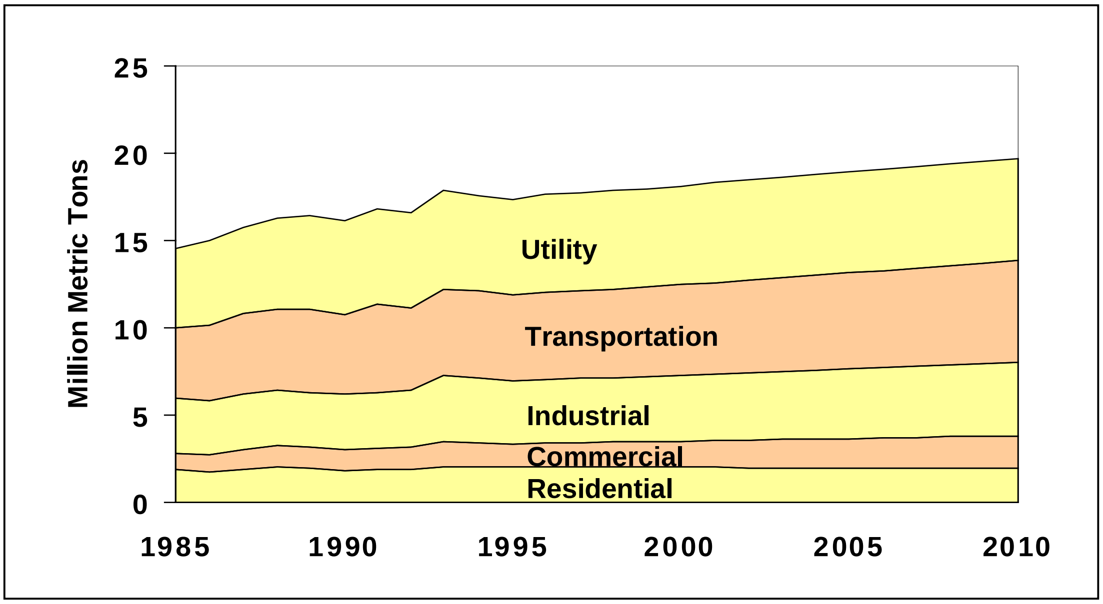
[2] There is a potential methodological problem associated with USEPA's approach to counting $CO_2$ emissions from this sector. USEPA limits each state to counting $CO_2$ emissions from generation within its borders. If a state is a net importer of electricity, this limit would be less than the emissions from electricity consumption in the state. Further, such a limit could affect the energy efficiency potential that could be investigated for electricity importers. $CO_2$ reductions from efficiency gains beyond an amount equal to the growth in $CO_2$ emissions from in-state generation would have to be disregarded under the USEPA's methodology. The reverse problem occurs with states that are electricity exporters. While USEPA's approach prevents double-counting between state and national estimates of $CO_2$ emissions, it could affect BAU forecasts and estimates of energy-efficiency potential in importing or exporting states. Fortunately, Delaware is projected to be self-sufficient in electricity supply through 2010.

basis of the forecasted fuel mix for 2010 (obtained from the state's utility with generation facilities located in Delaware).

Having obtained forecasts of non-electrical energy demand, electrical energy demand and losses in the electricity utility system, total energy demand to the year 2010 was calculated. These data formed the basis for the calculation of the forecast emissions for the state to the year 2010, as presented in Figure 1-1.

**Figure 1-1**

**BAU Forecast of $CO_2$ Emissions in Delaware through 2010**




**Reducing Greenhouse Gas Emissions in Delaware: Goals**

The Consortium has adopted a target for greenhouse gas emission reduction that is equivalent to that established for the U.S. under the Kyoto Protocol. As noted above (see the Introduction to this Action Plan), the U.S. target is to reduce emissions to 7% below those of 1990 during the target years of 2008-2012, although the United States has not ratified the Kyoto Protocol. Until the U.S. Senate has ratified the Kyoto Protocol, its target has no standing in U.S. national policy. However, the Kyoto Protocol target offers a reasonable basis for analysis at this time.

As is shown in Chapters 2-7, the Consortium was able to identify cost-effective $CO_2$ emission reduction strategies approaching the goal of a 7% reduction below 1990 levels. The target adopted by DCCC is a “soft target” for Delaware. That is, when cost-effective $CO_2$ emission reduction strategies were estimated to be available in a sector, the target could be met; when such savings were not found to be available, the target would not be met.

Examination of plans developed by other states’ for USEPA’s State and Local Climate Change Program reveals that the 1990 benchmark is commonly adopted especially for State reports produced or underway in the post-Kyoto period.

With a 1990 emissions baseline of 15.6 mmt$CO_2$, the DCCC’s emissions goal translates to a reduction in State emissions to 14.5 mmt$CO_2$ in 2010. CEEP analyzed the likely trend of emissions in the absence of any intervening policy initiatives and arrived at a BAU forecast of state emissions reaching 18.8 mmt$CO_2$ by the year 2010 (Table 1-1). Accordingly, Delaware would need to reduce its greenhouse gas emissions by 23% below the BAU forecast for 2010 to meet the DCCC’s target.

**Table 1-1**

**BAU Energy and $CO_2$ Emission Distributions by Sector in 2010**

| | Energy (trillion Btus) | $CO_2$ Emissions (mmt) |
|---|---|---|
| Industrial | 105.0 | 4.22 |
| Residential | 33.4 | 1.95 |
| Commercial | 28.9 | 1.86 |
| Transportation | 68.6 | 4.92 |
| Utilities | 85.0 | 5.81 |
| **TOTAL** | **320.9** | **18.76** |