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Total Energy Cycle Assessment Of Electric and Conventional Vehicles: An Energy and Environmental Analysis

Volume II: Appendices A-D to Technical Report

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Total Energy Cycle Assessment Of Electric and Conventional Vehicles: An Energy and Environmental Analysis:

APPENDICES

These appendices provide details and documentation of various components of the EVTECA. Appendix A provides further explanation of overall methodological issues. Appendix B gives details of the vehicle analysis, and Appendix C gives details of the electric utility analysis. In Appendix D, the inputs and outputs of each of the other (non-utility, non-vehicle) processes included in the EVTECA are documented. Appendix D also provides further explanation of the derivation of the material content of automobiles. Tables summarizing the results of the EVTECA for Houston and Washington, D.C., can be found in Appendix E.

APPENDIX A
Methodological Issues: Details

Appendix A.1 explains how the EVTECA was coordinated with the South Coast Air Quality Management District (SCAQMD). Appendix A.2 provides the data-gathering guidance provided to the EVTECA team.

A.1 Air Quality Modeling and Management Coordination

While the EVTECA focuses on developing an inventory of emissions and residuals associated with EVs, it will also serve as an example of a cost-shared effort to address the fundamental reason that EVs are being developed and marketed - to expand the options air quality management districts have to improve urban air quality. NREL worked with the South Coast Air Quality Management District (SCAQMD), which is generally acknowledged to be on of the foremost air quality management agencies in the world, to use the inventory to help analyze the effects of EV use on air quality in the Los Angeles area. NREL and the SCAQMD have a well established working relationship and developed a cost-shared approach to conduct an analysis of the potential role of EVs in achieving air quality standards as part of the State Implementation Plan (SIP) revision process mandated by the Clean Air Act. This collaboration also increased the relevance of the EVTECA to the development or regional and national environmental policy and regulations.

The mutual interest between NREL and the SCAQMD in energy and environmental issues was a major factor in selecting the Los Angeles region as on the four regions to be studied in the EVTECA. Through an informal arrangement between NREL and the SCAQMD, the SCAQMD agreed to provide cost-share by modeling the air quality effects of one or more scenarios of EV penetration as part of the Air Quality Management Plan (AQMP) revision process. This arrangement for air quality modeling represented an important step in the progression of TECAs sponsored by DOE from compiling emission inventories to analyzing the impact of these emissions. The SCAQMD had also formed an Air Quality Modeling Working to provide technical expertise and peer review for air quality modeling. Through this Working Group, the EVTECA team had access to state-of-the-art in air quality modeling. In turn, NREL provided the SCAQMD data and information from the EVTECA, particularly the Utility Analysis, to help prepare an Environmental Impact report for the AQMP as required by the California Environmental Quality Act. The SCAQMD planned to conduct a TECA of EVs as an important element of the EIR but instead agreed to incorporate appropriate parts of EVTECA into its EIR.

The collaborations between NREL and the SCAQMD on the EVTECA began with the selection of the Los Angeles region, more specifically the area within the SCAQMD. In addition to the mutual interest in EVs, the Los Angeles region was selected because the SCAQMD is classified by the EPA as an extreme ozone non-attainment areas and as a serious CO non-attainment area. Furthermore, Los Angeles is one of the largest metropolitan areas in the U.S., is the largest automobile market in the US, and represents the largest potential market for EVs. The automobile industry must meet California's mandated Zero Emissions Vehicle (ZEV) requirements, and public interest in EVs is focused on the Los Angeles auto market.

The SCAQMD established an Energy Planning Working Group to coordinate the activities of transportation, energy, and air quality planning and regulatory agencies, utilities, and industry in the District and in the State (e.g., California Air Resources Board, Public Utilities Commission, California Energy Commission) as part of its AQMP revision process. This Working Group (or its individual members agencies and organizations) helped provide NREL, information and data on:

- utility load curves and capacity expansion plans;
- in-basin and out-of-basin electricity generation based on a cost-production model used by the CEC; and
- regional economic, population, and transportation demand trend projections.

As part of the SIP revision process mandated by the Clean Air Act, the SCAQMD prepared an Ozone Attainment Plan in which EVs will play a significant role. The EVTECA would assist the SCAQMD in preparing the Attainment Plan if the schedules were compatible. Information, data, and analysis from the EVTECA could make major contributions to the SIP revision process and provide a better factual and analytic foundation for subsequent policy decision. NREL worked with the SCAQMD to establish an informal coordination process whereby the SCAQMD defined criteria (type, level of detail, format, etc) for information, data, and analysis that will be the most useful for the SIP revision process. The EVTECA team attempted to meet these criteria as long as they did not compromise the analytic integrity of the EVTECA. In turn, the SCAQMD agreed to test and validate the EVTECA by using the information, data, and analysis as inputs to its air quality modeling, management, and planning functions. In addition, the EVTECA would benefit from peer review by experts from the California Air Resources Board, Southern California Edison, EPA, Motor Vehicle Manufacturers Association, among others, who serve on the technical review committee that reviews and helps SCAQMD interpret air quality modeling techniques and results. By contributing to this process, the ETVECA will be more relevant and valuable to the larger community of experts analyzing energy, transportation, and environmental issues and will assist the SCAQMD address a fundamental regulatory requirement that will in all likelihood will be required in other states where EVs are expected to play a prominent role in helping urban areas attain national air quality standards. In turn, DOE will benefit from the EVTECA by strengthening its working relationship with SCAQMD, where some of the most innovative air quality, energy, and transportation analysis and modeling tools and techniques are being developed and tested.[1]

In order to coordinate the air quality analysis with the other tasks in the EVTECA, NREL also worked with the SCAQMD in developing the EV market penetration scenario assumptions that underlie the EVTECA. All of the scenarios (described earlier) are based on some variant of the California ZEV mandate. For example, the "high EV market penetration" regional scenario was based on the assumption that the study regions other than Los Angeles will adopt the California Low Emission Vehicle Program(LEVP) before 1998 and that new passenger cars and light-duty trucks sold in these regions will conform to the requirements of the California LEVP. For the "high EV" scenario for the Los Angeles region, we assumed that the penetration of EVs will be that percentage proposed in the 1994 Air Quality Management Plan by the South Coast Air Quality Management District. This percentage follows the California LEV requirements for ZEVs to 2003 (10%) and increases to 20% of new light-duty vehicle sales by 2005 and to 50% by 2009.

When NREL completed its initial dispatch simulation modeling runs for the SCAQMD region as part of the utility analysis, NREL discussed the results with the air quality modeling group at SCAQMD. NREL's simulation showed that emissions even from the high EV market penetration scenario was less than 5% of the baseline emissions inventory for 2000 and 2010 and below the threshold that the SCAQMD will run its urban airshed model. Although this finding abbreviated the anticipated collaboration on air quality modeling between NREL and SCAQMD, it was nonetheless a significant finding that the utility emissions

1 SCAQMD is co-sponsor with DOE and DOT of the Fuel Cell Bus Program.

from EV charging (as simulated by NREL) was too small to model in the Los Angeles region where EV market penetration will most likely be the highest in the nation.

Even though the SCAQMD did not run its model for the EVTECA, NREL continued to work with the SCAQMD because of the mutual interest in the ZEV mandate and the intense debate in California about amending the mandate to include an "equivalent ZEV" (or ZEV) classification. NREL arranged a meeting with the SCAQMD, CEC, CARB, Southern California Edison, and Los Angeles Department of Water and Power to brief them on the EVTECA in general and on the utility analysis in particular. The discussion focused on methodological differences between NREL's study and the one done by CEC for CARB to come up with proposed emission standards and regulations for the EZEV classification. The major differences between the two studies appear to be due to the CEC-CARB looking at only in-basin emissions and to different assumptions made about future resource additions to the two utility systems. The CEC-CARB study assumes mostly repowering existing facilities with additional emission control (e.g., selective catalytic reduction for NO). If funding and time permit, NREL agreed to work to see how close it can come to the CEC-CARB results by using the same assumptions. Continuing coordination with these organization is important, because CARB will conduct a public hearing in January on adoption of the proposed EZEV regulations.

A.2 Unit Process Data Documentation Format

A.2.1 EVTECA Data Collection Guidance

There are two primary types of data associated with the EVTECA: unit process data and scenario data. Unit process data are any data that describe a process, but are not dependent upon the specific scenario in which the process is used. Among other pieces of data, unit process data includes information that describes how inputs and outputs associated with the process relate to one another. The figure below helps illustrate this concept.

A complete unit process characterization is a peer-reviewable, stand-alone write-up that includes two items: 1) a brief, textual summary that describes how the data for the process was developed and any underlying assumptions, and 2) a complete set of process data that is documented using the standard EVTECA unit process characterization forms.

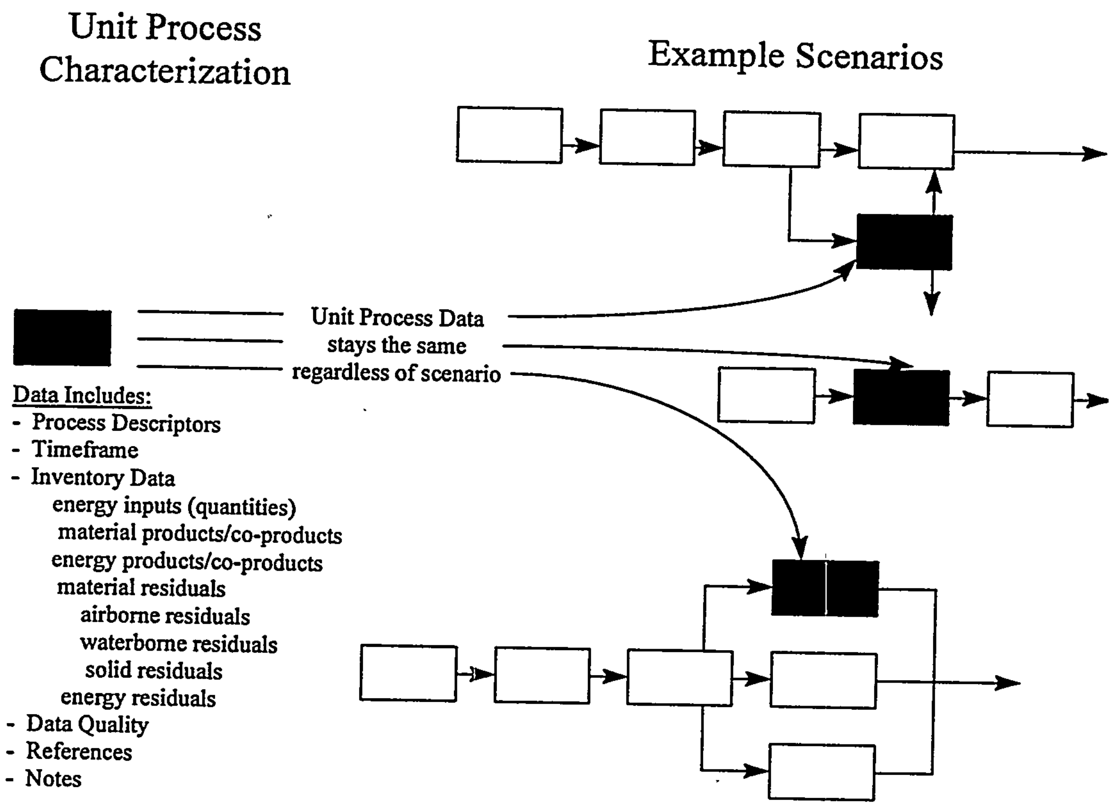

Figure A.1 How Unit Process Data Fits into Scenarios

Scenario data is any data that describes the relationship between multiple processes (e.g., processes in the figures below).

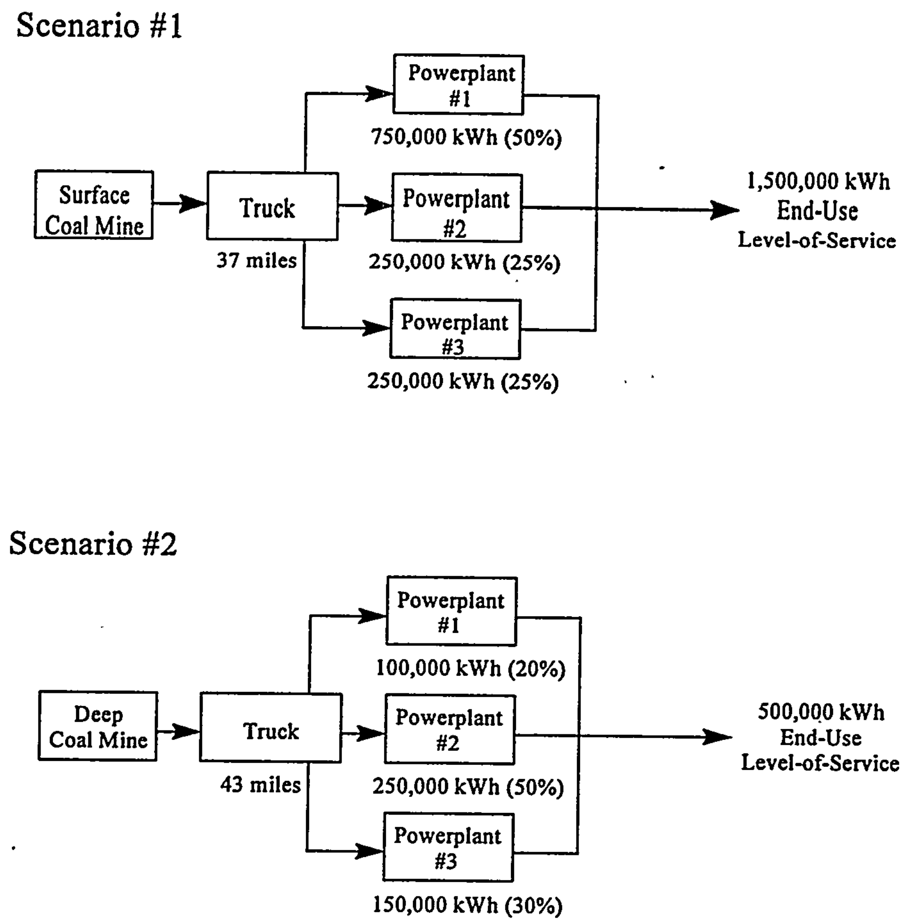

Figure A.2 Example Scenario

In reference to the above figures, the following are all examples of scenario data: the end-user level-of-service, the fraction that each power plant contributes to the end-use energy demand, the miles traveled as part of the truck transportation process, and the link from the truck transportation process to a specific type of coal mine (rather than a generic coal mine). These pieces of data vary with each scenario, whereas the data associated with each individual unit process (e.g., the fuel efficiency of the truck transportation process) remains the same in both scenarios.

A.2.2 Unit Process Data Collection Guidance

Depending upon the type of process that is being characterized and the level of detail that is available to characterize it, different data collection formats are applicable. The information that is required to completely characterize a unit process can be divided into three types: 1) basic information which is required for all processes; 2) inventory information which describes the inputs and outputs associated with the process and how they relate to one another; 3) support information such as references and various types of notes. The figure below illustrates how each of these types of information would be gathered together to comprise a complete set of unit process data documentation forms. Each of the three types of information is discussed individually in the sections that follow.

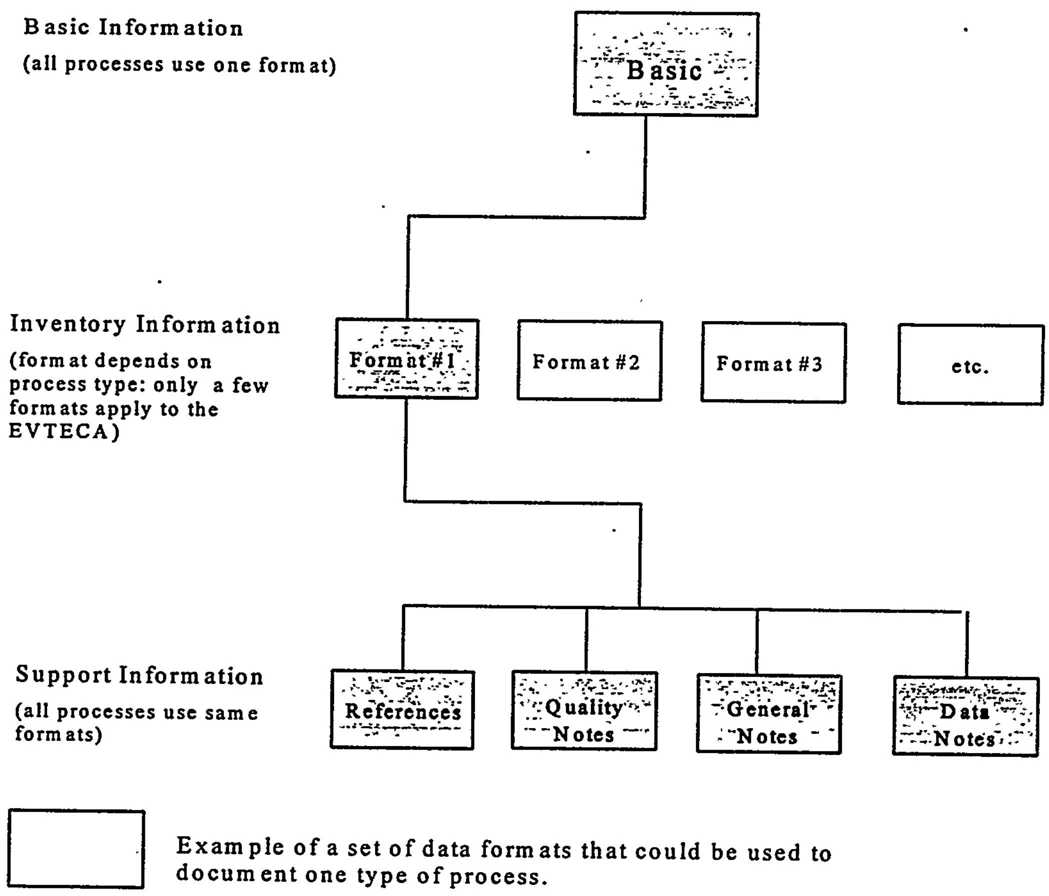

Figure A.3 Gathering Information

A.2.2.1 Basic Information

It takes three pieces of information to uniquely identify a process characterization: a name, a geographic location, and a time frame. The process characterization forms include a separate field for each of these three pieces of information.

A. Process Name. Identify the process name.

B. Geographic Location. Identify the geographic location upon which the data is based. Use one of the following six conventions:

Global Average Process
National Average Process
Regional Average Process - (list specific region after hyphen)
Site-Specific Process - (list specific site after hyphen)
Best Practice

Note that the location upon which the data is based may be different than the intended use for the data.

Global Average Process. If the data has been collected from sources that represent the average process on an international level, use the term "global average process." There will probably not be processes in the EVTECA that fall within this category.

National Average Process. If the data has been collected from sources that represent the average process on a national level, use the term "national average process." There will probably be quite a few processes in the EVTECA for which this is the appropriate designation. For example, if data for a deep coal mining process is collected from national statistics compiled by the U.S. Bureau of Mines (that ignore regional differences in energy consumption, emissions, etc.), the process should be identified as a "national average process."

Process Name:	**Deep Coal Mine**
Geographic Location:	**National Average Process**
Time frame:	
Process Description:	

Regional Average Process. If the data has been collected from sources that represent an average process on a regional level, use the term "regional average process." For example, if a refinery process characterization is based on data for West Coast refineries, the process should be identified as a "regional average process."

Process Name: **Refinery**
Geographic Location: **Regional Average Process - West Coast**
Time frame:
Process Description:

As a second example, you could have a second process characterization with the same name but representative of an alternative location.

Process Name: **Refinery**
Geographic Location: **Regional Average Process - East Coast**
Time frame:
Process Description:

Site-Specific Process. If the data has been collected from sources that represent a process at a specific location, use the term "site-specific process."

For example, if a refinery process characterization is based on a refinery in Wilmington, Delaware, the process should be identified as such.

Process Name: **Refinery**
Geographic Location: **Site-Specific Process - Wilmington, DE**
Time frame:
Process Description:

Best Practice. If the data has been collected from sources that describe the best available process, use the term"best practice process."

For example, if the basis for a characterization of a refinery s a study conducted by a petroleum trade association and the refinery process characterization is based on a refinery in Wilmington, Delaware, the process should be identified as such.

Process Name: **Refinery** Geographic Location: **Best Practice** Time frame: Process Description:

C. Time frame. A time frame (i.e., 1980,, 1985, 1990, 1995, 2000, 2010) should be identified for each process characterization. The identified time frame should be the year associated with the data (which is not necessarily the time frame for with we intend to use the information).

As an example, if a data set for a refining process is developed and based upon references from a 1992 source (and the data was actually two years old at that point in time), the appropriate time frame for this process characterization is the year 1990. The data set should not falsely be labeled with the year 2010 simply because we are using the data in a year 2010 scenario.

Process Name: **Refinery** Geographic Location: **Regional Average Process - East Coast** Time frame: **1990** Process Description:

After developing and documenting the 1990 refinery data set, an analyst might choose to develop a second process characterization by taking this data set and making adjustments to it in order to reflect the technological and regulatory change that is expected to take place in the refining industry over the next 20 years. In this case, the newly documented data set would be identified with a 2010 time frame.

Process Name: **Refinery** Geographic Location: **Regional Average Process - East Coast** Time frame: **2010** Process Description:

Given the level of uncertainty in the data, unless there is a compelling argument to be more specific, identify the time frame using a five-year increment (1985, 1990, 1995, 2000, 2005, 2010).

D. <u>Process Description</u>. Provide a brief explanation of what's included in the process boundaries as well as general process descriptors (e.g., nameplate capacity, utilization, heat rates, etc.).

Four examples of the basic process information follow:

Process Name:	**Tempered Flat Glass Production**
Geographic Location:	**National Average**
Time frame:	**1990**
Process Description:	Process boundaries include: batch preparation, melting and fining, forming, and post forming activities. Furnace technology is side-port regenerative with nameplace capacity of 650 tons/day. Characterization is based on an average daily furnace production rate of 500 tons/day.

Process Name:	**Primary Aluminum Production**
Geographic Location:	**National Average Process**
Time frame:	**1990**
Process Description:	Based on the Hall Process for aluminum production with an efficiency of 7.62 kWh per pound of aluminum. Prior boundaries include anode manufacture, Hall process, and ingot casting. Does not include alumina production.

Process Name:	**Bauxite Mining**
Geographic Location:	**Global Average Process**
Time frame:	**1990**
Process Description:	Process boundaries include: ore crushing, screening, washing and drying, but not calcining.

Process Name: **Steel Sheet Production**

Geographic Location: **National Average Process**

Time frame: **2010**

Process Description: Quantities of airborne residuals have been reduced from the current 1990 process to account for additional emission controls that will be added be meet CAAA requirements. In addition, the energy intensity has been reduced by 2.5% from 1990 levels to account for expected efficiency improvements.

Process boundaries include: continuous casting, reheat, strip milling, pickling, cold rolling, annealing, and tempering.

A.2.2.2 Unit Process Inventory Information

To provide a reasonable level of consistency in the EVTECA, several inventory data documentation formats have been developed. These formats are consistent with formats that are commonly used in life-cycle assessments conducted by various DOE offices, EPA, and the private sector. The completed data formats will be included in the final study documentation.

The first format is designed to support a proportional representation (i.e., model) of a process. Most processes in the EVTECA are assumed to be adequately represented by a unit process characterization which describes all individual inputs and outputs as proportional to one another. That is, as the demand for a specific output from a process is doubled, all other outputs and associated inputs also double. If the demand for a specific output is decreased by 30%, all other outputs and associated inputs are reduced by 30%.

The proportional model and the associated inventory data format will apply to most processes in the EV and RFG TECs, such as:

- coal mining
- oil production
- refining
- battery manufacturing
- bauxite mining
- alumina production
- aluminum production
- ore mining
- steel production, etc.

The second format is designed to support a representation (i.e., model) of a process which describes the inputs and outputs of a process as a function of distance (e.g., lbs of fuel consumed per mile traveled, or lbs of emissions per mile traveled). Most transportation processes in the EVTECA will be characterized by a distance model.

A.2.1.2.1 Proportional Model

The refinery example below presents unit process inventory data that is based on a proportional model. The discussion that follows the example explains each entry in the data format:

Process Name:	Refinery				
Geographic Location:	National Average				
Timeframe:	1990				
Process Description:	Based on an integrated refinery (as opposed to a straight run refinery).				

	Total Annual		***per MBtu of RFT***		
	Value	Units	Value	Units	DQI
Inputs					
1 Crude Oil	6.42×10^6	bbls	0.519	MBtu	A
2 MTBE	281×10^6	bbls	0.023	lbs	A
3 Electricity	1,503,000	kWh	3.45	kWh	A
4 Natural Gas	42.8×10^9	mmscf	1.2×10^{-4}	MBtu	A
5 Other	NC	NC	NC	NC	NC
Outputs					
Products					
6 Motor Gasoline	2.600×10^9	bbls			A
7 Diesel Fuel No. 2	NC	NC	NC	NC	NC
8 Diesel Fuel No. 6	etc.	etc.	etc.	etc.	etc.
9 Jet Fuel					
10 Residual Fuel Oil					
11 Still Gas					
12 Petroleum Coke					
13 Propane					
14 Asphalt/Road Oil					
15 Petrochemical Fdstks					
16 Lubricants					
17 Other Products/Co-Products	NC	NC	NC	NC	NC
Airborne Residuals					
18 NO_x			6.65×10^{-6}	tons	B
19 SO_x			5.27×10^{-5}	tons	B
20 CO			3.34×10^{-5}	tons	B
21 Pb			1.30×10^{-6}	tons	B
22 PM_{10}			0.77×10^{-7}	tons	B
23 TSP			1.00×10^{-7}	tons	C
24 CO_2			1.00×10^{-6}	tons	B
25 CH_4			2.68×10^{8}	tons	C
26 NMVOCs			2.16×10^{-2}	tons	B
27 Other Greenhouse Gases	NC	NC	NC	NC	NC
Other Airborne Residuals	NC	NC	NC	NC	NC
Waterborne Residuals					
28 Wastewater			10.5	tons	
29 Chromium			2.2×10^{-9}	tons	
30 Other Heavy Metals			5.0×10^{-10}	tons	
31 Penols			3.4×10^{-9}	tons	
Other Waterborne Residuals	NC	NC	NC	NC	NC
Solid Residuals					
33 Non-hazardous	8.18×10^9	lbs	3.3×10^{-4}	tons	
33 Hazardous	4.85×10^9	lbs	1.7×10^{-4}	tons	
34 Radioactive	DNA	DNA	DNA	DNA	DNA

The left column of the data format includes an identification number. This number serves as a cross-reference for additional notes and references. Numbers do not need to be in any particular sequence.

E. Values. In nearly all cases, inventory data will be collected in one of two forms: 1) *totals* based on some time frame (e.g., 16 tons of product produced annually, or 2) as a *coefficient* that expresses quantity in terms of another inventory item (E.G., 69 emissions per ton of product).

When data is collected in terms of totals, it should be documented as totals on the unit process characterization form and then be converted to a coefficient. If data is collected in terms of a coefficient, it should be documented as a coefficient on the until process characterization form (do not back calculate totals from coefficients). All coefficients should be expressed in standards units and have the appropriate number of scientific digits. All calculations in the EVTECA will be based on the final coefficients for each process.

Box 1 provides guidance on the use of the terms not available, not applicable, not characterized, and negligible.

Attachment 1 includes a target list of inventory items for the EVTECA. All target items appear on the data documentation format. Additional items can be added on a case-by-case basis as deemed appropriate by the individual analyst.

F. Units. Totals based on some time frame (e.g., 16 tons of product produced annually) should be reported in industry standard units. If the original, referenceable data must be modified or converted through calculations to arrive at a value suitable for use in the EVTECA, these calculations should be documented in supported notes attached to the characterization.

To maintain consistency across the EVTECA and facilitate final data manipulations, coefficients should be expressed in MBTUs for energy data and tons for materials data. For example, CO2 emissions would be expressed as tons of CO2 per MBTU of reformulated gasoline. Coal, oil, natural gas, gasoline and other refinery products are all examples for energy-related data. Plastics, glass, steel, and batteries are examples of material-related data.

G. Data Quality Indicators., A data quality indicator (DQI) should be assigned to each numerical value in the unit process characterization. Box 2 provides additional guidance on assigning DQIs.

One of the issues that arises when compiling unit process inventory data is the allocation of material and energy inputs and residuals outputs to the various useful products that are produced by the process. In the case of processes like coal mining, power generation, glass production, and battery production, the process produces one primary product. Consequently, it is reasonable to allocate all inputs and residuals associated with the process to the primary product. However, in the case of oil/gas production, refining operations, co-generation units, plastics production, and other multi-products processes, an allocation scheme is required. Typically, barring detailed information about the process, inputs and residuals are allocated to final products based on their mass or energy content.

For processes that require allocation, a set of data forms should be prepared for the process with no allocation of emissions (this defines the base situation). An additional set of data forms should be prepared showing the allocation strategy

A.2.1.2.2 **Distance Model**

The distance model uses essentially the same format with a few minor exceptions as shown below.

Process Name:	Heavy Duty Diesel Truck				
Geographic Location:	National Average				
Timeframe:	2000				
Process Description:	Based on Class 8 tractor-trailers. Increases in flue economy are based on DOT production				
1 Vehicle Fuel: No. 2 Diesel Fuel					
2 Vehicle Efficiency: 22000 BTU/mile (6 MPG)					
	Total Annual		*per MBTU of RFT*		
	Value	Units	Value	Units	DQI
Inputs					
3 Lubricants			1	gm	A
Other	NC	NC	NC	NC	NC
Outputs					
Airborne Residuals					
4 NO_x			10	gm	B
5 SO_x			0.56	gm	A
6 CO			8.1	gm	A
7 Pb	NC	NC	NC	NC	NC
8 PM_{10}	NC	NC	NC	NC	NC
9 TSP			0.22	NC	NC
10 CO_2			1800	gm	A
11 CH_4	NC	NC	NC	NC	NC
12 Evaporative NMVOCs			2.7	gm	C
13 Exhaust NMVOCs	NC	NC	NC	NC	NC
14 Other Greenhouse Gases	DNA	DNA	DNA	DNA	DNA
Other Airborne Residuals	NC	NC	NC	NC	NC
Waterborne Residuals	DNA	DNA	DNA	DNA	DNA
Solid Residuals	DNA	DNA	DNA	DNA	DNA

Box 1.--Definitions: Not Available, Not Applicable, Not Characterized, and Negligible

The terms "not applicable", "negligible", and "not available" often have differing meanings in different analysis. The following definitions are provided to ensure consistent use of terms for TECA.

Not Available is used to indicate that a factor is applicable but that data were not available. It is denoted by a "NA" in the data reporting format.

Not Applicable is used to refer to a factor (such as an environmental factor) that does not apply (DNA) to the specific unit process being characterized. In the data reporting format for environmental factors, for example, emissions of radioactive materials may not apply to the ethanol conversion energy cycle. Therefore, any reporting format that requests a data value for radioactive materials would receive a "DNA", denoting that this factor is not applicable.

Not Characterized (NC) is sued to denote that no attempt was made to collect data for this factor. This recognizes the fact that there will be more factors that are applicable to an energy cycle than a TECA can comfortably analyze. Factors that have not been characterized (denoted by "NC") fall outside of the scope of the TECA, as defined by the data development, analysis, and management teams or the cost of collecting the information likely exceeds the value-added to the study.

Negligible should not be used in a TECA. One of the underlying principles of this type of assessment is that there are many environmental factors associated with energy and materials use that have not traditionally been characterized in conventional environmental analysis. A definitive judgment regarding the importance of any given factor cannot be made until the analysis is complete.

Box 2.--Data Quality Indicators

1. The letter "A" is used to indicate that data quality is very good:
   - little adaptation of collected data is required
   - primary data are used that are peer reviewed *and* accepted
   - original data are based on a large sample size, very detailed engineering estimates *or* modeling results
   - recent data (published within the last 3 years).

2. The letter "B" is used to indicate that data quality is good:
   - some adaptation of collected data is required
   - primary data are used that are peer reviewed
   - original data are based on multiple samples, detailed engineering estimate or modeling results
   - recent data (published within the last 5 years).

3. The letter "C" is used to indicate that data are fair:
   - major adaptation of collected data is required
   - secondary source data are used with review of the primary data upon which they are based
   - original data are based on small sample size, detailed engineering estimates, or modeling results.

4. The letter "D" is used to indicate that data are poor:
   - major adaptation of collected data is required
   - secondary data sources are used without review of the primary sources upon which they are based
   - original data are based on rough engineering estimates or very small sample size.

A.2.2.3 Support Information

Using the identification number as a cross-reference indicator, as appropriate, for each inventory item document the reference, logic behind assignment of quality indicators, provide additional data notes to describe the calculations that were necessary to arrive at a final answer, and provide any general notes or assumptions that apply. This documentation should be grouped into four categories: references, quality notes, general notes, and data notes.

General News	
Process Name:	Refinery
Geographic Location:	National Average
Timeframe:	1990
1. xxxx	
2. xxxx	
3. xxxx	
4. xxxx	
etc.	

Attachment 1
Target Inventory Items

This is a minimum target list. It will sometimes be impossible to locate data for some of these items. In addition, we will seek to identify material and energy flows (e.g., a particularly high volume of a toxic waste) that may not fall on the target list, but are of particular concern ("red flag" items).

<u>Materials</u>

Raw Materials/Products/ Co-Products
- (including all items of significant quantity)

Airborne Residuals
- NOx
- SOx
- CO
- Pb
- PM-10
- TSP
- CO2
- CH4
- NMVOCs
- Other Greenhouse Gases (as specific as possible)

Waterborne Residuals
- Wastewater

Solid Residuals
- Nonhazardous
- Hazardous
- Radioactive*
  - LLW
  - TRU
  - HLW
  - Spent Fuel
  - Mixed

<u>Energy</u>

Electricity
Mechanical*
Radiative (light)*
Thermal*

* List these items only when applicable.

APPENDIX B
Vehicle Analysis: Detailed Documentation [1]

Appendix B provides detailed documentation of various aspects of the vehicle analysis. The following topics are included: projections of new vehicle sales and EV stocks (B.1), selection of battery and vehicle types and performance characteristics (B.2), estimates of EV and CV energy consumption (B.3), simulation of vehicle travel patterns, driving cycles, and EV energy use and emissions (B.4), and EV battery recharge patterns (B.5).

B.1. Projections of Annual New Electric Vehicle Sales and Estimation of Electric Vehicle Stocks in Two Target Years

B.1.1 Introduction

This memorandum presents projections of annual electric vehicle (EV) sales in each of the four metropolitan areas. To do so, first, annual new light-duty vehicle (LDV) sales is projected. And then, with the projected new LDV sales and the established EV market penetration scenarios in the form of EV sales as percentage of total new LDV sales, the volume of annual EV sales is calculated. Finally, in total number of EVs in use in each of the two target years (2000 and 2010) is calculated from annual EV sales.

The LDV category includes three vehicle types: passenger cars, vans, and light trucks For regulatory purposes (e.g. fuel economy and emission standards) vans and light trucks are typically combined into one category: LDTs or light-duty trucks. This category is further disaggregated into Class 1 (less than 6,000 lbs GVW) and Class 2 (greater than 6,000 lbs and up to 10,000 lbs). In this analysis, we projected sales of cars and vans and light trucks less than 6,000 lbs GVW. The CARB ZEV mandate applies to all cars, but only to LDTs less than 3750 lbs. Therefore, we have overestimated the number of LDTs required to be EVs in the sales projections presented below. However, we do not believe that this overestimate is critical to the overall assessment of EVs in this TECA.

B.1.2 Projection of New Vehicle Sales

New Vehicle Sales in Base Year 1992

During this study, new vehicle sales data in 1992 was available. So, 1992 is selected as the base year for projecting future new vehicle sales. That is, 1992 new vehicle sales by passenger cars, vans, and LDTs is collected or estimated for each of the four metropolitan areas, and future annual new vehicle sales from 1993 to 2010 is projected from the base year 1992.

To estimate new vehicle sales for each of the four areas, new vehicle sales data at county level may be needed. Such data are generally not available to the public. This section presents the estimates of county-specific vehicle sales and then estimates of vehicle sales for each metropolitan area. In estimating new vehicle sales, new vehicle registrations are treated here as an approximation for new vehicle sales, though there are some minor discrepancies between new vehicle registrations and new vehicle sales.

[1] This section was prepared by Michael Wang, Argonne National Laboratory, in August 1994. It was modified in December 1996 to include the discussion of methane.

- *The Chicago Metropolitan Area.*

In the EVTECA, the Chicago metropolitan area is defined to include six Illinois counties--Cook, Du Page, Kane, Lake, McHenry, and Will. Data on new vehicle registrations for each of the six counties were obtained from the Office of the Secretary of the State of Illinois (Table B.1.1). As the table shows, it is estimated that 198,716 new cars, 32,281 new vans, and 44,078 new LDTs were registered in 1992 in the Chicago metropolitan area.

Table B.1.1 Estimates of New Vehicle Registrations in the Chicago Metropolitan Area in 1992

County	Cars[a]	All Trucks[b]	Vans[c]	LDTs[d]
Cook	105,174	49,958	17,086	23,329
Du Page	45,790	21,750	7,439	10,157
Kane	9,771	4,641	1,587	2,167
Lake	21,020	9,985	3,415	4,663
McHenry	6,230	2,959	1,012	1,382
Will	10,731	5,097	1,743	2,380
TOTAL	**198,716**	**94,390**	**32,281**	**44,078**

[a] From the Office of the Secretary of the State of Illinois (1993). The Office of the Secretary provided new vehicle registrations for vans and LDTs as well as for cars in each county. However, it is found that the provided data on van and LDT registrations were not consistent with statewide data presented by American Motor Vehicle Manufacturers Association (1993). Because of less precise definition of vans and LDTs used in the vehicle registration process, it is suspected that the provided county-specific data on van and LDT registrations may not be accurate. Thus, we conduct our own estimates of new van and LDT registrations.
[b] To estimate registrations of all trucks, a ratio of new trucks to new cars is applied to the presented new car registrations. Based on data presented by American Motor Vehicle Manufacturers Association (1993), the ratio is calculated as being 0.475 in 1992 in Illinois. Note that trucks include vans and light, medium, and heavy trucks.
[c] To estimate new van registrations, the percentage of new van registrations as of new truck registrations is applied to the estimated new truck registrations. Based on data presented by American Motor Vehicle Manufacturers Association (1993), the percentage is calculated as being 34.2% in 1992 nationwide. Vans here include minivans, vans, station wagons, mini passenger carriers, and passenger carriers.
[d] Based on data presented by American Motor Vehicle Manufacturers Association (1993), it is calculated that new LDT sales with GVW less than 6,000 lbs account for 46.7% of all new truck sales in 1992 nationwide. This percentage is applied to the estimated all new truck registrations to estimate LDT registrations.

- *The Houston Metropolitan Area.*

In the EVTECA, the Houston metropolitan area is defined to include eight Texas counties--Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, and Waller. Estimates of new vehicle registrations for the eight Texas counties are presented in Table B.1.2. As the table shows, it is estimated that 117,947 new passenger cars, 34,362 new vans, and 46,919 new LDTs were registered in 1992 in the Houston metropolitan area.

Table B.1.2 Estimates of New Vehicle Registrations in the Houston Metropolitan Area in 1992

County	All-age, all-type vehicles[a]	New Vehicles[b]				
		All Vehicles	Cars[c]	All Trucks[d]	Vans[e]	LDTs[f]
Brazoria	175,783	12,779	6,901	5,879	2,010	2,745
Chambers	21,014	1,528	825	703	240	328
Fort Bend	175,035	12,725	6,872	5,854	2,002	2,733
Galveston	175,232	12,739	6,879	5,860	2,004	2,737
Harris	2,211,467	160,774	86,818	73,956	25,293	34,536
Liberty	47,254	3,435	1,855	1,580	540	738
Montgomery	172,460	12,538	6,770	5,767	1,972	2,697
Waller	26,155	1,901	1,027	875	299	408
TOTAL	**3,004,400**	**218,420**	**117,947**	**100,473**	**34,362**	**46,919**

[a] From Texas Department of Motor Vehicles (1993).
[b] To estimate new vehicle registrations, new vehicle registrations as the percentage of all-age vehicle registrations are applied to the presented all-age vehicle registrations. With data presented by American Automobile Manufacturers Association (1993), the percentage is calculated as being 7.27% in 1992 in Texas.
[c] To estimate new car registrations, new car registrations as the percentage of all new vehicle registrations are applied to the estimated all new vehicle registrations. Based on data presented by American Motor Vehicle Manufacturers Association (1993), the percentage is calculated as being 54.0% in 1992 in Texas.
[d] Calculated as the difference between all new vehicle registrations and new car registrations. Trucks here include vans and light, medium, and heavy trucks.
[e] Calculated in the way as Footnote c of Table B.1.1 describes.
[f] Calculated in the way as Footnote d of Table B.1.1 describes.

- *The Los Angeles Metropolitan Area.*

In the EVTECA, the geographic boundary of the South Coast Air Basin is treated as the boundary of the Los Angeles metropolitan area. The South Coast Air Basin contains the entire Orange county and the majority of Los Angeles, Riverside, and San Bernadino counties. Table B.1.3 presents estimates of new vehicle registrations in the Los Angeles metropolitan area. It is estimated that 315,190 new passenger cars, 53,023 new vans, and 61,260 new LDTs were registered in 1992 in the Los Angeles Metropolitan area.

Table B.1.3 Estimates of New Vehicle Registrations in the Los Angeles Metropolitan Area in 1992

County	All-Age Vehicles[b]		New Vehicles[d]		
	Cars & Vans	All Trucks[c]	Cars[e]	Vans[e]	LDTs[f]
Los Angeles[a]	4,663,925	1,002,992	204,008	34,319	36,338
Orange	1,508,254	327,462	65,973	11,098	11,864
Riverside[a]	463,608	158,156	20,279	3,411	5,730
San Bernadino[a]	569,939	202,267	24,930	4,194	7,328
TOTAL	7,205,726	1,690,877	315,190	53,023	61,260

[a] Only a portion of Los Angeles, Riverside, and San Bernadino counties is within the South Coast Air Basin (SCAB). To allocate a portion of total vehicle registrations in each county to the SCAB, the percentage of total county population living in the SCAB is used; 97.3% of the total population in Los Angeles county, 74% in Riverside county, and 78% in San Bernadino county live in the SCAB (South Coast Air Quality Management District, 1994). SCAB-portion vehicle registrations in each of the three counties are presented here.
[b] From California Department of Motor Vehicles (1993).
[c] Trucks here exclude vans.
[d] To estimate new vehicle registrations, new vehicle registrations as the percentage of total vehicle registrations are applied to the presented total vehicle registrations. Based on data presented by American Motor Vehicle manufacturers Association (1993), the percentage is calculated as being 5.11% in 1992 in California.
[e] The registrations of new cars and vans are divided into registrations of new cars and registrations of new vans using the percentage of new cars as of total of new cars and vans. With data presented by American Motor Vehicle Manufacturers Association (1993), the percentage is calculated as being 85.6% in 1992 nationwide.
[f] To estimate LDT registrations, LDT registrations as the percentage of total truck registrations are applied to the presented truck registrations (trucks here do not include vans). Based on data presented by American Motor Vehicle Manufacturers Association (1993), the percentage is calculated as being 70.9% in 1992 nationwide.

- *The Washington, D.C. Metropolitan Area.*

In the EVTECA, the Washington DC metropolitan area is defined to include four Maryland counties (Charles, Frederick, Montgomery, and Prince George's), four Virginia counties (Fairfax, Loudoun, Prince William, and Stafford), and the District of Columbia. Table B.1.4 presents estimates of new vehicle registrations for the Washington, D.C. metropolitan area. As the table shows, 109,929 new cars, 16,273 new vans, and 22,218 new LDTs were registered in 1992 in the Washington, D.C. metropolitan area.

Projections of Annual New Vehicle Sales

Annual sales of cars, vans, and LDTs from 1993 to 2010 are projected with the estimated new vehicle sales in base year 1992 and annual rates of increase in new vehicle sales. Data Resources, Inc. (DRI) has projected annual new vehicles sales nationwide for the next 25 years (DRI, 1993). Using DRI's projections of new vehicle sales, annual rates of increase in new vehicle sales for cars and LDTs are calculated. Since DRI's projections for LDTs are for vans and LDTs together, same annual rates of increases are assumed for vans and for LDTs here. Because the increases in new vehicle sales will be likely to diminish over time, two annual rates of increase are calculated; one applies to years between 1993 and 2000, and the other applies to years after 2000. In summary, estimated annual rates of increase in new vehicle sales are 1.1% for cars and 2.63% for vans and LDTs between 1993 and 2000; and 0.51% for cars and 1.02% for vans and LDTs after 2000.

Table B.1.5 presents projections of new vehicle sales for each metropolitan area by vehicle type between 1993 and 2010. Among the three vehicle types, passenger cars account for more LDV sales than vans and LDTs combined. The shares of cars, vans, and LDTs vary considerably among the four areas. For example, in 1993, the shares are 71.9%, 11.9%, and 16.2% for cars, vans, and LDTs in the Chicago area; 58.8%, 17.4%, and 23.8% in the Houston area; 73.1%, 12.5%, and 14.4% in the Los Angeles area; and 73.8%, 11.1%, and 15.1% in the Washington, D.C. area.

The above projections are for household and fleet vehicles together. Because the EVTECA include household and fleet applications, and because the two applications have different vehicle usage patterns, thus different energy and emission results, the projected vehicle sales need to be divided into household and fleet vehicles. According to vehicle registration statistics by Bobit Publishing Company, in 1992, fleet new car registrations accounted for 30.8% of total new vehicle registrations, fleet new vans for 28.1%, and fleet new LDTs for 9.6% (Bobit Publishing Co., 1993). These percentages are used here to divide the projected total vehicle sales into fleet and household vehicle sales. These percentages area assumed to remain unchanged between 1992 and 2010. During the study, fleet vehicle data from several sources were reviewed, and some discrepancies among the reviewed sources were found. There certainly is a need of studying fleet vehicle sales, registrations, and usage. It is believed here that Bobit Publishing Company's data on shares of fleet cars, vans, and LDTs is reasonable. Tables 6-7 present the projections of household and fleet vehicle sales.

Table B.1.4 Estimates of New Vehicle Registrations in the Washington, D.C. Metropolitan Area in 1992

	All-age, all-type vehicles[a]	New Vehicles[b]: All vehicles	Cars[c]	All trucks[d]	Vans[e]	LDTs[f]
Maryland:						
Charles	85,500	6,019	4,159	1,860	636	869
Frederick	145,000	10,208	7,054	3,154	1,079	1,473
Montgomery	562,000	39,565	27,339	12,226	4,181	5,709
Prince George's	495,000	38,848	24,080	10,768	3,683	5,028
TOTAL	1,287,500	90,640	62,632	28,008	9,579	13,079
Virginia:	All-age LDVs[g]	New Vehicles[h]: LDVs	Cars[i]		Vans[i]	LDTs[i]
Fairfax	619,582	34,635	23,655		3,983	5,438
Loudoun	78,906	4,411	3,013		507	693
Prince William	154,809	8,654	5,911		995	1,359
Stafford	51,575	2,883	1,969		332	453
TOTAL	904,872	50,582	34,548		5,817	7,941
Washington, D.C.:		New Vehicles:	Cars[j]	Trucks[j]	Vans[e]	LDTs[f]
			12,749	2564	877	1197
GRAND TOTAL			109,929		16,273	22,218

[a] Data on all-age, all-type vehicle registrations for the four Maryland counties are from Maryland Department of Motor Vehicles (1993).
[b] To estimate new vehicle registrations, new vehicle registrations as the percentage of all-age vehicle registrations are applied to the presented all-age vehicle registrations. Based on data presented by American Motor Vehicle Manufacturers Association (1993), the percentage is calculated as being 7.04% in 1992 in Maryland.
[c] Estimated with the percentage of new car registrations as of all new vehicle registrations. Based on data presented by American Motor Vehicle Manufacturers Association (1993), the percentage is calculated as being 69.1% in 1992 in Maryland.
[d] Calculated as the difference between all new vehicle registrations and new car registrations.
[e] Calculated in the way as Footnote c of Table B.1.1 describes.
[f] Calculated in the way as Footnote d of Table B.1.1 describes.
[g] Data on all-age LDV registrations for the four Virginia counties are from Virginia Department of Motor Vehicles (1993).
[h] To estimate new vehicle registrations, new vehicle registrations as the percentage of all-age vehicle registrations are applied to the presented all-age vehicle registrations. Based on data presented by American Motor Vehicle Manufacturers Association (1993), the percentage is calculated as being 5.59% in 1992 in Virginia.
[i] Registrations of new LDVs are divided into registrations of new cars, new vans, and new LDTs. Based on data presented by American Motor Vehicle Manufacturers Association (1993), it is calculated that in 1992 nationwide, new car sales accounted for 68.3% of new LDV sales, new vans 11.5%, and new LDTs 15.7%.
[j] New vehicle registrations for the District of Columbia are from American Automobile Manufacturers Association (1993).

Table B.1.5 Projections of Annual New Vehicle Sales in the Four Studied Areas

Year	Chicago				Houston				Los Angeles				Washington, D.C.			
	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total
1993	200,900	33,130	45,240	279,270	119,250	35,270	48,150	202,670	318,660	54,420	62,870	435,950	111,140	16,700	22,800	150,640
1994	203,110	34,000	46,430	283,540	120,560	36,190	49,420	206,170	322,160	55,850	64,530	442,540	112,360	17,140	23,400	152,900
1995	205,350	34,900	47,650	287,900	121,880	37,150	50,720	209,750	325,710	57,320	66,220	449,250	113,600	17,590	24,020	155,210
1996	207,610	35,810	48,900	292,320	123,220	38,120	52,050	213,390	329,290	58,830	67,960	456,080	114,850	18,050	24,650	157,550
1997	209,890	36,760	50,190	296,840	124,580	39,120	53,420	217,120	332,910	60,370	69,750	463,030	116,110	18,530	25,300	159,940
1998	212,200	37,720	51,510	301,430	125,950	40,150	54,830	220,480	336,570	61,960	71,590	470,300	117,390	19,020	25,960	162,370
1999	214,530	38,710	52,860	306,010	127,330	41,210	56,270	224,810	340,280	63,590	73,470	477,340	118,680	19,520	26,650	164,850
2000	216,890	39,730	54,250	310,870	128,740	42,290	57,750	228,780	344,020	65,260	75,400	484,680	119,980	20,030	27,350	167,360
2001	218,000	40,140	54,810	312,950	129,390	42,730	58,340	234,460	345,770	65,930	76,170	487,870	120,600	20,230	27,630	168,460
2002	219,110	40,550	55,360	315,020	130,050	43,160	58,930	232,140	347,540	66,600	76,950	491,090	121,210	20,440	27,910	169,560
2003	220,230	40,960	55,930	317,120	130,710	43,600	59,530	233,840	349,310	67,280	77,730	494,320	121,830	20,650	28,190	170,670
2004	221,350	41,380	56,500	319,230	131,380	44,050	60,140	235,570	351,090	67,970	78,520	497,580	122,450	20,860	28,480	171,790
2005	222,480	41,800	57,080	321,360	132,050	44,500	60,750	237,300	352,880	68,660	79,330	500,870	123,070	21,070	28,770	172,910
2006	223,610	42,230	57,660	323,500	132,720	44,950	61,370	239,040	354,680	69,360	80,130	504,170	123,700	21,290	29,060	164,050
2007	224,750	42,660	58,250	325,660	133,400	45,410	62,000	240,810	356,480	70,070	80,950	507,500	124,330	21,500	29,360	175,190
2008	225,900	43,090	58,840	327,830	134,080	45,870	62,630	242,580	358,310	70,780	81,780	510,870	124,970	21,720	29,660	176,350
2009	227,050	43,530	59,440	330,020	134,770	46,340	63,270	244,380	360,140	71,500	82,610	514,250	125,600	21,940	29,960	177,500
2010	228,210	43,980	60,050	332,240	135,450	46,810	63,920	246,180	361,970	72,230	83,450	517,650	126,250	22,170	30,270	178,690

Table B.1.6 Projections of Annual New Vehicle Sales in the Four Studied Areas: Household Vehicles

Year	Chicago				Houston				Los Angeles				Washington, D.C.			
	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total
1993	139,020	23,820	40,890	203,740	82,520	25,360	43,530	151,400	220,510	39,130	56,840	316,470	76,910	12,010	20,610	109,5300
1994	140,550	24,450	41,970	206,970	83,430	26,020	44,680	154,120	222,940	40,160	58,330	321,420	77,750	12,320	21,160	111,230
1995	142,100	25,090	43,070	210,260	84,340	26,710	45,850	156,900	225,3905	41,210	59,870	326,4602	78,610	12,650	21,710	112,970
1996	143,660	25,750	44,210	213,620	85,270	27,410	47,060	159,740	227,870	42,300	61,440	331,600	79,470	12,980	22,280	114,740
1997	145,230	26,430	45,370	217,040	86,210	28,.130	48,290	162,630	230,370	43,410	63,060	336,840	80,350	13,320	22,870	116,540
1998	146,840	27,120	46,560	220,530	87,160	28,870	49,560	165,590	232,910	44,550	64,710	342,170	81,230	13,670	23,470	118,370
1999	148,460	27,840	47,790	224,080	88,120	29,630	50,870	168,610	235,470	45,720	66,420	347,610	82,130	14,030	24,090	120,240
2000	150,090	28,.570	49,040	227,700	89,080	30,410	52,210	171,700	238,060	46,920	68,160	353,150	83,030	14,400	24,720	122,150
2001	150,850	28,860	49,540	229,260	89,540	30,720	52,740	173,000	239,280	47,400	68,860	355,540	83,450	14,550	24,970	122,970
2002	151,620	29,150	50,050	230,830	90,000	31,030	53,280	174,300	240,500	47,890	69,560	357,940	83,880	14,700	25,230	123,800
2003	152,400	29,450	50,560	232,410	90,450	31,350	53,820	175,620	241,720	48,370	70,230	360,364	84,310	14,850	25,490	124,640
2004	153,170	29,750	51,080	234,000	90,920	31,670	54,370	176,950	242,950	48,870	70,990	362,810	84,740	15,000	25,750	125,480
2005	153,960	30,060	51,600	235,610	91,380	31,990	54,920	178,290	244,190	49,370	71,710	365,270	85,170	15,150	26,010	126,330
2006	154,740	30,360	52,120	237,230	91,850	31,320	55,480	179,650	245,440	49,870	72,440	367,750	85,600	15,310	26,270	127,180
2007	155,530	30,670	52,660	238,860	92,310	32,650	56,050	181,010	246,690	50,380	73,180	370,250	86,040	15,460	26,540	128,040
2008	156,320	30,980	53,190	240,500	92,790	32,980	56,620	182,380	247,950	50,890	73,930	372,770	86,480	15,620	26,810	128,910
2009	157,120	31,300	53,740	242,150	93,260	33,320	57,200	183,770	249,210	51,410	74,680	375,300	86,920	15,780	27,090	129,780
2010	157,920	31,620	54,280	243,820	93,730	33,660	57,780	185,170	250,480	51,940	75,440	377,860	87,360	15,940	27,360	130,660

Table B.1.7 Projections of Annual New Vehicle Sales in the Four Studied Areas: Fleet Vehicles

Year	Chicago				Houston				Los Angeles				Washington, D.C.			
	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total	Cars	Vans	LDTs	Total
1993	61,880	9,310	4,340	75,530	36,730	9,910	4,620	51,260	98,150	15,290	6,040	119,470	34,230	4,690	2,190	41,110
1994	62,560	9,550	4,460	76,570	37,130	10,170	4,740	52,050	99,230	15,690	6,190	121,110	34,610	4,820	2,250	41,670
1995	63,250	9,810	4,570	77,630	37,540	10,450	4,870	52,850	100,310	16,110	6,360	122,780	34,990	4,940	2,310	42,240
1996	63,940	10,060	4,700	78,700	37,950	10,710	5,000	53,660	101,420	16,530	6,530	124,460	35,370	5,070	2,370	42,810
1997	64,650	10,330	4,820	79,790	38,370	10,990	5,130	54,490	102,540	16,960	6,700	126,200	35,760	5,210	2,430	43,400
1998	65,360	10,600	4,950	80,900	38,790	11,280	5,260	55,340	103,670	17,410	6,870	127,950	36,160	5,340	2,490	43,990
1999	66,080	10,880	5,080	82,030	39,220	11,580	5,400	56,200	104,810	17,870	7,050	129,730	36,550	5,480	2,560	44,600
2000	66,800	11,170	5,210	83,180	39,650	11,880	5,540	57,080	105,960	18,340	7,240	131,540	36,960	5,630	2,630	45,210
2001	67,140	11,280	5,260	83,680	39,850	12,010	5,600	57,460	106,500	18,530	7,310	132,340	37,140	5,690	2,650	45,480
2002	67,490	11,390	5,320	84,190	40,060	12,130	5,660	57,840	107,040	18,710	7,390	133,140	37,330	5,740	2,680	45,760
2003	67,830	11,510	5,370	84,710	40,260	12,250	5,720	58,230	107,590	18,910	7,460	133,960	37,520	5,800	2,710	46,030
2004	68,180	11,630	5,420	85,230	40,470	12,380	5,770	58,620	108,140	19,100	7,540	134,770	37,720	5,860	2,730	46,310
2005	68,520	11,750	5,480	85,750	40,670	12,500	5,830	59,010	108,690	19,290	7,620	135,600	37,910	5,920	2,760	46,590
2006	68,870	11,870	5,540	86,270	40,880	12,630	5,890	59,400	109,240	19,490	7,690	136,420	38,100	5,980	2,790	46,870
2007	69,220	11,990	5,590	86,800	41,090	12,760	5,950	59,800	109,800	19,690	7,770	137,260	38,300	6,040	2,820	47,160
2008	69,580	12,110	5,650	87,340	41,300	12,890	6,010	60,200	110,360	19,890	7,850	138,100	38,490	6,100	2,850	47,440
2009	69,930	12,230	5,710	87,870	41,510	13,020	6,070	60,600	110,920	20,090	7,930	138,940	38,690	6,170	2,880	47,730
2010	70,290	12,360	5,760	88,410	41,720	13,150	6,140	61,010	111,490	20,300	8,010	139,800	38,880	6,230	2,910	48,02

B.1.3 Projection of Annual EV Sales

EV Market Penetration Scenarios

Annual EV sales is estimated with the annual new LDV sales projected in the above section and EV market penetration scenarios. Two EV market penetration scenarios (the low and the high penetration scenario) are established in the EVTECA. Table B.1.8 presents the two scenarios.

Table B.1.8 EV Market Penetration Scenarios (EV Sales as % of total New LDV Sales)

Model-Year	Low Penetration Scenario		High Penetration Scenario	
	3 Cities[a]	Los Angeles[b]	3 Cities[c]	Los Angeles[d]
1998	0	2	2	2/2
1999	0	2	2	2/2
2000	0	2	2	2/2
2001	1	5	5	5/5
2002	1	5	5	5/5
2003	1	10	10	10/10
2004	2	10	10	10/10
2005	2	10	10	20/15
2006	3	10	10	20/15
2007	3	10	10	35/25
2008	3	10	10	35/25
2009	3	10	10	50/35
2010	3	10	10	50/35

[a] The low EV penetration scenario for Chicago, Houston, and Washington, D.C. is assumed by the EVTECA team.
[b] The low EV penetration scenario for Los Angeles is the zero-emission vehicle penetration scheme required by the California Air Resources Board in its low-emission vehicle program.
[c] The zero-emission vehicle penetration scheme required by the California Air Resources Board in its low-emission vehicle program is assumed to be the high EV penetration scenario for Chicago, Houston, and Washington, D.C.
[d] The high EV penetration scenario for Los Angles is based on EV penetration assumptions made by the South Coast Air Quality Management District in its 1994 air quality management plan. The South Coast Air Quality Management District assumes California Air Resources Board's zero-emission vehicle scheme between 1998 and 2004. The district assumes that in the south coast basin, electric car sales will account for 50% of total new car sales by 2010, and electric light-duty trucks for 35% of total new light-duty truck sales. The presentation format here is in [electric car penetration rate/electric light truck penetration rate].

EV Sales Projections for Vehicle Types and for Vehicle Applications

The EV penetration scenarios presented in Table B.1.8 are supposed to apply to sales of all LDVs. To predict EV sales by EV types (i.e., cars and vans here) and by EV applications (i.e., household and fleet), total light-duty EV sales needs to be broken down to three EV groups--household cars, fleet cars, and fleet vans. To do so, electric van sales as a percentage of total EV sales and electric fleet car sales as a percentage of total electric car sales are assumed. Table B.1.9 presents the assumptions of electric van sales as percentages of total EV sales. As the table shows, under the low EV market penetration scenario and in earlier years, fleet vans account for a larger share of total EV sales than household and fleet cars. As EV market penetration rate increases, the share of electric vans becomes small, simply because fleet van application of EVs becomes exhausted.

To divide electric car sales into household and fleet electric cars, assumptions of fleet electric car sales as percentages of total electric car sales are made. Table B.1.10 presents assumed percentage sales of fleet electric cars. As the table shows, except a few cases, more electric cars are sold to fleet applications than to household applications. Furthermore, fleet electric cars account for a higher share of total electric car sales than household electric cars under the low EV market penetration scenario and in earlier years.

An explicit criterion used in assuming percentages of electric van sales percentages and fleet electric car is that the estimated electric vehicle sales for each of the three vehicle applications (household cars, fleet cars, and fleet vans) would account for a reasonable percentage of total vehicle sales for that application.

Table B.1.9 Assumed Sales of Fleet Electric Vans as Percentage of Total EV Sales

Model-Year	Low-Penetration Scenario		High-Penetration Scenario	
	3 Cities	Los Angeles	3 Cities	Los Angeles
1998	90	60	60	60
1999	90	60	60	60
2000	90	60	60	60
2001	80	40	40	40
2002	80	40	40	40
2003	80	20	20	20
2004	80	20	20	20
2005	80	20	20	17
2006	60	20	20	17
2007	60	20	20	10
2008	60	20	20	10
2009	60	20	20	7
2010	60	20	20	7

Table B.1.10 Sales of Fleet Electric Cars as Percentages of Sales of All Electric Cars

Model Year	Chicago	Houston	Los Angeles	Washington, D.C.
Low EV Market Penetration Scenario:				
1998	n/a	n/a	66.8	n/a
1999	n/a	n/a	66.8	n/a
2000	n/a	n/a	66.8	n/a
2001	52.4	75.7	66.8	75.7
2002	52.4	75.7	66.8	75.7
2003	52.4	75.7	66.8	75.7
2004	52.4	75.7	66.8	75.7
2005	52.4	75.7	66.8	75.7
2006	52.4	75.7	66.8	75.7
2007	52.4	75.7	66.8	75.7
2008	52.4	75.7	66.8	75.7
2009	52.4	75.7	66.8	75.7
2010	52.4	75.7	66.8	75.7
High EV Market Penetration Scenario:				
1998	66.8	66.8	66.8	66.8
1999	66.8	66.8	66.8	66.8
2000	66.8	66.8	66.8	66.8
2001	66.8	66.8	66.8	66.8
2002	66.8	66.8	66.8	66.8
2003	66.8	66.8	66.8	66.8
2004	66.8	66.8	66.8	66.8
2005	66.8	66.8	48.8	66.8
2006	66.8	66.8	48.8	66.8
2007	66.8	66.8	45.4	66.8
2008	66.8	66.8	45.4	66.8
2009	66.8	66.8	40.5	66.8
2010	66.8	66.8	40.5	66.8

Table B.1.11 Projected Annual EV Sales

Model Year	Chicago			Houston			Los Angeles			Washington, D.C.		
	HH Cars	Fleet Cars	Fleet Vans	HH Cars	Fleet Cars	Fleet Vans	HH Cars	Fleet Cars	Fleet Vans	HH Cars	Fleet Cars	Fleet Vans
Low EV Market Penetration Scenario:												
1998	0	0	0	0	0	0	1,250	2,511	5,641	0	0	0
1999	0	0	0	0	0	0	1,269	2,549	5,728	0	0	0
2000	0	0	0	0	0	0	1,289	2,589	5,816	0	0	0
2001	298	328	2,504	112	349	1,844	4,865	9,771	9,757	82	255	1,348
2002	300	330	2,520	113	351	1,857	4,897	9,836	9,822	83	257	1,356
2003	302	332	2,537	114	354	1,871	13,144	26,402	9,886	83	258	1,365
2004	608	669	5,108	229	713	3,769	13,230	26,576	9,952	167	520	2,749
2005	612	673	5,142	231	718	3,797	13,318	26,751	10,017	168	523	2,767
2006	1,849	2,033	5,823	698	2,170	4,303	13,406	26,928	10,083	508	1,580	3,133
2007	1,862	2,046	5,862	703	2,186	4,335	13,496	27,106	10,,150	512	1,591	3,154
2008	1,874	2,060	5,901	708	2,203	4,367	13,584	27,286	10,217	515	1,601	3,174
2009	1,887	2,074	5940	714	2,219	4,399	13,674	27,466	10,285	518	1,612	3,195
2010	1,899	2,087	5,980	719	2,235	4,431	13,764	27,648	10,353	522	1,622	3,216

Table B.1.11 Projected Annual EV Sales (cont'd.)

Model Year	Chicago			Houston			Los Angeles			Washington, D.C		
	HH Cars	Fleet Cars	Fleet Vans	HH Cars	Fleet Cars	Fleet Vans	HH Cars	Fleet Cars	Fleet Vans	HH Cars	Fleet Cars	Fleet Vans
High EV Market Penetration Scenario:												
1998	801	1,610	3,617	587	1,180	2,651	1,250	2,511	5,641	432	867	1,948
1999	814	1,635	3,673	598	1,201	2,698	1,269	2,549	5,728	438	880	1,978
2000	827	1,660	3,731	608	1,222	2,745	1,289	2,589	5,816	445	894	2,008
2001	3,120	6,268	6,259	2,298	4,616	4,609	4,856	9,771	9,757	1,680	3,374	3,369
2002	3,141	6,310	6,300	2,315	4,650	4,643	4,897	9,836	9,822	1,691	3,396	3,391
2003	8,432	16,937	6,342	6,218	12,490	4,677	13,144	26,402	9,886	4,538	9,115	3,413
2004	8,488	17,050	6,385	6,264	12,582	4,711	13,230	26,576	9,952	4,568	9,175	3,436
2005	8,545	17,164	6,427	6,310	12,674	4,746	39,540	37,695	15,538	4,598	9,235	3,458
2006	8,602	17,278	6,470	6,356	12,768	4,781	39,776	37,887	15,697	4,628	9,296	3,481
2007	8,659	17,394	6,513	6,403	12,862	4,816	80,028	66,641	15,857	4,658	9,357	3,504
2008	8,717	17,510	6,557	6,450	12,957	4,852	80,548	66,981	16,019	4,689	9,419	3,527
2009	8,775	17,627	6,601	6,498	13,052	4,887	129,665	88,160	16,182	4,720	9,481	3,550
2010	8,834	17,745	6,645	6,546	13,149	4,924	130,519	88,610	16,347	4,751	9,543	3,574

With annual new LDV sales, EV market penetration scenarios, and sales percentages of electric vans and fleet electric cars, EV sales are projected by model year, for each vehicle group, and in each of the four cities. Table B.1.11 presents the projected EV sales.

For model years 2003-2010, it is implicitly assumed that as total EV sales increase, mini-compact cars and full-size vans account for smaller percentages of total EV sales, because the market for mini-compact cars and full-size vans is limited, relative to that for compact cars and minivans. In particular, under the low EV market penetration scenario, household cars are divided evenly between mini-compact and compact cars in Chicago, Houston, and Washington, D.C.; in Los Angeles, mini-compact cars account for 30% of car sales, and compact cars for the remaining 70%. In each of the four cities, minivans account for 80% of fleet van sales, and full-size vans for the remaining 20%. Under the high EV market penetration scenario, in Chicago, Houston, and Washington, D.C., mini-compact cars account for 30% of household car sales, and compact cars for the remaining 70%. In Los Angeles, mini-compact cars account for 10-30% of household car sales, and compact cars for the remaining 70-90%, depending on model years.

EV Sales by EV Type

Various EV types are assumed in the EVTECA. Assumed EV types are presented in a separate memorandum. For the EVTECA simulation, the projected EV sales by vehicle group need to be further divided into EV types. To do so, shares of EV types within an EV group are assumed (Tables 12-13). For some EV types, more than one battery type are applied (for example, electric compact cars in model years 2003-2010 are equipped with Na-S, Ni-Cd, or Ni-MH batteries). For those EV types, total number of EVs for an EV type is divided evenly among the batteries types applied to the EV type.

As Table B.1.12 shows, for model years 1998-2002, it is assumed that household cars are divided evenly between 2-seaters and compact cars; and mini-minivans account for 30% of fleet vans, minivans for 40%, and full-size vans for the remaining 30%. In determining these allocation ratios, it is implicitly assumed that 2-seaters and mini-minivans account for a relatively large share between 1998 and 2002, because total EV sales is small in that period.

B.1.4 Estimates of EV Stocks in the Two Target Years

EV stocks by model year and by vehicle type in the two target years have been estimated with the IMPACTT (the Integrated Market Penetration and Anticipated Costs of Transportation Technologies) model developed at the Center for Transportation Research, Argonne National laboratory. The IMPACTT estimates vehicle stocks by considering vehicle survival and vehicle usage rates. Both vehicle survival and vehicle usage rates are functions of vehicle age, vehicle operation and maintenance costs, the rate of depreciation in vehicle value, and the rate of vehicle scrappage. Since the EVTECA does not consider vehicle costs, in running the IMPACTT, vehicle costs were fixed so that cost effect on vehicle stocks was eliminated. Also, some of the IMPACTT's parameters were changed in order to generate vehicle lifetime and of lifetime VMT that match the 13 years of vehicle lifetime and 130,000 miles of vehicle lifetime VMT assumed in the EVTECA. Tables 14-17 present estimated EV stocks in each of the two target years.

Table B.1.12 Shares of EV Types Within Each EV Group: Model Years 1998-2002

Model Year	3 Cities						Los Angeles					
	HH Cars		Fleet Cars	Fleet Vans			HH Cars		Fleet Cars	Fleet Vans		
	2-seat	Comp	Comp	MMVan	MVan	FSVan	2-seat	Comp	Comp	MMVan	MVan	FSVan
Low Penetration Scenario:												
1998	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
1999	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
2000	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
2001	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
2002	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
High Penetration Scenario:												
1998	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
1999	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
2000	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
2001	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3
2002	0.5	0.5	1.0	0.3	0.4	0.3	0.5	0.5	1.0	0.3	0.4	0.3

Table B.1.13 Shares of EV Types Within Each EV Group: Model Years 2003-2010

Model Year	3 Cities					Los Angeles				
	HH Cars		Fleet Cars	Fleet Vans		HH Cars		Fleet Cars	Fleet Vans	
	MComp	Comp	Comp	MVan	FSVan	MComp	Comp	Comp	MVan	FSVan
Low Penetration Scenario:										
2003	0.5	0.5	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2004	0.5	0.5	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2005	0.5	0.5	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2006	0.5	0.5	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2007	0.5	0.5	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2008	0.5	0.5	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2009	0.5	0.5	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2010	0.5	0.5	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
High Penetration Scenario:										
2003	0.3	0.7	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2004	0.3	0.7	1.0	0.8	0.2	0.3	0.7	1.0	0.8	0.2
2005	0.3	0.7	1.0	0.8	0.2	0.2	0.8	1.0	0.8	0.2
2006	0.3	0.7	1.0	0.8	0.2	0.2	0.8	1.0	0.8	0.2
2007	0.3	0.7	1.0	0.8	0.2	0.11	0.89	1.0	0.8	0.2
2008	0.3	0.7	1.0	0.8	0.2	0.11	0.89	1.0	0.8	0.2
2009	0.3	0.7	1.0	0.8	0.2	0.1	0.9	1.0	0.8	0.2
2010	0.3	0.7	1.0	0.8	0.2	0.1	0.9	1.0	0.8	0.2

Table B.1.14 Estimated EV Stocks in 2000: the Low EV Penetration Scenario

Model Year	Household EVs		Fleet EVs			
	2-Seat (Pb-A)	Compact (Pb-A)	Compact (Pb-A)	MMVan (Na-S)	MVan (Ni-Cd)	FSVan (Pb-A)
Chicago:						
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0
Houston:						
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0
Los Angeles:						
1998	623	623	2,487	1,676	2,235	1,676
1999	634	634	2,543	1,714	2,285	1,714
2000	645	645	2,589	1,745	2,326	1,745
TOTAL	1,901	1,901	7,619	5,135	6,847	5,135
Washington, D.C.:						
1998	0	0	0	0	0	0
1999	0	0	0	0	0	0
2000	0	0	0	0	0	0
TOTAL	0	0	0	0	0	0

Table B.1.15 Estimated EV Stocks in 2000: the High EV Penetration Scenario

Model Year	Household EVs		Fleet EVs			
	2-Seat (Pb-A)	Compact (Pb-A)	Compact (Pb-A)	MMVan (Na-S)	MVan (Ni-Cd)	FSVan (Pb-A)
Chicago:						
1998	399	399	1,595	1,075	1,433	1,075
1999	407	407	1,631	1,099	1,466	1,099
2000	414	414	1,660	1,119	1,492	1,119
TOTAL	1,219	1,219	4,886	3,293	4,391	3,293
Houston:						
1998	293	293	1,169	788	117	88
1999	299	299	1,198	807	119	90
2000	304	304	1,222	824	122	91
TOTAL	895	895	3,589	2,419	358	269
Los Angeles:						
1998	623	623	2,511	1,676	2,235	1,676
1999	634	634	2,529	1,714	2,285	1,714
2000	645	645	2,589	1,745	2,326	1,745
TOTAL	1,901	1,901	7,629	5,135	6,847	5,135
Washington, D.C.:						
1998	215	215	859	579	772	579
1999	219	219	878	592	789	592
2000	223	223	894	602	803	602
TOTAL	657	657	2,631	1,773	2,364	1,773

Table B.1.16 Estimated EV Stocks in 2010: the Low EV Penetration Scenario

Model Year	Household Cars						Fleet Vehicles											
	2-seat	M. Comp	Compact				Compact Cars				MM Vans	MiniVans			Full-Size Vans			
	Pb-A	Pb-A	Pb-A	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH	Na-S	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH
Chicago:																		
1998	0		0				0				0	0			0			
1999	0		0				0				0	0			0			
2000	0		0				0				0	0			0			
2001	117		117				159				365	487			365			
2002	125		125				199				457	609			457			
2003		130		43	43	43		79	79	79		483	483	483		121	121	121
2004		277		92	92	92		180	180	180		1,101	1,101	1,101		275	275	275
2005		290		97	97	97		198	198	198		1,208	1,208	1,208		302	302	302
2006		897		299	299	299		632	632	632		1,449	1,449	1,449		362	362	362
2007		917		306	306	306		659	659	659		1,510	1,510	1,510		378	378	378
2008		931		310	310	310		676	676	676		1,550	1,550	1,550		388	388	388
2009		941		314	314	314		688	688	688		1,576	1,576	1,576		394	394	394
2010		950		317	317	317		696	696	696		1,595	1,595	1,595		1,196	1,196	1,196
TOTAL	242	5,331	242	1,777	1,777	1,777	358	3,808	3,808	3,808	822	11,569	10,473	10,473	822	3,415	3,415	3,415

Table B.1.16 Estimated EV Stocks in 2010: the Low EV Penetration Scenario (cont'd.)

Model Year	Household Cars						Fleet Vehicles												
	2-seat	M. Comp	Compact				Compact Cars				MM Vans	MiniVans			Full-Size Vans			
	Pb-A	Pb-A	Pb-A	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH	Na-S	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH
Houston:																			
1999	0		0				0				0	0			0			
2000	0		0				0				0	0			0			
2001	44		44				170				269	359			269			
2002	47		47				212				337	449			337			
2003		49		16	16	16		84	84	84		356	356	356		89	89	89
2004		105		35	35	35		192	192	192		813	813	813		203	203	203
2005		110		37	37	37		211	211	211		892	892	892		223	223	223
2006		339		113	113	113		675	675	675		1,070	1,070	1,070		268	268	268
2007		346		115	115	115		704	704	704		1,117	1,117	1,117		279	279	279
2008		352		117	117	117		723	723	723		1,147	1,147	1,147		287	287	287
2009		356		119	119	119		736	736	736		1,167	1,167	1,167		292	292	292
2010		360		120	120	120		745	745	745		1,182	1,182	1,182		295	295	295
TOTAL	91	2,015	91	672	672	672	382	4,070	4,070	4,070	606	8,552	7,744	7,744	606	1,936	1,936	1,936

Table B.1.16 Estimated EV Stocks in 2010: the Low EV Penetration Scenario (cont'd.)

Model Year	Household Cars						Fleet Vehicles											
	2-seat	M. Comp	Compact				Compact Cars				MM Vans	MiniVans			Full-Size Vans			
	Pb-A	Pb-A	Pb-A	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH	Na-S	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH
Los Angeles:																		
1998	308		308				475				320	426			320			
1999	384		384				693				467	623			467			
2000	465		465				965				651	868			651			
2001	1,905		1,905				4,753				1,424	1,899			1,424			
2002	2,037		2,037				5,941				1,780	2,373			1,780			
2003		3,392		2,639	2,639	2,639		6,285	6,285	6,285		1,883	1,883	1,883		471	471	471
2004		3,615		2,811	2,811	2,811		7,162	7,162	7,162		2,146	2,146	2,146		536	536	536
2005		3,780		2,940	2,940	2,904		7,857	7,857	7,857		2,354	2,354	2,354		588	588	588
2006		3,900		3,033	3,033	3,033		8,374	8,374	8,374		2,509	2,509	2,509		627	627	627
2007		3,986		3,100	3,100	3,100		8,729	8,729	8,729		2,615	2,615	2,615		654	654	654
2008		4,046		3,147	3,147	3,147		8,961	8,961	8,961		2,684	2,684	2,684		671	671	671
2009		4,091		3,182	3,182	3,182		9,108	9,108	9,108		2,728	2,728	2,728		682	682	682
2010		4,129		3,212	3,212	3,212		9,216	9,216	9,216		2,761	2,761	2,761		690	690	690
TOTAL	5,098	30,939	5.098	24,064	24,064	24,064	12,827	65,692	65,692	65,692	4,642	25,868	19,679	19,679	4,642	4,920	4,920	4,920

Table B.1.16 Estimated EV Stocks in 2010: the Low EV Penetration Scenario (cont'd.)

Model Year	Household Cars						Fleet Vehicles													
	2-seat	M. Comp	Compact				Compact Cars				MM Vans	MiniVans			Full-Size Vans			
	Pb-A	Pb-A	Pb-A	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH	Na-S	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH
Washington, D.C.:																		
1998	0		0				0				0	0			0			
1999	0		0				0				0	0			0			
2000	0		0				0				0	0			0			
2001	32		32				124				197	262			197			
2002	35		35				155				246	328			246			
2003		36		12	12	12		61	61	61		260	260	260		65	65	65
2004		76		25	25	25		140	140	140		593	593	593		148	148	148
2005		80		27	27	27		154	154	154		650	650	650		163	163	163
2006		247		82	82	82		491	491	491		779	779	779		195	195	195
2007		252		84	84	84		512	512	512		813	813	813		203	203	203
2008		256		85	85	85		526	526	526		834	834	834		208	208	208
2009		259		86	86	86		534	534	534		848	848	848		212	212	212
2010		261		87	87	87		541	541	541		858	858	858		214	214	214
TOTAL	67	1,465	67	488	488	488	279	2,960	2,960	2,960	443	6,224	5,634	5,634	443	1,408	1,408	1,408

Table B.1.17 Estimated EV Stocks in 2010: the High EV Penetration Scenario

Model Year	Household Cars						Fleet Vehicles											
	2-seat	M. Comp	Compact				Compact Cars				MM Vans	MiniVans			Full-Size Vans			
	Pb-A	Pb-A	Pb-A	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH	Na-S	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH
Chicago:																		
1998	198		198				304				205	274			205			
1999	246		246				445				300	400			300			
2000	298		298				619				417	556			417			
2001	1,222		1,222				3,049				914	1,218			914			
2002	1,307		1,307				3,811				1,142	1,522			1,142			
2003		2,177		1,693	1,693	1,693		4,032	4,032	4,032		1,208	1,208	1,208		302	302	302
2004		2,319		1,804	1,804	1,804		4,595	4,595	4,595		1,377	1,377	1,377		344	344	344
2005		2,425		1,886	1,886	1,886		5,041	5,041	5,041		1,510	1,510	1,510		378	378	378
2006		2,503		1,946	1,946	1,946		5,373	5,373	5,373		1,610	1,610	1,610		402	402	402
2007		2,558		1,989	1,989	1,989		5,602	5,602	5,602		1,678	1,678	1,678		420	420	420
2008		2,597		2,020	2,020	2,020		5,750	5,750	5,750		1,723	1,723	1,723		431	431	431
2009		2,626		2,042	2,042	2,042		5,845	5,845	5,845		1,751	1,751	1,751		438	438	438
2010		2,650		2,061	2,061	2,061		5,915	5,915	5,915		1,772	1,772	1,772		443	443	443
TOTAL	3,271	19,853	3,271	15,441	15,441	15,441	8,228	42,154	42,154	42,154	2,977	16,598	12,628	12,628	2,978	3,158	3,158	3,158

Table B.1.17 Estimated EV Stocks in 2010: the High EV Penetration Scenario (cont'd.)

Model Year	Household Cars						Fleet Vehicles											
	2-seat	M. Comp	Compact				Compact Cars				MM Vans	MiniVans			Full-Size Vans			
	Pb-A	Pb-A	Pb-A	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH	Na-S	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH
Houston:																		
1998	145		145				223				150	200			150			
1999	181		181				327				220	294			220			
2000	220		220				456				307	410			307			
2001	900		900				2,245				673	897			673			
2002	963		963				2,808				841	1,122			841			
2003		1,605		1,248	1,248	1,248		2,973	2,973	2,973		891	891	891		223	223	223
2004		1,711		1,331	1,331	1,331		3,391	3,391	3,391		1,016	1,016	1,016		254	254	254
2005		1,791		1,393	1,393	1,393		3,723	3,723	3,723		1,115	1,115	1,115		279	279	279
2006		1,849		1,438	1,438	1,438		3,970	3,970	3,970		1,189	1,189	1,189		297	297	297
2007		1,891		1,471	1,471	1,471		4,142	4,142	4,142		1,241	1,241	1,241		310	310	310
2008		1,922		1,495	1,495	1,495		4,255	4,255	4,255		1,275	1,275	1,275		319	319	319
2009		1,944		1,512	1,512	1,512		4,328	4,328	4,328		1,297	1,297	1,297		324	324	324
2010		1,964		1,527	1,527	1,527		4,383	4,383	4,383		1,313	1,313	1,313		328	328	328
TOTAL	2,408	14,677	2,408	11,415	11,415	11,415	6,059	31,165	31,165	31,165	2,192	12,258	9,336	9,336	2,192	2,334	2,334	2,334

Table B.1.17 Estimated EV Stocks in 2010: the High EV Penetration Scenario (cont'd.)

Model Year	Household Cars						Fleet Vehicles												
	2-seat	M. Comp	Compact				Compact Cars				MM Vans	MiniVans			Full-Size Vans			
	Pb-A	Pb-A	Pb-A	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH	Na-S	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH
Los Angeles:																		
1998	308		308				475				320	462			320			
1999	384		384				688				467	623			467			
2000	465		465				966				651	868			651			
2001	1,902		1,902				4,753				1,424	1,898			1,424			
2002	2,038		2,038				5,941				1,780	2,373			1,780			
2003		3,393		2,639	2,639	2,639		6,286	6,286	6,286		1,883	1,883	1,883		471	471	471
2004		3,614		2,811	2,811	2,811		7,162	7,162	7,162		2,146	2,146	2,146		536	536	536
2005		7,481		9,975	9,975	9,975		11,072	11,072	11,072		3,651	3,651	3,651		913	913	913
2006		7,715		10,286	10,286	10,286		11,782	11,782	11,782		3,905	3,905	3,905		976	976	976
2007		8,667		23,373	23,373	23,373		21,461	21,461	21,461		4,085	4,085	4,085		1,021	1,021	1,021
2008		8,798		23,727	23,727	23,727		21,996	21,996	21,996		4,209	4,209	4,209		1,052	1,052	1,052
2009		12,932		38,795	38,795	38,795		29,234	29,234	29,234		4,293	4,293	4,293		1,073	1,073	1,073
2010		13,052		39,156	39,156	39,156		29,537	29,537	29,537		4,359	4,359	4,359		1,090	1,090	1,090
TOTAL	5,096	69,391	5,096	149,515	149,515	149,515	12,823	138,530	138,530	138,530	4,641	34,719	28,530	28,530	4,641	7,133	7,133	7,133

Table B.1.17 Estimated EV Stocks in 2010: the High EV Penetration Scenario (cont'd.)

Model Year	Household Cars						Fleet Vehicles											
	2-seat	M. Comp	Compact				Compact Cars				MM Vans	MiniVans			Full-Size Vans			
	Pb-A	Pb-A	Pb-A	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH	Na-S	Na-S	Ni-Cd	Ni-MH	Pb-A	Na-S	Ni-Cd	Ni-MH
Washington, D.C.:																		
1998	107		107				164				110	147			110			
1999	133		133				239				161	215			161			
2000	161		161				333				225	300			225			
2001	658		658				1,641				492	656			492			
2002	704		704				2,051				614	819			614			
2003		1,171		911	911	911		2,170	2,170	2,170		650	650	650		163	163	163
2004		1,248		971	971	971		2,473	2,473	2,473		741	741	741		185	185	185
2005		1,305		1,015	1,015	1,015		2,713	2,713	2,713		813	813	813		203	203	203
2006		1,346		1,047	1,047	1,047		2,891	2,891	2,891		866	866	866		216	216	216
2007		1,376		1,070	1,070	1,070		3,013	3,013	3,013		903	903	903		226	226	226
2008		1,397		1,086	1,066	1,086		3,093	3,093	3,093		927	927	927		232	232	232
2009		1,412		1,098	1,098	1,098		3,144	3,144	3,144		942	942	942		235	235	235
2010		1,425		1,109	1,109	1,109		3,181	3,181	3,181		953	953	953		238	238	238
TOTAL	1,761	10,681	1,761	8,307	8,307	8,307	4,428	22,677	22,677	22,677	1,603	8,930	6,794	6,794	1,603	1,698	1,698	1,698

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B.2 Selection of Battery Types and Electric Vehicle Types and Designed Electric Vehicle Performance Characteristics

B.2.1 Introduction

Electric vehicle (EV) batteries are the most dominant factor determining EV characteristics and performance. In this section, selection of EV battery types for the EVTECA is presented. Performance attributes of selected EV battery types are assessed. Considered EV models and prototypes produced and designed by auto makers and market potentials of given vehicle size categories (e.g., sub-compact, compact, and standard), electric vehicle types are selected. EV types are further attached with certain given battery types. And then, EV performance characteristics in terms of driving range, top speed, acceleration rate, and passenger or cargo capacity are determined. With battery performance characteristics, EV performance characteristics, specified driving cycles, and energy efficiencies of vehicle components, EV per-mile electricity consumption will be estimated with the EAGLE model.

B.2.2 Selected EV Battery Types and Their Performance Characteristics

Battery Type Selection

Various battery technologies are currently researched and developed for EV applications. Such battery types include lead-acid battery, nickel-cadmium battery, sodium-sulfur battery, zinc-bromine battery, nickel-metal hydride battery, and lithium-polymer battery. Some non-chemical batteries such ad flywheels are researched for EV applications as well. Mass introduction of EVs will rely on improvements and commercial readiness of battery technologies. To promote battery R&D, the three domestic auto makers and the U.S. DOE jointly established the U.S. Advanced Battery Consortium (USABC). The USABC has set the mid-term and the long-term battery performance goals (Table B.2.1). The consortium selects the battery types with potentials of meeting the goals and funds R&D of the selected battery types.

To select battery types for the EVTECA, the following criteria are implicitly used: (1) the battery types that auto makers have already used or announced to use in their EV models or prototypes; (2) large potentials of improving battery performance due to current R&D activities; (3) commercial readiness of battery development before 2010; and (4) information on battery performance and material compositions can be obtained from published materials. Because the EVTECA analyzes environmental impacts of EV battery production, recycling, and disposal, specific battery types must be selected. Battery performance goals such as the USABC mid-term and long-term goals cannot be used in the EVTECA.

After consulting with the DOE, the EVTECA team has selected four battery technologies--lead-acid (Pb-acid), sodium-sulfur (Na-S), nickel-cadmium (Ni-Cd), and nickel-metal hydride (Ni-MH). Other battery types such as zinc-air and lithium-polymer have potentials of improving battery performance. They are not included here because of time and resource constraints to the EVTECA.

Table B.2.1 USABC Mid-Term and Long-Term Battery Primary Performance Goals (U.S. DOE, 1992)

Performance Attribute	Mid-Term Goals	Long-Term Goals
Power Density (w/l)	250	600
Speci. Power (w/kg, 80% DOD & for 30 sec.)	150 (200 desired)	400
Energy Density (wh/l, C/3 rate)	135	300
Specific Energy (wh/kg, C/3 rate)	80 (100 desired)	200
Life (years)	5	10
Life Cycles (80% DOD)	600	1000
Operating Temperature (°C)	-30 - 65	-40 - 85
Normal Recharge Time (hrs)	<6	3 - 6

Pb-acid battery is commercially mature. Pb-acid batteries have been in use as automotive batteries to provide accessory power for decades. The highly publicized GM Impact uses Pb-acid battery. The low specific energy of Pb-acid battery may limit its wide application to EVs. Various advanced designs have been researched for Pb-acid batteries to increase their energy density and lifetime. One example is the horizon woven design by Electrosource, Inc. (1993). Recently, BDM International and Electrosource have jointly created a company--Horizon Battery Technology--to start to produce the advanced horizon Pb-acid battery.

Na-S battery has been used in prototype EVs produced by the Ford Motor Company. The battery has higher specific energy, but lower specific power than Pb-acid battery. Na-S battery requires a thermal management system to maintain its operating temperatures (usually 320-360 °C). Such thermal management systems increase the complexity of Na-S battery design and its costs, and reduces its reliability.

Ni-Cd battery is commercially mature to some degree. Chrysler uses Ni-Cd battery in its electric TEVan (TEVan can be equipped with nickel iron or Ni-Cd battery).

Ni-MH battery is currently in the development stage. Test results indicate high specific energy and power for Ni-MH battery. The battery has the potential of meeting the USABC mid-term battery performance goals.

Tested Performance Characteristics for the Selected Battery Types

Battery tests have been conducted by various parties for the four selected battery types. Table B.2.2 compiles test results for the four battery types from various published sources.

Battery performance is affected by discharge rates, recharge rates, history of battery use, ambient environmental conditions, and many other factors. Battery tests may be conducted with different discharge and recharge schedules, for batteries with different cycles cumulated, and with different states of battery DOD. These factors, as well as battery types and designs, contribute to the differences in battery performance characteristics. Caution must be taken in comparing testing results from different studies presented in Table B.2.2.

Nevertheless, Table B.2.2 shows general differences in battery performance characteristics among the four battery types. Pb-acid batteries usually have lower specific energy, but higher specific power. Advanced design of Pb-acid batteries such as Electrosource's woven horizon design can improve specific energy and power for Pb-acid batteries dramatically. Na-S batteries generally have higher specific energy, but lower specific power. One disadvantage for Na-S batteries not shown in Table B.2.2 is the needed thermal management system for maintaining Na-S battery operating temperature. The systems can increase energy consumption and costs significantly. Ni-Cd batteries have specific energy higher than Pb-acid batteries, but lower than Na-S batteries. Ni-Cd batteries have specific power higher than both Pb-acid and Na-S batteries. Ni-MH batteries improve specific energy and power significantly. Ni-MH batteries will be very likely to meet the USABC mid-term battery performance goals.

Assumptions of Battery Performance Characteristics

The EVTECA analyzes energy and environmental impacts of EVs in two target years--2000 and 2010. In order to determine EV fleets in these two years, EVs are assumed to be introduced before 2000. To account the progress in EV battery technologies over time, EV penetration period is divided into two sub-periods: a pre-2003 period and a 2003 and beyond period. For the pre-2003 period, it is assumed that advanced Pb-acid, Na-S, and Ni-Cd batteries will be applied to EVs. Ni-MH battery is not assumed in the pre-2003 period. For the 2003 and beyond period, it is assumed that advanced Pb-acid, Na-S, Ni-Cd, and Ni-MH batteries will be applied to EVs.

Based on battery performance characteristics presented in Table B.2.2, battery performance characteristics is assumed for each battery type in the two EV penetration periods (Table B.2.3). These battery performance assumptions have been discussed with the Battery Testing Program, Chemical Technology Division of Argonne National Laboratory.

B.2.3 Selection of EV Types

EV type selection is based on the types of EVs that manufacturers will probably produce, the types of trips that EVs will probably make, and battery technologies to be applied. Depending on the types of EVs selected, EV driving range, top speed, acceleration rate, weight, and other performance attributes will be assumed. EV types are selected for each of the two EV penetration periods--the pre-2003 period and the 2003 and beyond period; and for each of the two EV applications--household and fleet.

Manufacturer-Produced EV Models and Prototypes

In order to meet California's zero-emission vehicle sales requirements, vehicle manufacturers have been developing various EV models and prototypes. Table B.2.4 presents various EV models and prototypes developed by manufacturers. Note that the EV models and and prototypes here are OEM (original equipment manufacturer) produced. EV models converted from conventional vehicle chassis by after-market converters are not presented here.

Table B.2.2 Tested Performance Characteristics for the Four Selected Battery Types

Developer	Data Source	Energy Attribute[a]		Power Attribute[c]		Energy Eff. (%)	Proj. Life Cycles
		wh/kg	wh/liter	w/kg	w/liter		
Pb-Acid:							
Sonnenschein	DeLuca (1992), Vissers et al. (1993)	36	92	91		84	370
Chloride	DeLuca (1992), U.S. DOE (1992)	33	78	68,92[d]		68	149
Electrosource	Electrosource (1993)	50	103	310	1030[d]		900
Exide	Dickinson et al. (1993)	32	86			80	
Delco	Dickinson et al. (1993)	25	60	55[e]		84	
Johnson Control	Dickinson et al. (1993)	33	83	82[e]		85	
Chloride	Dickinson et al. (1993)	29	79			70	
Na-S:							
CSPL	DeLuca (1992), U.S. DOE (1993)	79	123	90		88	795
CSPL	Burke (1992)	60-68	81-92	85	115	85-90	
ABB	DeLuca (1992), U.S. DOE (1992)	81	83	152		91	592
Ni-Cd:							
SAFT	Cornu (1990)	56[b]	101[b]	208[e]	378[e]	70	2000
SAFT	DeLuca (1992), Vissers et al. (1993)	55	104	175		78	1018
Marathon	Dickinson et al. (1993)	35	85	>138[e]		65	
Ni-MH:							
Ovonics	U.S. DOE (1992)	55	152	183[d]		80	
Ovonics	Ovonics (1993)	80	210	175	475		1000

[a] At a 3-hour constant current discharge rate, except as noted.
[b] At a 5-hour constant current discharge rate, except as noted.
[c] At 80% of depth of discharge.
[d] At 50% of depth od discharge and for 15 seconds.
[d] At 0% of depth of discharge.
[e] At 50% of depth of discharge.

Table B.2.3 Assumed Battery Performance Characteristics

Battery Type	Specific Energy (wh/kg, C/3 rate)	Specific Power (w/kg, 80% DOD)	Energy Efficiency (%)
Pre-2003 Period:			
Advanced Pb-Acid	45	150	78
Na-S[a]	80	150	85
Ni-Cd	55	175	80
2003 and Beyond Period:			
Advanced Pb-Acid[b]	47	158	82
Na-S[a,b]	88	158	89
Ni-Cd[b,c]	58	184	84
Ni-MH[c]	80	225	78

[a] Energy losses due to thermal management systems are not included here. The USABC has set a target of 3.2 watts per Kwh of energy delivered for high temperature batteries such as Na-S battery. Thermal energy losses of Na-S will be taken into account in EV energy consumption calculation.
[b] Assuming 5% improvement in battery performance for Na-S and Ni-Cd batteries between the pre-2003 period and the 2003 and beyond period.
[c] Because of memory effects, Ni-Cd and Ni-MH batteries need complete discharge in order to maintain their full capacity. However, recent technology advances for the batteries show that memory effects can be eliminated. Thus, routine complete discharge may not be needed for Ni-Cd and Ni-MH batteries.

There are a total of 23 EV models or prototypes presented in Table B.2.4. Among them, nineteen are cars and four are vans. Among the nineteen cars, eight are 4- or 5-passenger cars; six are 2-seater cars; one is a 4-seater car; and four are unspecified. Among the four vans, the GM G-Van and Griffon van are full-size vans; the Chrysler TEVan is a minivan; and the Ford Ecostar is smaller than minivan. The Ecostar is named as mini-minivan here.

Among the EV models or prototypes presented, nine are equipped with Pb-acid battery, five with Ni-Cd battery, three with Na-S battery, and none with Ni-MH battery. The remaining six models or prototypes are equipped with zinc-air, sodium-iron, lithium-carbon, and nickel-iron batteries.

Selected EV Types for the Two EV Penetration Periods

EV types are selected by considering the EV models and prototypes presented in Table B.2.4. For the pre-2003 period, a 2-seater mini-compact car similar to the GM Impact and a 4-passenger compact car similar to Honda Elect Vic and Toyota EV-50 are selected for household EV applications. The 2-seater car is selected because there are six 2-seater models or prototypes already produced or designed by vehicle manufacturers (though 2-seater cars account for only about 2% of total car sales in the U.S. [Murrell et al., 1993]). The 4-passenger compact car is selected because it accounts for a

Table B.2.4 EV Models and Prototypes and Their Performance

Model	Manufacturer	Capacity	Weight (lbs)	Battery Type	Range (miles)	Top Speed (mph)	Acce. Rate (sec.)	Tech. Status[a]	Source
Passenger Cars									
E1	BMW	2-seater	1940	Na-S	155	75	18 (0-50)	PT	Auto. Eng. 1992
E2	BMW	4-passenger	2200	Na-S	267	75	15.6 (0-50)	PT	Auto. Eng.1992
Citela	Citroen		1740	Ni-Cd	68	68	8.5 (0-31)	PT	Auto. Eng. 1992
Elec. Dream	Chubu	2-seater	1540		75 (25 mph)	50	10 (0-40)	PT	Auto. Eng. 1992
Hijet	Daihatsu			Pb-Acid	80 (25 mph)	50		PT	Auto. News, June 7, 1993
Rugger	Daihatsu			Pb-Acid	125 (25 mph)	56		PT	Auto. News, June 7, 1993
Cinq. Elettra	Fiat	2-seater		Ni-Cd	62	50-53	10 (0-25)	PT	Auto. Eng. 1992
Impact 3	GM	2-seater	2910	Sealed Pb-Acid	70-90	75	8.5 (0-60)	CA	GM, 1993
APS Saturn	Demi/APS	2-seater	2100	Zinc-O_2	218 (37 mph)	124	10 (0-87)	PT	Auto. Eng. 1992
Elect Vic	Honda	4-passenger	3330	Pb-Acid	65 (40 mph)	81		PT	Road & Track, Oct. 1993
Miata/Eunos	Mazda	2-seater	3100	Ni-Cd	120 (25 mph)	80	4.2 (0-25)	PT	Auto News, Feb. 22, 1993
190E	Mercedes	5-passenger		Na-Ni	93	75		PT	Auto. Eng. 1992
FEV	Nissan	4-passenger	1985	Ni-Cd	155 (25 mph)	80		PT	Auto. Eng. 1992
Cedric/Gloria	Nissan	4-passenger	3810	Sealed Pb-Acid	75 (25 mph)	56		PT	Clean Fuels Report, Feb. 1993
Impuls	Opel	4-passenger	2930	Pb-Acid	65			PT	Auto. Eng. 1992

Model	Manufacturer	Capacity	Weight (lbs)	Battery Type	Range (miles)	Top Speed (mph)	Acce. Rate (sec.)	Tech. Status[a]	Source
Passenger Cars (cont'd)									
Twin	Opel	4-passenger	1630	Li-C		75	7 (0-31)	PT	Auto. Eng 1992
Town-Ace Van	Toyota	4-passenger	2870		87 (15 mph)	53	10 (0-31)	PT	Auto. Eng. 1992
EV-50	Toyota	4-seater	3200	Sealed Pb-acid	68 (urban) 155 (25 mph)	72		PT	Toyota (1994)
City-STROMer	VW			Na-S	75	65		PT	Auto. Eng. 1992

Model	Manufacturer	Capacity	Weight (lbs)	Battery Type	Range (miles)	Top Speed (mph)	Acce. Rate (sec.)	Tech. Status[a]	Source
Vans									
Caravan	Chrysler	5-passenger	5900	Ni-Fe or Ni-Cd	80-120	65	25 (0-60)	CA	Auto. Eng. 1992; Chrysler, 1992; Auto. News, Sept. 20, 1993
Ecostar	Ford	850 lb	3100	Na-S	100	70	12 (0-50)	CA	Auto. Eng. 1992; Ford, 1992
G-Van	GM	1550 lb	7670	Pb-Acid	60			CA	Risser et al. 1990
Griffon	GM	2200 lb		Pb-Acid	50-60	50		CA	Tripp, 1990

[a] PT represents prototype, CA represents commercially available.

large percentage of the passenger car market. Compact cars currently account for about 30% of total car sales in the U.S. (Murrell et al., 1993). No vans are selected for household applications. For fleet EV applications, a 4-passenger compact car, a mini-minivan similar to the Ford Ecostar, a minivan similar to the Chrysler TEVan, and a full-size van similar to the GM G-Van are selected. In the U.S., minivans account for 24% of total light-duty truck sales, and full-size vans for about 5% (Murrell et al., 1993).

For the 2003 and beyond period, a 4-seater mini-compact car and a 4-passenger compact car are selected for household EV applications. As one may note, between the pre-2003 period and 2003 and beyond period, the 2-seater car is changed to the 4-seater mini-compact car. The 4-seater mini-compact car can cover the market of both 2-seater cars and mini-compact cars (both together account for 3.2% of total car sales in the U.S. [Murrell et al., 1993]). A 4-passenger compact car, a minivan, and a full-size van are selected for fleet applications. The mini-minivan is dropped out from fleet applications in the 2003 and beyond period due to its limited market in the U.S.

Combinations of Selected Battery Types and Selected EV Types

Based on advances in battery technologies and manufacturers' intention of using certain battery types, batteries from the four battery types are determined for each of the above selected EV types. It is determined that in the pre-2003 period, Pb-acid batteries will be applied to the mini-compact car, the compact car, and the full-size van; Na-S batteries to the mini-minivan; and Ni-Cd batteries to the minivan. In the 2003 and beyond period, advanced Pb-acid batteries will be applied to the subcompact car; and Na-S, Ni-Cd, and Ni-MH all will be applied to the compact car, the minivan, and the full-size van. The combinations of battery types and vehicle types for the two time periods are summarized in Table B.2.5.

Based on designed performance characteristics of EV models or prototypes presented in Table B.2.3 and range and power demand of potential EV trips, EV performance characteristics in terms of driving range, top speed, and acceleration rate is assumed for each vehicle-battery combination (Table B.2.5). Note that electric vans are assumed to have shorter driving range, lower top speed, and lower acceleration rate than electric cars.

As the table shows, EV performance characteristics are assumed to improve between the pre-2003 period and 2003 and beyond period, mainly due to improvements in battery technologies and changes in battery types. Significant improvements are assumed for EV driving ranges and acceleration rates. Note that small improvement in driving range is assumed for Pb-acid battery, relative to other battery types. This is because Pb-acid battery in the 2003 and beyond period still has lower specific energy, leading to less improvement in EV driving range.

Table B.2.5 Combinations of Battery Types and EV Types and Their Designed Performance Characteristics

Application	EV Type	Battery Type	Capacity	Range[a]	Top Speed (mph)[a]	0-60mph Seconds[a]
Pre-2003 Period						
Household	2-Seater	Pb-Acid	2 Seats	75	75	15
	Compact	Pb-Acid	4 Passengers	75	75	15
Fleet	Compact	Pb-Acid	4 Passengers	75	75	15
	Mini-Minivan	Na-S	850 lb	65	65	18
	Minivan	Ni-Cd	1000 lb	65	65	18
	Full-Size Van	Pb-Acid	1500 lb	65	65	18
2003 and Beyond Period						
Household	Mini-Compact	Pb-Acid	4 Seats	100	75	12
	Compact	Na-S	4 Passengers	150	75	12
		Ni-Cd	4 Passengers	150	75	12
		Ni-MH	4 Passengers	150	75	12
Fleet	Compact	Na-S	4 Passengers	150	75	12
		Ni-Cd	4 Passengers	150	75	12
		Ni-MH	4 Passengers	150	75	12
	Minivan	Na-S	1000 lb	120	65	15
		Ni-Cd	1000 lb	120	65	15
		Ni-MH	1000 lb	120	65	15
	Full-Size Van	Na-S	1500 lb	120	65	15
		Ni-Cd	1500 lb	120	65	15
		Ni-MH	1500 lb	120	65	15

[a] To or at 80% depth of discharge.

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B.3 Estimates of Energy Consumption of Electric and Conventional Vehicles

B.3.1 Introduction

Fuel consumption of conventional vehicles (CVs) and electric vehicles (EVs) is estimated using the EAGLES software package developed at Argonne National Laboratory. EAGLES is an upgraded and expanded version of DIANE -- an interactive computer model for simulating battery performance in electric vehicle applications [Marr et al., 1990 and 1992]. Performance characteristics of selected batteries and EVs are based on data provided by Wang [Wang 1994]. For EVs, the analysis comprises two parts. For each combination of battery type and EV type, the size of the battery is determined on the basis of meeting the performance requirements (i.e., range, top speed, and 0-60 mph acceleration). Once the weight and capacity of the battery pack is determined, actual performances of the vehicle under a given driving cycle is then evaluated. CV fuel economy is estimated using the EAGLES model based on the formulation of An and Ross [An and Ross 1993].

B.3.2 Assumptions Used in the EAGLES Calculations

The following assumptions are made in the analysis:

Vehicle Curb Weights and Other Vehicle Parameters

In the present analysis, improvements in vehicle characteristics are assumed to occur in two steps: one in the pre-2008 period, and one in the 2008-2010 period. The curb weight (excluding the battery pack) of an EV is assumed to be 80% of the curb weight of its CV counterpart in the same size class (e.g., compact passenger car), chosen from 1993 models [Murrell et. al. 1993]. The 20% reduction in curb weight approximately accounts for the difference between the removal of the engine and accessories, cooling system, exhaust system, and fuel storage system from a CV (typically around 23%) and the inclusion of a motor/controller (about 1.5 kg/kW) [Cuenca 1994]. In Tables B.3.1a and B.3.1b, the curb weight reduction from 1993 models for both CVs (and thus EVs) in pre-2008 period and in 2008-2010 period are estimates based on CV fuel economy projections [EIA 1994] and the assumptions that the fuel economy gain available from a 10-percent weight reduction is 6.6 percent, including the effect of engine downsizing to maintain constant performance [OTA 1991]. Other listed vehicle parameters include drag coefficient, rolling resistance, drivetrain efficiency for both vehicle types in the two time periods. These are estimated and projected values based on available information in published literature [Brogan and Venkateswaran 1991; OTA 1991; Burke and MacDowall 1991; Burke 1992; ARB 1994]. Also shown in the tables are the projected motor/controller efficiency and charger efficiency for EVs for the respective time periods [Barnett and Tataria 1991; Burke 1992; MEVP 1993; ARB 1994]. Vehicles of the same type (CVs or EVs) in each time period are assumed to have the same characteristics. A 10% improvement in the drag coefficient and the rolling resistance is assumed from the pre-2008 period to the 2008-2010 period.

Vehicle Driving Cycles

Vehicle fuel consumption varies significantly with trip characteristics (i.e., average speed, top speed, maximum acceleration rate, and idling time). Driving cycles in the form of repeatable speed-time sequences are designed to represent driving patterns in a particular environment. Two driving cycles are selected for the present study, i.e., the FUDS [Environment Reporter 1992] and the LA-92 [Austin et al. 1992]. It is further assumed that the FUDS is applied to all van operations, and the LA-92 to all passenger car operations [Wang 1994]. Table B.3.2 shows the characteristics of these two driving cycles. Both cycles represent combinations of urban and freeway driving, with the FUDS having lower average and top speeds than the LA-92. The idling time in the FUDS is relatively longer than that in the LA-92.

Table B.3.1a Assumed Vehicle Parameters -- Cars

Year	Pre-2008		2008-2010	
Vehicle Type	CV	EV	CV	EV
Drag Coefficient	0.3	.22	0.27	0.20
Rolling Resistance	0.008	0.005	0.007	0.0045
Drivetran Eff., %	80	90	85	92.5
Motor Eff., %	na[a]	90	na[a]	92.5
Charger Eff., %	na[a]	87.5	na[a]	90
Curb Wt. Reduction[b], %	3	3	7	7

[a] Not applicable
[b] From curb weights of 1993 models; EV curb weight does not include battery.

Table B.3.1b Assumed Vehicle Parameters -- Vans

Year	Pre-2008		2008-2010	
Vehicle Type	CV	EV	CV	EV
Drag Coefficient	0.35	.32	0.32	0.29
Rolling Resistance	0.01	0.007	0.009	0.0063
Drivetran Eff., %	80	90	85	92.5
Motor Eff., %	na[a]	90	na[a]	92.5
Charger Eff., %	na[a]	87.5	na[a]	90
Curb Wt. Reduction[b], %	4	4	9	9

[a] Not applicable
[b] From curb weights of 1993 models; EV curb weight does not include battery.

Table B.3.2 Characteristics of Driving Cycles

Driving Cycle	FUDS	LA-92
Cycle Duration, s	1371	1431
Cycle Range, miles	7.46	9.82
Max. Speed, mph	56.7	67.2
Ave. Speed, mph	19.6	24.7
Max. Acc., mph/s	4.2	6.9
% Time with speed >40 mph	8.0	23.0
% Distance with speed >40 mph	21.3	49.6
Idling, %	19.0	16.0

B.3.3 Battery Sizing

In designing an EV, the capacity of the battery is determined by the power and energy demands of the vehicle, which in turn depend on the driving cycle characteristics. For the purposes of battery sizing, we choose the LA-92 for all passenger cars and the FUDS for all vans. This choice of driving cycle in general tends to result in the passenger vehicles of having a higher accelerating capability than the vans because of the higher accelerating rates demaneded by the LA-92. In battery sizing as well as in actual vehicle performance evaluations, we assume an average payload of 1.5 persons (225 lbs) for all household vehicles and fleet passenger cars. For a fleet van, the average payload is assumed to be half of the design maximum payload of that vehicle.

Energy recovery by regenerative braking is taken into consideration in estimating the energy consumption of EVs. It is assumed that 50% of braking energy is converted into useful energy by regenerative braking. This corresponds to approximately 20% fuel savings for a vehicle over the FUDS cycle [Wyczalek and Wang 1992; ARB 1994].

B.3.4 Climate Comfort Control

Vehicle climate control systems (including cooling and heating) could have a significant impact on vehicle fuel economy. Because the power sources employed in the conventional and electric vehicles are quite different, it is necessary to consider them separately.

Conventional Vehicles

For a conventional vehicle, the loss of fuel economy due to the operation of air conditioning system depends on the capacity of the system, the type of fan drive, ambient air temperature, and vehicle speed. We estimate the power requirements of the air conditioning system for a compact car and for a minivan, taking into consideration the size of the compressor, the average fraction of time the compressor is on in urban driving conditions, and the power demands of accessories such as fan(s) and electrical clutch. We then estimate the power requirements of air conditioning systems for other passenger cars and vans, based on the relative interior volumes of the vehicles. Similar estimates are made for the heating systems which employ fans to circulate waste engine heat to the passenger compartment. Table B.3.3 is a summary of the estimates of cooling and heating loads for the conventional vehicles, assuming the compressor is on 2/3 of the time for both driving cycles.

Electric Vehicles

Energy consumed by air conditioning system as well as heating and defrosting systems can significantly impact vehicle range.

Dieckmann and Mallory [Dieckmann and Mallory 1991a; 1991b] have developed a thermal load model that can be used to predict electric vehicle cooling and heating loads. In their model, both cooling and heating loads are separated into a steady-state and a transient loads. For each cooling/heating cycle, cooling and heating performances (capacity, COP, and electric power consumption, vs. ambient temperature) were evaluated for a set of baseline cooling and heating loads for an electric minivan, under a consistent set of assumptions of air flow rates, motor efficiencies, etc. The calculations were performed under the assumption that a combination of rather modest thermal design measures were employed. These design measures include rooftop insulation, wavelength-selective glass (e.g. PPG Sungate) for all windows, limitations on the ventilation makeup air flow rate, and provision of an efficient low voltage mode of interior blower operation to limit hot soak temperatures when the vehicle is parked. Plots of the steady-state and peak transient loads for both cooling and heating are presented in their report for a minivan [Dieckmann and Mallory 1991b]. Transient loads are shown for several interior air time constants, averaged over the time period required for the transient load to fall to within 20 percent of the steady-state load. They found that the interior air cool down rate corresponding to a 6-minute time constant approximates wind tunnel test data reasonably well. In their analysis, air conditioning system design (vapor cycle with variable speed compressor) capacities were established by the worst case (i.e. Phoenix) cooling load.

For EV heating, it is assumed that the air conditioning system is used as an electrically driven heat pump system. Heating would be provided by combination of vehicle waste heat, the heat pump, and, when necessary, backup electric resistance heat.

For both cooling and heating calculations, we assume a transient of 12 minutes (equals to two 6-minute time constants) before the steady state is reached.

In the present analysis, windshield de-icing, defogging and defrosting loads are assumed to be taken up by an electrically heated windshield. To heat the windshield, an electric current is passed through a thin transparent metallic film coating between the windshield laminations. A 1000 Watts of power can clear the windshield in less than one minute. The energy consumption, therefore, is quite modest, on the order of 10 to 20 Wh per defrost/defog [Dieckmann and Mallory 1991b], and is not included in the estimation of heating requirements.

Table B.3.3 Estimates of Cooling and Heating Loads for Conventional Vehicles

Application	Vehicle Type	Cooling Load, kW	Heating Load, kW
Household	2-Seater	1.15	0.12
	Mini-Compact	1.85	0.19
	Compact	2.40	0.25
Fleet	Compact	2.40	0.25
	Mini-Minivan	2.70	0.36
	Minivan	3.75	0.50
	Full-size Van	5.80	0.78

- *Seasonal Ambient Temperatures*

In the estimation of cooling and heating loads, we assume ambient temperature of an area to be the three-month average of the daily high temperatures during the summer (from June to August, for cooling load calculations) and the average daily low temperatures during winter (from December to February, for heating load calculations) for that area. Table B.3.4 lists ambient temperatures [Bair 1992] for the four studied metropolitan areas.

- *Coefficient of Performance*

A coefficient of performance (COP) is defined as cooling (or heating) capacity divided by power consumption in Btu/hr. In the estimation of electrical energy consumptions due to cooling and heating, we use values of COP, listed in Table B.3.5, which are based on Dieckmann and Mallory's cooling/heating performance data [Dieckmann and Mallory 1991b] for vapor cycle with variable-speed compressor. For resistance heating, we assume COP = 1.

- *Vehicle Waste Heat*

Vehicle waste heat sources could be utilized as a primary or supplemental heat source. The battery pack, the main controller, and the motor/transmission are the major waste heat sources. The latter two of these are reasonably compact, so heat dissipated in these components might be recovered and used for interior heating. In general, recovered driveline waste heat is in excess of the design steady-state heating requirements in milder climates. From the estimated rate of power dissipation in the main controller and traction motor/transmission for selected EVs [Dieckmann and Mallory 1991b], it is found that for every kW of power (including traction and regeneration) through controller and motor/transmission, approximately 0.26 kW of waste heat is generated. In our estimate of potential electric heating performance, recovery of 50% of the waste heat during steady state is assumed. No recovery of waste heat is assumed during transient warmup.

Table B.3.4 Ambient Temperatures during Summer and Winter

Metropolitan Area	Winter (Daily Low)				Summer (Daily High)			
	Dec.	Jan.	Feb.	Average	June	July	Aug.	Average
Chicago	20.3	13.6	18.1	17.3	79.4	83.3	82.1	81.6
Houston	42.7	40.8	43.2	42.2	90.9	93.6	93.1	92.5
L.A.	48.4	47.7	49.2	48.4	77.9	83.8	84.1	81.9
Washington, DC	31.2	27.5	29.0	29.2	84.0	87.9	86.4	86.1

Table B.3.5 Assumed COPs for Cooling and Heating Performance Calculations

Metropolitan Area	Cooling		Heating	
	Ambient Temp., °F	COP	Ambient Temp., °F	COP
Chicago	81.6	2.8	17.3	2.35
Houston	92.5	2.8	42.2	2.72
L.A.	81.9	2.8	48.4	2.80
Washington, DC	86.1	2.8	29.2	2.52

B.3.5 Results and Discussions

Fuel Economies of Conventional Vehicles

Fuel economies of the conventional vehicles are estimated for the base case (without either cooling or heating load), and the cases with cooling and with heating, respectively. Table B.3.6a is for vehicles with characteristics of the pre-2008 period, and Table B.3.6b the 2008-2010 period. For the case with heating, estimated fuel economies with engine cold start are also given. In addition, fuel consumption of a conventional vehicle can be affected by seasonal factors. For instance, cold weather can cause a decrease in engine efficiency, increases in air density and rolling resistance, which can all affect fuel economy. The total incremental cold weather fuel consumption penalty (including heating/defrosting) is in the neighborhood of six percent of the annual average fuel consumption [Gur, et al. 1987; Lawrence 1991]. A 5% penalty is assumed for wintertime CV fuel economy in this analysis, though results in Table B.3.6 do not include this penalty.

Performances of Electric Vehicles

For EVs, because of the assumed battery technology switch at year 2003, three time periods are considered. These are the pre-2003 period, the 2003-2007 period, and the 2008-2010 period. Tables B.3.7a through B.3.7c show the predicted performances of EVs for these periods. Note that the effects of thermal losses of the high-temperature Na-S batteries are considered in our analysis but are not included in these tables.

Thermal losses of a Na-S battery can be as high as 7.3 watts per kWh for a battery capacity of 9.6 kWh. As battery capacity increases, the thermal losses decrease due to the decreased surface-to-volume ratio. The thermal losses are less than 5 watts per kWh for a battery capacity of 19.2 kWh [Eriksson and Birnbreier 1992]. The USABC establishes a thermal loss goal of 3.2 watts per kWh. This is used in estimating thermal losses for Na-S batteries. For other battery types (i.e., pb-acid, Ni-Cd, and Ni-MH), no thermal loss is assumed. Also not included in these tables are possible ambient temperature effects on lead-acid battery capacities [Keller and Whitehead 1991; Kahlen 1992].

Energy Consumptions of Electric Vehicles

Energy consumptions are estimated for the base case without cooling/heating and, for each metropolitan area, the additional energy consumptions for cooling and heating, respectively. Note that all energy consumptions listed in Tables B.3.8a through B.3.8c are expressed in kWh/mile at wall outlets. Because of the energy consumptions (and thus waste heats) for the same type of vehicle (e.g. minivan) using different battery technologies might be different, the heating kWh/mile might be slightly different for areas of colder climate (e.g., Chicago). Appendix A contains the spreadsheet printouts of cooling/heating energy consumption calculations. Appendix B is a spreadsheet printout of energy consumptions at battery terminals as well as at the wall outlet.

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Table B.3.6a Conventional Vehicle Fuel Economy -- Pre-2008 Period

Application	Driving Cycle	Vehicle Type	Curb Weight, lbs	Payload, lbs	Fuel Economy, Base, mpg	Fuel Economy w/cooling, mpg	Fuel Economy w/heating[a], mpg
Household	LA-92	2-Seater	2230	225	33.7	30.6	33.6 (32.8)
	LA-92	Mini-Compact	2230	225	33.7	28.8	33.3 (32.6)
	LA-92	Compact	2652	225	27.1	23.1	26.8 (26.1)
Fleet	LA-92	Compact	2652	225	27.1	23.1	26.8 (26.1)
	FUDS	Mini-Minivan	2322	425	28.3	22.4	27.5 (26.7)
	FUDS	Minivan	3144	500	21.8	17.0	21.1 (20.5)
	FUDS	Full-size Van	5568	750	13.8	10.6	13.4 (13.0)

[a] Numbers in parentheses indicate fuel economy with engine cold start

Table B.3.6b Conventional Vehicle Fuel Economy -- 2008-2010 Period

Application	Driving Cycle	Vehicle Type	Curb Weight, lbs	Payload, lbs	Fuel Economy, Base, mpg	Fuel Economy w/cooling, mpg	Fuel Economy w/heating[a], mpg
Household	LA-92	Mini-Compact	2139	225	36.4	30.9	36.0 (35.1)
	LA-92	Compact	2543	225	29.1	24.5	28.7 (28.0)
Fleet	LA-92	Compact	2543	225	29.1	24.5	28.7 (28.0)
	FUDS	Minivan	2980	500	23.2	17.8	22.4 (21.8)
	FUDS	Full-Size Van	5278	750	14.8	11.4	14.3 (13.9)

[a] Numbers in parentheses indicate fuel economy with engine cold start

Table B.3.7a Predicted Performances of Electric Vehicles -- Pre-2003 Period

Application	Vehicle Type (Driving Cycle)	Battery Type	Battery Weight, lbs	Curb Weight[a], lbs	Payload, lbs	Range, to 80% DOD, miles	Range, to 100% DOD, miles	Peak Speed[b] @ 80% DOD, mph	Acceleration (0-60 mph) @ 80% DOD, s
Household	2-Seater (LA-92)	Pb-Acid	772	1784	225	75	94	119	13.0
	Compact (LA-92)	Pb-Acid	878	2122	225	75	94	120	13.0
Fleet	Compact (LA-92)	Pb-Acid	878	2122	225	75	94	120	13.0
	Mini-Minivan (FUDS)	Na-S	617	1858	425	107	134	89	18.0
	Minivan (FUDS)	Ni-Cd	679	2515	500	65	81	92	18.0
	Full-Size Van (FUDS)	Pb-Acid	1394	4454	750	65	81	98	18.0

[a] Battery weight not included
[b] Not sustainable

Table B.3.7b Predicted Performances of Electric Vehicles -- 2003-2007 Period

Application	Vehicle Type (Driving Cycle)	Battery Type	Battery Weight, lbs	Curb Weight[a], lbs	Payload, lbs	Range, to 80% DOD, miles	Range, to 100% DOD, miles	Peak Speed[b] @ 80% DOD, mph	Acceleration (0-60 mph) @ 80% DOD, s
Household	Mini-Compact (LA-92)	Pb-Acid	1054	1784	225	100	125	120	10.0
	Compact (LA-92)	Na-S	902	2122	225	150	188	120	12.0
		Ni-Cd	1568	2122	225	150	188	120	7.2
		Ni-MH	1014	2122	225	150	188	120	8.0
Fleet	Compact (LA-92)	Na-S	902	2122	225	150	188	120	12.0
		Ni-Cd	1568	2122	225	150	188	120	7.2
		Ni-MH	1014	2122	225	150	188	120	8.0
	Minivan (FUDS)	Na-S	919	2515	500	135	169	99	15.0
		Ni-Cd	1332	2515	500	120	150	118	9.7
		Ni-MH	893	2515	500	120	150	110	10.7
	Full-Size Van (FUDS)	Na-S	1555	4454	750	140	175	104	15.0
		Ni-Cd	2161	4454	750	120	150	120	10.0
		Ni-MH	1449	4454	750	120	150	115	11.0

[a] Battery weight not included
[b] Not sustainable

Table B.3.7c Predicted Performances of Electric Vehicles -- 2008-2010 Period

Application	Vehicle Type (Driving Cycle)	Battery Type	Battery Weight, lbs	Curb Weight[a], lbs	Payload, lbs	Range, to 80% DOD, miles	Range, to 100% DOD, miles	Peak Speed[b] @ 80% DOD, mph	Acceleration (0-60 mph) @ 80% DOD, s
Household	Mini-Compact (LA-92)	Pb-Acid	904	1711	225	100	125	120	10.0
	Compact (LA-92)	Na-S	803	2034	225	154	193	120	12.0
		Ni-Cd	1336	2034	225	150	188	120	7.3
		Ni-MH	873	2034	225	150	188	120	8.0
Fleet	Compact (LA-92)	Na-S	803	2034	225	154	193	120	12.0
		Ni-Cd	1336	2034	225	150	188	120	7.3
		Ni-MH	873	2034	225	150	188	120	8.0
	Minivan (FUDS)	Na-S	811	2384	500	139	174	100	15.0
		Ni-Cd	1127	2384	500	120	150	118	10.0
		Ni-MH	761	2384	500	120	150	111	11.0
	Full-Size Van (FUDS)	Na-S	1372	4230	750	144	180	105	15.0
		Ni-Cd	1828	4230	750	120	150	120	10.2
		Ni-MH	1235	4230	750	120	150	115	11.4

[a] Battery weight not included
[b] Not sustainable

Table B.3.8a Energy Consumptions[a] of Electric Vehicles -- Pre-2003 Period

Application	Vehicle Type (Driving Cycle)	Batt. Type	Base, kWh/mile	Chicago		Houston		Los Angeles		Washington,DC	
				Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile
Household	2-Seater (LA-92)	Pb-Acid	0.245	0.019	0.018	0.022	0.007	0.019	0.006	0.021	0.012
	Compact (LA-92)	Pb-Acid	0.279	0.040	0.038	0.045	0.016	0.040	0.012	0.042	0.025
Fleet	Compact (LA-92)	Pb-Acid	0.279	0.040	0.038	0.045	0.016	0.040	0.012	0.042	0.025
	Mini-Minivan (FUDS)	Na-S	0.225	0.039	0.052	0.048	0.017	0.040	0.013	0.043	0.028
	Minivan (FUDS)	Ni-Cd	0.297	0.057	0.080	0.070	0.026	0.060	0.020	0.063	0.044
	Full-size Van (FUDS)	Pb-Acid	0.510	0.091	0.127	0.113	0.041	0.094	0.032	0.100	0.070

[a] All energy consumptions in this table are expressed in kWh/mile at wall outlets;
Effects of thermal losses for Na-S batteries are not included in this table;
Effects of ambient temperataure on Pb-Acid capacity are not included in this table.

Table B.3.8b Energy Consumptions[a] of Electric Vehicles -- 2003-2007 Period

Application	Vehicle Type (Driving Cycle)	Batt. Type	Base, kWh/mile	Chicago		Houston		Los Angeles		Washington,DC	
				Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile
Household	Mini-Compact (LA-92)	Pb-Acid	0.250	0.028	0.028	0.033	0.011	0.029	0.008	0.031	0.018
	Compact (LA-92)	Na-S	0.246	0.035	0.033	0.040	0.014	0.035	0.010	0.037	0.022
		Ni-Cd	0.299	0.037	0.035	0.042	0.015	0.037	0.011	0.039	0.023
		Ni-MH	0.288	0.040	0.038	0.045	0.016	0.040	0.012	0.042	0.025
Fleet	Compact (LA-92)	Na-S	0.246	0.035	0.033	0.040	0.014	0.035	0.010	0.037	0.022
		Ni-Cd	0.299	0.037	0.035	0.042	0.015	0.037	0.011	0.039	0.023
		Ni-MH	0.288	0.040	0.038	0.045	0.016	0.040	0.012	0.042	0.025
	Minivan (FUDS)	Na-S	0.279	0.051	0.072	0.063	0.023	0.054	0.018	0.057	0.040
		Ni-Cd	0.318	0.054	0.076	0.067	0.024	0.057	0.019	0.060	0.042
		Ni-MH	0.317	0.059	0.082	0.072	0.026	0.062	0.021	0.064	0.045
	Full-size Van (FUDS)	Na-S	0.455	0.080	0.112	0.099	0.036	0.082	0.028	0.087	0.062
		Ni-Cd	0.515	0.084	0.118	0.105	0.038	0.087	0.030	0.093	0.065
		Ni-MH	0.514	0.091	0.127	0.113	0.041	0.094	0.032	0.100	0.070

[a] All energy consumptions in this table are expressed in kWh/mile at wall outlets;
Effects of thermal losses for Na-S batteries are not included in this table;
Effects of ambient temperature on Pb-Acid capacity are not included in this table.

Table B.3.8c Energy Consumptions[a] of Electric Vehicles -- 2008-2010 Period

Application	Vehicle Type (Driving Cycle)	Batt. Type	Base, kWh/mile	Chicago		Houston		Los Angeles		Washington,DC	
				Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile	Cool, kWh/mile	Heat, kWh/mile
Household	Mini-Compact (LA-92)	Pb-Acid	0.209	0.027	0.027	0.033	0.011	0.028	0.008	0.030	0.018
	Compact (LA-92)	Na-S	0.208	0.034	0.032	0.039	0.014	0.034	0.010	0.036	0.021
		Ni-Cd	0.248	0.036	0.034	0.041	0.015	0.036	0.011	0.038	0.022
		Ni-MH	0.241	0.038	0.037	0.044	0.016	0.038	0.011	0.041	0.024
Fleet	Compact (LA-92)	Na-S	0.208	0.034	0.032	0.039	0.014	0.034	0.010	0.036	0.021
		Ni-Cd	0.248	0.036	0.034	0.041	0.015	0.036	0.011	0.038	0.022
		Ni-MH	0.241	0.038	0.037	0.044	0.016	0.038	0.011	0.041	0.024
	Minivan (FUDS)	Na-S	0.232	0.050	0.070	0.061	0.022	0.052	0.017	0.055	0.039
		Ni-Cd	0.261	0.053	0.074	0.065	0.024	0.056	0.019	0.058	0.041
		Ni-MH	0.262	0.057	0.080	0.070	0.026	0.060	0.020	0.063	0.044
	Full-size Van (FUDS)	Na-S	0.379	0.077	0.109	0.096	0.035	0.080	0.027	0.085	0.060
		Ni-Cd	0.424	0.082	0.115	0.102	0.037	0.085	0.029	0.090	0.063
		Ni-MH	0.426	0.088	0.124	0.110	0.040	0.091	0.031	0.097	0.068

[a] All energy consumptions in this table are expressed in kWh/mile at wall outlets;
Effects of thermal losses for Na-S batteries are not included in this table;
Effects of ambient temperataure on Pb-Acid capacity are not included in this table.

B.4 Vehicle Travel Patterns In the Four Studied Areas and Driving Cycle Selection for Simulating EV Energy Consumption and CV Energy Consumption and Emissions

B.4.1 Introduction

Vehicle travel patterns represent how vehicles are actually used on road. On-road actual vehicle usage patterns affect EV energy consumption and CV (conventional vehicles, i.e., gasoline vehicles) energy consumption and emissions. Vehicle travel patterns are represented by parameters such as travel speed, trip length, trips per day, number of cold and hot starts, and other factors. These travel parameters are usually used to determine a driving cycle in the form of second-by-second speed changes over a given driven distance) applicable to given vehicle applications. Driving cycles are used in estimating EV and CV energy consumption with the EAGLES model. Travel parameters are used in estimating CV vehicle operation emissions with Mobile5a.

Because of differences in geography, urban sprawl patterns, available transportation alternatives, and climate among the four metropolitan areas, one might expect that differences in travel patterns exist among the four areas. In this section, data on travel patterns in each of the areas are collected and compared. Possible travel pattern differences among the four areas will be determined. Based on the collected travel pattern data, driving cycles will be selected for the four studied areas. The selected driving cycles will be used to estimate per-mile EV energy consumption and per-mile CV energy consumption and emissions. Estimated per-mile energy consumption and emissions together with collected daily mileage will be used to calculate total energy consumption and emissions.

Travel patterns of fleet vehicles and household vehicles are certainly different. To accurately estimate EV energy and emission impacts, energy consumption and emissions need to be estimated for fleet vehicles and household vehicles, separately. To do so, travel patterns are analyzed for fleet vehicles and household vehicles, separately.

In the EVTECA, it is assumed that replacement of CVs with daily mileage less than or equal to 90 miles with EVs will not change vehicle trip characteristics. That is, it is assumed that use of EVs for replacing GVs will not cause changes in travel speed, trip length, trips per day, etc., though in reality, use of EVs will certainly cause such changes, mainly because of the differences in vehicle characteristics and vehicle operating costs between EVs and GVs. Such changes are a secondary effect of introducing EVs.

B.4.2 Data Sources for Identifying Vehicle Trip Characteristics

Household Vehicle Trip Characteristics

Two general data sources are available for identifying household vehicle trip characteristics. One source is documents generated by transportation planning agencies in the four metropolitan areas. Transportation planning agencies are generally responsible for making and evaluating transportation plans. For their missions, these agencies conduct simulations of travel patterns. During transportation simulation, vehicle travel speeds on different road types within a metropolitan area are usually projected. Although projected vehicle travel speeds are for all vehicle applications including both household and fleet applications, the primary focus of transportation planning agencies is usually household trips.

The other source for identifying household vehicle trip characteristics is the 1990 nationwide personal transportation survey (NPTS) (Federal Highway Administration, 1991). Through the survey, randomly selected households were asked to record and report trips made by household members during given selected days. The NPTS contains comprehensive information on the amount and the nature of personal travel in the U.S. Travel speeds, trip length and trips per day can be determined for each of the four metropolitan areas from the NPTS database.

Speed Data Collected or Estimated by Transportation Planning Agencies in the Four Metropolitan Areas.

During the EVTECA, transportation planning agencies in the four metropolitan areas were contacted, and data on vehicle travel speed and total numbers of trips were obtained. The obtained travel data for each metropolitan area are summarized below.

- *The Chicago Metropolitan Area*

The Chicago Area Transportation Study (CATS) conducted a study between June and October of 1990 to determine average speeds on some state highways and various major streets in the Chicago area (CATS, 1991). Vehicle speeds were determined by measuring the time that a vehicle spent to pass two points on a road segment. Usually, intersections were selected as the points where vehicle license plate numbers and the time when vehicles passed through were recorded. With the distance between two intersections and the time spent by vehicles between the two intersections, average travel speed for the road segment between the two intersections was calculated.

During the study, the CATS determined travel speeds on 68 segments of major highways and streets, and for three periods of time (the AM peak period [between 6:30am and 8:30am], the mid-day period [between 11:00am and 1:30pm], and the PM peak period [between 3:30pm and 6:30pm]). The study accumulated a total of 408 data cohorts. For the EVTECA, the 408 cohorts were divided into three general locations--the downtown area, central city areas, and suburban areas. Average speed for each of the three locations was then calculated. Table B.4.1 presents estimated average speeds for the three general locations.

Table B.4.1 Estimated Average Travel Speeds in the Chicago Area (mph, Based on CATS, 1991)

Location	AM Period	Mid-Day	PM Period
Downtown	15.0	12.1	13.0
Central City	26.7	25.1	23.4
Suburban	33.6	35.9	31.3
All Locations	26.6	28.7	24.1

The table clearly shows that vehicle travel speeds decrease from suburban areas to the downtown area. Interestingly, the lowest speed in the downtown area occurred during the mid-day period, while the lowest speed in central city and suburban areas occurred during the PM period, meaning that vehicle travel level in the downtown area is high during the mid-day period, and vehicle travel level in central city and suburban areas is high during the PM period.

CATS' data show differences in travel speeds among locations and among travel periods for vehicles travelling on major streets, highways, and freeways. The data cannot be used to estimate average speeds of typical trips. This is because the CATS study does not cover the complete trip that a vehicle makes. A complete trip includes getting the vehicle started and parked, travelling on neighborhood streets, and travelling on major streets, highways, and freeways. The CATS study measures speeds for vehicle travelling on major streets, highways, and freeways. Even for these segments, the study may not fully account for stopping and idling time spent by vehicles in intersections. Because of these limitations, use of CATS' speed data may lead to overestimates of actual speeds for complete trips. Nevertheless, Table B.4.1 does provide useful information about the temporal and spatial distribution of speeds in the Chicago area.

- *The Houston Metropolitan Area*

In preparing the 1994 transportation improvement program and the final 1990 base year ozone state implementation plan for the Houston metropolitan area, the Houston-Galveston Area Council (H-GAC) predicts total trips and trip length by trip purpose and average travel speed by road type (H-GAC, 1993a and 1993b). Table B.4.2 presents total trips and trip length by trip purpose for the Houston area. As the table shows, home-based trips account for the majority of all trips, and home-based work trips are longer than any other trips except external-local vehicle trips.

Table B.4.2 Total Trips and Average Trip Length by Trip Purpose in the Houston Metropolitan Area (for Year 1990, from H-GAC, 1993b)

Trip Purpose	Total Trips	Minutes/Trip
Home-Based Work Trips	2,200,500	21.7
Home-Based School Trips	1,285,100	9.1
Home-Based Shopping Trips	1,479,700	9.6
Home-Based Other Trips	3,390,300	12.0
Non-Home-Based Trips	3,806,200	13.0
Truck-Taxi Trips	375,600	13.1
External-Local Vehicle Trips	201,300	39.7
Total or Weighted Average	12,738,700	13.9

The H-GAC estimates daily average travel speeds on various road types in each of the eight counties in the Houston area. Table B.4.3 presents H-GAC estimated vehicle travel speeds on different road types.

Table B.4.3 Daily Average Speeds in the Houston Metropolitan Area (for Year 1990, adapted from H-GAC, 1993b)

County	Freeway	Princi. Arterial	Other Arterial	Major Collector	Other Collector	Local Street	All Roads
Harris	52	32	27	47	26	21	35
Brazoria	60	42	40	53	41	27	43
Fort Bend	58	43	35	55	36	24	41
Waller	67	51	47	55	48	33	54
Montgomery	64	34	42	51	44	31	49
Liberty	60	44	52	57	48	34	49
Chambers	61	56	54	55	51	36	57
Galveston	58	34	34	56	31	22	37
All	53	34	29	52	31	23	37

Among the eight counties, Harris county where city of Houston is located has the lowest travel speed for every road type. This indirectly indicates that downtown houston has lower speed than any other parts of the area. The H-GAC's speed data are not disaggregated into different time periods during a day (e.g., the AM and PM peak period). The data are too aggregate to be used for identifying characteristics of potential EV trips. The speed data are average speeds for vehicles travelling on a given road type. Average speeds for typical trips cannot be estimated from the data.

- *The Los Angeles Metropolitan Area*

The Southern California Association of Governments (SCAG) estimates vehicle travel speeds on different road types for different time periods of a day in the Los Angeles metropolitan area (SCAG, 1993). Table B.4.4 presents SCAG-estimated speeds on different road types and for different travel time periods.

Table B.4.4 Vehicle Travel Speeds in the Los Angeles Metropolitan Area (for Year 1990, from SCAG, 1993)

		CBD	CBD Fringe	Residential	Semi-Rural	Rural
Freeway	Peak	25	35	40	55	55
	Off-peak	40	45	50	55	55
Major Arterial	Peak	15	20	25	40	50
	Off-peak	20	25	30	40	50
Primary Arterial	Peak	15	20	25	40	50
	Off-peak	20	25	30	40	50
Secondary Arterial	Peak	15	20	25	35	50
	Off-peak	20	25	30	35	50
Zone Connector	Peak	15	20	25	35	35
	Off-peak	20	25	30	40	40

The SCAG's speed data show that vehicle travel speeds decrease from rural areas to central business districts (CBDs). Average speeds decrease by 5 mph from CBD fringes to CBDs for vehicles travelling on all road types and during off-peak time, and for vehicles travelling on all road types except freeways and during peak time. Speeds decrease by 10 mph from CBD fringes to CBDs for peak-time freeway travels. Average speeds decrease by 5 mph from residential areas to CBD fringes. In CBDs, CBD fringes, and residential areas, average speeds for travel on all road types except freeways decrease by 10 mph from off-peak time to peak time; speeds on freeways decrease by 15 mph.

The SCAG speed data are for vehicles travelling on each road type. Average speeds for complete trips are represented by the data. The SCAG does not estimate speeds on local streets.

- *The Washington D.C. Metropolitan Area*

The Metropolitan Washington Council of Governments (MWCOG) estimates speeds for home-based work trips based on the 1980 census data. The MWCOG feed its estimated speed data into the MINUTP computer model to simulate travel patterns in the Washington D.C. area. Based on MWCOG's estimated speed data, average speeds on different road types and in different locations are estimated here (Table B.4.5). Since the speeds estimated by the MWCOG are for work trips, these speeds can be treated as peak-hour speeds.

Table B.4.5 Vehicle Travel Speeds for Work Trips in the Washington D.C. Metropolitan Area (Based on data presented by MWCOG, 1993)

	Local Streets	Collectors	Minor Arterials	Major Arterials	Express-ways	Freeways
Downtown	10	12	14	15	16	25
Central City	15	15	16	17	19	33
Suburban	25	30	32	32	40	42

The above table shows that travel speeds decrease dramatically on all road types from suburban areas to the downtown area in the Washington, D.C. area. However, the speed data are average speeds for vehicles travelling on a given road type. Average speeds for complete trips are represented.

B.4.3 Summary

In general, the above presented data show travel speeds in each metropolitan area. The data for the Chicago area and the Los Angeles area identify spatial and temporal distribution of on-road travel speeds in each area. Data for the Washington, D.C. area identify spatial distribution of speeds there. Data for the Houston area are too aggregate to identify spatial and temporal distribution of speeds there.

There are at least three major problems for using the above speed data to characterize EV trips in the four areas. The first problem is that all the above speed data are for vehicles travelling on a given road type. The data do not represent average speeds for complete trips, because the above sources present neither speeds for the portions of trips made on local streets and getting on and off major roads nor the time spent for trip beginning and ending and vehicle stopping and idling. Because of the lack of data for these portions, actual average speeds for complete trips should be lower than the average speeds of on-road vehicles presented here.

The second problem is that there exist inconsistencies in the methods used to estimate travel speeds among the cited sources. For example, speed data for the Chicago area are based on actually measured time spent on road segments; speed data for the Washington D.C. area are based on the 1980 national household survey data where the time spent for trips was reported by surveyed households; and speed data for the Houston and Los Angeles areas are estimated from transportation models. Because of these inconsistencies, speeds cited here from those studies cannot be compared among the four areas. It is incorrect, or at least inaccurate, to determine the similarity or the difference in vehicle travel speeds among the four metropolitan areas from the above speed data.

The third problem is that other trip attributes such as trip length and trips per day are not available from those above sources. These attributes are needed for determining EV energy consumption and CV energy consumption and emissions.

Because of these problems, it is not accurate to use these above speed data to identify EV trip characteristics in the four metropolitan areas. However, they do provide a "frame of reference."

The 1990 Nationwide Personal Transportation Survey (NPTS) (Federal Highway Administration, 1991)

Data on household vehicle trip characteristics were generated from the 1990 NPTS database for the EVTECA. Values for average travel speed, trip time, trip length, and trips per day were generated for peak and off-peak periods, for working and non-working trips, and in each of the four metropolitan areas. Tables B.4.6-B.4.8 present trip characteristics data generated from the 1990 NPTS database.

As Table B.4.6 shows, average speeds for complete trips increase significantly with the increase in trip length. For example, average speeds for trips with trip length less than or equal to 5 miles are about 15 mph, while average speeds for trips with trip length greater than 30 miles are about 40 miles. If EVs are to be used for short trips, average speeds of EVs will be shorter. Average speeds in central cities are lower than those in suburban areas. Average speeds of working peak trips are lower than those of non-working off-peak trips. As EAGLES simulation will show later, penalty of reduced speeds on vehicle energy consumption is more severe for CVs than for EVs. Thus, if EVs are used for making short-distance trips in downtown areas and for working trips, EVs will achieve large benefits, relative to EVs to be introduced area-wide and for all trips.

There are some variations in travel speeds among the four cities. Chicago has the lowest speeds, Washington D.C. has the next lowest speeds, Los Angeles has high speeds, and Houston has the highest speeds.

Table B.4.7 shows that non-working off-peak trips have shorter trip length than working peak trips. Among the four areas, Washington D.C. has the longest trip length, Los Angeles has the next longest, Houston has short trip length, and Chicago has the shortest trip length.

Because of the methodology consistency of obtaining travel data for each of the four metropolitan areas in the 1990 NPTS, and because of the NPTS' nature of including every segment of a trip, the above NPTS trip data are chosen to use for characterizing trips of household vehicles in each of the metropolitan areas.

Table B.4.6 Vehicle Travel Speeds in the Four Metropolitan Areas (mile/hour, based on the 1990 NPTS, inter-city trips were excluded)

Trip Length (miles)	Chicago			Houston			Los Angeles			Washington, DC		
	C. City	Sub-urban	All	C. City	Sub-urban	All	C. City	Sub-urban	All	C. City	Sub-urban	All
Work, Peak Trips:												
<=5	13.1	16.9	15.4	14.9	22.3	18.2	16.2	18.6	17.4	18.0	17.2	18.0
6-10	19.4	22.6	21.5	25.6	24.1	25.6	26.4	28.5	27.7	22.3	18.6	19.4
11-20	23.1	28.0	26.2	30.5	30.0	30.5	31.5	30.1	30.6	30.3	27.9	28.0
<=20	18.2	22.4	20.9	24.5	17.2	25.7	25.8	27.2	26.7	21.9	23.8	23.6
21-30	35.8	32.6	33.0	42.3	37.9	39.3	37.2	38.1	37.6	35.0	34.6	34.7
<=30	19.6	24.7	23.0	26.3	29.6	27.9	28.6	29.4	28.9	26.9	26.3	26.4
>30	45.0	40.1	40.8	None	37.7	37.7	39.0	35.5	36.7	None	38.9	38.9
All	22.6	28.8	27.1	26.3	31.7	29.3	30.5	30.6	30.6	27.0	27.8	27.7
Non-Work, Off-Peak Trips:												
<=5	25.0	19.4	17.8	18.9	19.4	19.2	18.8	18.3	18.5	16.1	19.8	19.2
6-10	26.4	30.7	29.1	29.8	32.9	31.1	30.9	29.6	30.2	30.7	29.4	29.7
11-20	38.6	32.9	35.2	38.4	40.1	39.4	38.4	40.6	39.3	36.3	31.7	32.4
<=20	23.4	25.4	24.7	25.8	28.0	27.0	26.3	25.7	25.9	27.0	26.3	26.5
21-30	52.9	41.3	46.3	54.3	36.4	45.7	46.5	43.5	44.8	42.0	44.7	44.2
<=30	26.6	26.6	26.6	31.4	29.3	30.3	28.8	27.9	28.1	28.7	28.1	28.3
>30	50.2	41.4	42.0	46.7	48.9	48.7	45.3	49.6	47.1	51.8	42.7	46.7
All	27.0	28.2	27.8	31.9	32.7	32.4	31.5	29.9	30.6	35.0	29.6	30.8
All Trips[a]:												
<=5	13.8	18.3	16.5	18.0	18.8	18.4	16.8	18.3	17.6	16.3	19.3	18.7
6-10	23.2	27.8	26.1	29.0	30.0	29.5	29.9	28.7	29.2	25.6	25.8	25.8
11-20	31.4	31.6	31.5	33.3	37.2	35.4	35.7	35.3	35.5	36.2	29.1	29.8
<=20	21.2	24.6	23.2	25.6	27.8	26.6	26.1	26.8	26.4	24.9	25.3	25.3
21-30	45.5	33.7	36.5	51.5	38.3	43.7	41.5	40.4	40.9	36.8	39.1	38.6
<=30	23.5	26.1	25.1	28.5	29.5	29.0	28.5	28.8	28.7	27.2	27.1	27.2
>30	40.9	42.0	41.8	36.1	43.8	42.6	42.7	40.6	41.6	48.1	43.3	44.8
All	25.1	29.2	27.8	28.8	32.4	30.8	31.3	30.8	31.0	32.1	29.2	29.7

[a] Including working peak trips, non-working off-peak trips, and all other trips.

Table B.4.7 Travel Distance per Trip in the Four Metro Areas (miles/trip, based on the 1990 NPTS, inter-city trips were excluded)

Trip Length (miles)	Chicago			Houston			Los Angeles			Washington, DC		
	C. City	Sub-urban	All	C. City	Sub-urban	All	C. City	Sub-urban	All	C. City	Sub-urban	All
Work, Peak Trips:												
<=5	3.0	2.8	2.9	2.9	2.8	2.9	2.9	2.8	2.9	2.8	2.9	2.9
6-10	7.7	7.7	7.7	7.5	7.9	7.7	8.2	8.3	8.3	9.3	7.8	8.1
11-20	13.8	14.6	14.4	14.7	15.7	15.1	15.1	15.2	15.2	14.3	15.6	15.6
<=20	6.2	6.1	6.1	7.8	6.7	7.2	7.6	8.1	7.9	5.7	8.7	8.2
21-30	26.3	26.2	26.2	26.9	25.1	25.7	26.3	26.9	26.6	25.4	25.1	25.2
<=30	7.0	7.9	7.6	8.8	8.5	8.6	9.9	9.6	9.7	9.4	10.8	10.6
>30	41.8	41.7	41.8	None	39.4	39.4	43.1	41.2	41.9	None	39.6	39.6
All	8.7	11.3	10.5	8.8	11.2	10.1	12.0	12.3	12.2	9.4	12.3	11.8
Non-Work, Off-Peak Trips:												
<=5	2.1	2.5	2.3	2.4	2.3	2.4	2.4	2.2	2.2	2.1	2.5	2.4
6-10	8.3	8.1	8.1	8.4	8.4	8.4	8.2	8.1	8.1	8.6	8.2	8.3
11-20	16.0	14.7	15.3	15.3	14.9	15.1	15.8	14.7	15.2	17.7	14.7	15.2
<=20	4.8	4.6	4.6	4.8	4.8	4.8	4.7	4.3	4.4	5.8	5.4	5.5
21-30	27.8	25.1	26.4	26.1	26.7	26.3	26.4	27.9	27.2	25.4	26.2	26.0
<=30	5.7	5.0	5.3	6.6	5.8	6.2	5.6	5.1	5.3	6.7	6.2	6.3
>30	46.6	63.6	62.0	35.0	49.5	47.5	58.5	50.6	54.7	70.0	50.6	58.5
All	5.8	6.0	5.9	6.8	7.5	7.2	7.1	5.9	6.4	10.6	7.1	7.7
All Trips[a]:												
<=5	2.2	2.5	2.4	2.6	2.3	2.5	2.4	2.3	2.3	2.2	2.6	2.5
6-10	8.4	8.1	8.2	8.3	8.3	8.3	8.4	8.2	8.3	8.4	8.1	8.1
11-20	15.4	14.8	15.1	15.0	15.3	15.2	15.7	15.4	15.5	16.3	15.1	15.2
<=20	5.1	5.0	5.1	5.6	5.6	5.6	5.6	5.5	5.5	5.7	6.5	6.3
21-30	27.4	26.3	26.6	26.3	26.1	26.2	26.1	27.1	26.6	25.4	25.2	25.2
<=30	6.0	6.1	6.1	6.7	6.7	6.7	6.8	6.6	6.7	7.1	7.5	7.5
>30	42.5	49.6	48.1	35.0	44.1	42.6	50.7	44.7	47.4	59.0	42.1	46.4
All	6.9	8.1	7.7	7.0	8.7	7.9	8.8	8.1	8.4	10.4	8.9	9.2

[a] Including working peak trips, non-working off-peak trips, and other trips.

Table B.4.8 Trips per Day per Vehicle in the Four Metro Areas (based on the 1990 NPTS)

Area	Trips per Day[a]
Chicago	3.8
Houston	4.1
Los Angeles	3.9
Washington, D.C.	3.8

[a] When estimated trips per day per vehicle, vehicles without making trips were excluded.

As Table B.4.6 shows, average speed varies with travel time periods (peak and off-peak periods), with trip purpose (working trips and non-working trips), with location (central city and suburban), and with trip length. In determining average speeds for the trips made by EVs, it may not be proper to use average speeds for a certain trip purpose (e.g., working trips), because EVs will certainly be used for other trip purposes as well. To cover broad trip purposes, it is determined that average speeds for all trip purposes are used. EVs will be introduced to households in both central cities and in suburban areas. Speeds for trips made in both central cities and suburban areas are used to define average speeds of EV trips. However, because EVs will be most likely to be introduced to multi-vehicle households, it is reasonable to assume EVs will be used to make short-distance trips. Speeds and trip length for trips with trip length less than or equal to 30 miles per trip are used in determining average speeds and average trip length for each metropolitan area. Based on these reasons, average speeds and average trip length for each metropolitan area are determined from Tables B.4.6-B.4.8. The determined trip characteristics for each area are presented in Table B.4.9.

Table B.4.8 shows that there are about four trips per day per vehicle in each of the four metropolitan areas. Four trips per day are adopted for each area.

Table B.4.9 Average Speed, Trip Length, and Miles per Day for EV Trips

	Chicago	Houston	L.A.	D.C.
Avg. Speed (mph)[a]	25.1	29.0	28.7	27.2
Miles per Trip[a]	6.1	6.7	6.7	7.5
Miles per Day[b]	24.4	26.8	26.8	30.0

[a] Based on trip data for all trips with trip length less than or equal to 30 miles in each area. The data are presented in Tables B.4.6-B.4.7.
[b] Calculated from trip length presented in this table and assumed four trips per day for each area.

B.4.4 Fleet Vehicle Trip Characteristics

In 1984, the University of Michigan's Institute for Social Research conducted a telephone survey for the Detroit Edison Company to identify travel characteristics of commercial fleet vehicles (Berg et al., 1984).

The identified fleet vehicle travel characteristics were then used to estimate the potential size of EV market in fleet applications.

Through the survey, 583 commercial fleet managers were contacted through phone. They were asked questions about vehicle daily mileage, percentage of miles driven at speed greater than 40 mph, times spent on vehicle stopping and engine idling, among other questions. The survey revealed detailed information on daily mileage, top speed, stops, and other trip characteristics of fleet vehicles. The University of Michigan researchers estimated a total of 6 million cars and 7 million light trucks in fleet applications at that time. Based on the survey results and the EV performance characterized at the time of the survey, the University of Michigan researchers concluded that the fleet market for EV applications could be large.

Table B.4.10 shows that in Chicago, 73% of fleet cars and 63% of fleet light trucks travel less than or equal to 90 miles per day; in Houston, 77% of fleet cars and 59% of fleet light trucks; In Los Angeles, 79% of fleet cars and 75% of fleet light trucks; and in Washington, D.C., 95% of fleet cars and 38% of fleet light trucks. Thus, except for fleet light trucks in Washington, D.C., majority of fleet cars and light trucks travel less than 90 miles per day. Because of this, EVs designed with 90-miles driving range will be able to to replace majority of fleet vehicles.

For fleet vehicles travelling less than or equal to 90 miles per day, Table B.4.11 further shows that average daily mileage is 57 miles for cars and 40 miles for light trucks in Chicago; 54 miles for cars and 58 miles for light trucks in Houston; 61 miles for cars and 48 miles for light trucks in Los Angeles; and 42 miles for cars and 57 miles for light trucks in Washington, D.C. Table B.4.11 also shows that average daily mileage of light trucks with 500 or less lbs of payload is 36 miles. No light trucks with payload of 500 or less lbs make daily mileage exceeding 90 miles. This indicates that light trucks with less payload make short-distance travel and have less average daily mileage, which are ideal niche vehicle types for EVs.

Table B.4.12 shows that over 75% of the fleet vehicles with less than or equal to 90-mile daily mileage are parked for at least two hours during the day, implying that EVs which will replace these vehicles will have an opportunity of being recharged during the day to extend EV daily driving range, if necessary.

Tables B.4.10-B.4.12 together show that EV driving range will rarely be a limiting factor to EV fleet applications.

Table B.4.13 shows that about 20% of fleet cars and about 70% of fleet light trucks with daily mileage less than or equal to 90 miles are parked in company sites over night. This implies that while majority of fleet electric light trucks will be recharged at company sites over night, majority of fleet cars will be recharged at private homes. Recharge of EVs either at company sites or at private homes should not be a problem.

Table B.4.10 Percentage of Fleet Vehicles with a Given Daily Mileage Range

Regions	Daily Mileage Range				
	<=30	31-60	61-90	>90	All
Cars:					
All Surveyed Areas	18.0	28.0	22.0	32.0	100
Chicago	5.6	34.4	33.3	26.7	100
Houston	16.0	24.7	35.8	23.5	100
Los Angeles	1.0	29.9	48.0	21.1	100
Washington, D.C.	24.6	54.4	15.8	5.2	100
O_3 or CO Non-Attained and pop>=$3x10^6$	13.1	25.4	22.3	39.2	100
O_3 or CO Non-Attained and pop<$3x10^6$	21.5	29.0	23.5	26.0	100
O_3 and CO attained	20.6	27.5	20.0	31.9	100
Light Trucks:					
All Surveyed Areas	21.0	25.8	16.1	37.1	100
Chicago[a]	15.5	33.1	14.5	36.9	100
Houston	3.3	39.3	16.4	41.0	100
Los Angeles	13.9	41.6	19.2	25.3	100
Washington, D.C.	5.8	15.4	16.7	62.2	100
O_3 or CO Non-Attained and pop>=$3x10^6$	15.5	33.1	14.5	36.9	100
O_3 or CO Non-Attained and pop<$3x10^6$	17.9	22.4	13.8	45.9	100
O_3 and CO attained	25.2	24.0	17.8	32.8	100
Pop>$3x10^6$ and truck load<=500 lbs[b]	52.2	10.6	23.6	None	15.0

[a] Survey data from Chicago showed zero light trucks made daily mileage between 61 and 90, which is unrealistic. We use the percentages for the areas with O_3 or CO non-attainment and population greater than or equal to 3 million for Chicago.

[b] The percentages here are relative to the total number of fleet vehicles in the areas with O_3 or CO non-attainment and population greater than 3 million.

Table B.4.11 Average Daily Mileage of Fleet Vehicles

Region	Daily Mileage Range					
	<=30	31-60	61-90	<=90	>90	All
Cars:						
All Surveyed Areas	16.7	45.2	73.3	46.7	143.3	77.6
Chicago	25.0	49.9	68.7	56.5	138.0[a]	78.3
Houston	21.7	50.6	71.5	54.3	108.0	66.9
Los Angeles	20.0	46.6	71.0	61.1	140.0	77.7
Washington, D.C.	13.5	41.9	84.9	41.7	100.0	44.7
O_3 or CO Non-Attained and pop>=3x10^6	21.2	46.7	72.8	50.8	138.0	85.0
O_3 or CO Non-Attained and pop<3x10^6	16.0	43.6	74.5	45.4	137.0	69.2
O_3 and CO attained	15.1	45.1	72.8	44.2	152.0	78.6
Light Trucks:						
All Surveyed Areas	17.0	42.9	72.8	41.9	128.0[c]	98.6
Chicago	11.1	37.9	75.0[a]	39.8	104.0	63.5
Houston	20.0	50.0	84.6	57.9	158.0	98.9
Los Angeles	24.5	42.5	75.6	47.7	129.0	68.3
Washington, D.C.	30.0	42.6	78.8	56.8	96.0	81.2
O_3 or CO Non-Attained and pop>=3x10^6	18.4	43.2	75.0	44.4	128.0	75.3
O_3 or CO Non-Attained and pop<3x10^6	16.3	44.1	74.8	42.7	128.0[b]	172.8
O_3 and CO attained	16.9	42.0	70.9	40.2	114.0	64.4
Pop>3x10^6 and truck load<=500 lbs	14.0	47.7	75.7	35.9	None	35.9

[a] Survey data showed unrealistic daily mileage for Chicago. Daily mileage for the areas with O_3 or CO non-attainment and population greater than or equal to 3 million is adopted here for Chicago.

[b] Survey data showed unrealistic daily mileage of fleet light trucks for areas with O_3 or CO non-attainment and population less than 3 million. Daily mileage for the areas with O_3 or CO non-attainment and population greater than or equal to 3 million is adopted here for the areas with O_3 or CO non-attainment and population less than 3 million.

[c] The calculated average daily mileage of fleet light trucks with unrealistic daily mileage in the areas with O_3 or CO non-attainment and population less than 3 million does not represent the actual daily mileage. The daily average mileage for the areas with O_3 or CO non-attainment and population greater than or equal to 3 million is adopted here for all surveyed areas.

Table B.4.12 Percentage of Fleet Vehicles Parked More than Two Hours During the Day

Miles per Day	Daily Mileage Range		
	31-60	61-90	31-90
Cars:			
All Surveyed Areas	82.0	73.0	78.0
O_3 or CO Non-Attained and pop>=3x10^6	72.0	76.0	73.9
O_3 or CO Non-Attained and pop<3x10^6	74.0	73.0	73.6
O_3 and CO attained	96.0	71.0	85.5
Light Trucks:			
All Surveyed Areas	88.0	70.0	81.1
O_3 or CO Non-Attained and pop>=3x10^6	88.0	74.0	83.7
O_3 or CO Non-Attained and pop<3x10^6	87.0	66.0	79.0
O_3 and CO attained	90.0	70.0	81.5

Table B.4.13 Percentage of Fleet Vehicles Left in Companies over Night

Miles per Day	Daily Mileage Range		
	31-60	61-90	31-90
Cars:			
All Surveyed Areas	21.0	25.0	22.8
O_3 or CO Non-Attained and pop>=3x10^6	25.0	24.0	24.5
O_3 or CO Non-Attained and pop<3x10^6	13.0	25.0	18.4
O_3 and CO attained	24.0	26.0	24.8
Light Trucks:			
All Surveyed Areas	69.0	69.0	69.0
O_3 or CO Non-Attained and pop>=3x10^6	74.0	76.0	74.6
O_3 or CO Non-Attained and pop<3x10^6	59.0	69.0	62.8
O_3 and CO attained	71.0	66.0	68.9

Table B.4.14 Percentage of Daily Mileage at Speed Greater than 40 mph

Region	Daily Mileage Range		
	31-60	61-90	31-90
Cars:			
All Surveyed Areas	12.8	10.9	12.0
Chicago	6.0	24.3	15.0
Houston	15.4	16.2	15.9
Los Angeles	9.9	13.8	12.3
Washington, D.C.	17.4	1.2	13.8
O_3 or CO Non-Attained and pop>=3x10[6]	12.0	10.4	11.3
O_3 or CO Non-Attained and pop<3x10[6]	10.3	12.6	11.3
O_3 and CO attained	15.1	9.8	12.9
Light Trucks:			
All Surveyed Areas	7.7	15.4	10.7
Chicago	2.6	3.5[a]	2.9
Houston	37.2	4.4	27.5
Los Angeles	9.2	3.3	7.3
Washington, D.C.	1.9	6.1	4.1
O_3 or CO Non-Attained and pop>=3x10[6]	6.3	3.5	5.4
O_3 or CO Non-Attained and pop<3x10[6]	7.0	11.8	8.8
O_3 and CO attained	9.0	21.7	14.4
Pop>3x10[6] and truck load<=500 lbs	13.8	5.9	8.3

[a] Survey data showed zero percentage for Chicago, which is unrealistic. The value for the areas with O_3 or CO non-attainment and population greater than or equal to 3 million is adopted here for Chicago.

Table B.4.15 Percentage of Fleet Vehicles Stopped More than 100 Times per Day

Region	Daily Mileage Range			
	<=30	31-60	61-90	<=90
Cars:				
All Surveyed Areas	2.0	12.0	29.0	14.9
O_3 or CO Non-Attained and pop>=3x10[6]	2.0	9.0	34.0	16.7
O_3 or CO Non-Attained and pop<3x10[6]	0.0	17.0	38.0	18.7
O_3 and CO attained	3.0	10.0	16.0	9.6
Light Trucks:				
All Surveyed Areas	9.0	9.0	36.0	15.9
O_3 or CO Non-Attained and pop>=3x10[6]	1.0	15.0	40.0	17.3
O_3 or CO Non-Attained and pop<3x10[6]	28.0	3.0	22.0	18.2
O_3 and CO attained	3.0	8.0	41.0	14.9

Table B.4.16 Percentage of Fleet Vehicles Stopped and Restarted More than 20 Times per Day

Region	Daily Mileage Range			
	<=30	31-60	61-90	<=90
Cars:				
All Surveyed Areas	1.0	8.0	37.0	15.5
O_3 or CO Non-Attained and pop>=3x10[6]	2.0	7.0	39.0	17.7
O_3 or CO Non-Attained and pop<3x10[6]	1.0	5.0	40.0	15.1
O_3 and CO attained	2.0	11.0	32.0	14.4
Light Trucks:				
All Surveyed Areas	10.0	26.0	50.0	26.8
O_3 or CO Non-Attained and pop>=3x10[6]	9.0	40.0	48.0	34.2
O_3 or CO Non-Attained and pop<3x10[6]	15.0	15.0	28.0	18.3
O_3 and CO attained	9.0	24.0	61.0	28.2

Table B.4.17 Percentage of Fleet Vehicles as Compact or Smaller Vehicles

Region	Daily Mileage Range			
	<=30	31-60	61-90	<=90
Cars:				
All Surveyed Areas	22.0	15.0	19.0	18.1
O_3 or CO Non-Attained and pop>=3x10^6	13.0	4.0	12.0	8.9
O_3 or CO Non-Attained and pop<3x10^6	11.0	25.0	26.0	21.3
O_3 and CO attained	36.0	15.0	20.0	75.7
Light Trucks:				
All Surveyed Areas	11.0	9.6	15.0	11.4
O_3 or CO Non-Attained and pop>=3x10^6	13.0	13.0	20.0	14.6
O_3 or CO Non-Attained and pop<3x10^6	14.0	9.0	12.0	11.4
O_3 and CO attained	9.0	7.0	15.0	9.9
Pop>3x10^6 and truck load<=500 lb[a]	52.2	10.6	23.6	23.8

[a] The percentages here are relative to total number of fleet trucks in the areas with O_3 or CO non-attainment and population greater than or equal to 3 million.

No average speeds are contained in the University of Michigan's survey. Some other trip characteristics indirectly show travel speeds of fleet vehicles. Table B.4.14 shows less than 15% of miles travelled by fleet cars and less than 10% of miles travelled by fleet light trucks have speeds exceeding 40 mph (except that in Houston, 28% of the mileage made by fleet light trucks have speeds exceeding 40 mph). This implies that high top speed may not be necessary for fleet EVs.

The University of Michigan's survey is the best available information so far for identifying travel characteristics of fleet cars and fleet light trucks. The University of Michigan's survey database has been re-analyzed by Argonne for the EVTECA. The following eight tables present results from re-analyzing the University of Michigan database.

Table B.4.15 shows about 10-18% of fleet cars and 15-18% of fleet light trucks have daily stops more than 100 times. Table B.4.16 shows about 15% of fleet cars and 18-35% of fleet light trucks have more than 20 times when engines are turned off and restarted a day. The energy consumption and emissions of fleet CVs during frequent idling and engine off and on operation will be greatly reduced by use of EVs, because EVs have virtually no energy loss during idling and/or restart (though energy may be used for heating or cooling).

Table B.4.17 shows that only about 10-20% of fleet vehicles are compact or smaller cars or smaller light trucks. The size of the EVs to be applied to fleet operations will probably need to be large.

With daily mileage data in Table B.4.11, daily mileage is assumed for fleet electric cars and electric light trucks and in each of the four metropolitan areas The assumed daily mileage is presented in Table B.4.18.

Table B.4.18 Daily Mileage of Fleet Electric Vehicles[a]

	Chicago	Houston	L.A.	D.C.
Cars	57	54	61	42
Light Trucks	40	58	48	57

[a] Assumed that fleet EVs will be assigned to make daily mileage less than or equal to 90 miles. These mileages are from Table B.4.11.

B.4.5 Selection of Driving Cycles for Simulating EV and CV Energy Consumption

The EAGLES computer model developed at Argonne National Laboratory will be used to estimate per-mile electricity consumption of EVs and fuel economy of CVs. EAGLES takes into consideration of vehicle power demand on a second-by-second basis. Because of this detailed simulation, a driving cycle in the form of speed changes second by second (so called speed profiles) needs to be specified in EAGLES. Such speed profiles are available for standard driving cycles developed for emission and fuel economy testing. In this section, the available standard driving cycles will be compared with the above presented vehicle travel characteristics. And then, driving cycles will be selected for EAGLES simulation.

Standard Driving Cycles

In the U.S., the federal urban driving schedule (FUDS) is used for vehicle emission testing. The highway driving cycle (HWY) together with the FUDS is used for vehicle fuel economy testing. The FUDS is supposed to represent typical urban driving and the HWY typical highway driving. The FUDS contains three driving segments (three bags). Speed profiles of bags 1 and 3 are exactly same. The only difference between bags 1 and 3 is that bag 1 is cold-started while bag 3 is hot-started. In the last several years, studies found that actual urban driving patterns are more aggressive than the FUDS. Efforts have been made to identify actual driving patterns in major urban areas. For example, the U.S. EPA has funded projects to collect actual travel data in several U.S. cities (Enns et al., 1993); and California Air Resources Board has funded a study to collect actual travel data in Los Angeles (Austin et al., 1992). The data collected during these studies indicate that the FUDS does not present aggressive driving modes such as high speed and high acceleration driving. With the collected data, new driving cycles representing aggressive driving modes have been or are being developed. With the data collected in Los Angeles, California Air Resource Board has developed a driving cycle called LA-92. Table B.4.19 presents specifications of the LA-92 together with those of the FUDS and the HWY. The LA-92 has already been used for vehicle emission testing in California to collect data on vehicle emission performance under aggressive driving.

Table B.4.19 Specifications of Three Standard Driving Cycles [a]

	FUDS[b]			LA-92[c]	HWY[b]
	Total	Bag 1	Bag 2		
Avg. mph	19.6	25.6	16.0	24.7	48.5
Top mph	56.7	56.7	34.3	67.2	60.0
Max. mph/sec	4.2	3.9	4.2	6.9	1.2
Cycle miles	7.46	3.6	3.86	9.82	10.5
Cycle seconds	1371	505	866	1431	780

[a] Some specifications were calculated with speed profiles, other were cited directly from the data sources.
[b] From *Federal Regulations* (1992).
[c] From Austin et al. (1992).

As Table B.4.19 shows, relative to the FUDS, the LA-92 driving cycle has high average speed, high top speed, and very high acceleration rate. Relative to the highway cycle, the LA-92 has high top speed and very high acceleration rate. Due to its aggressiveness, the LA-92 poses higher power demand than both the FUDS and the HWY.

Selected Driving Cycle for Household Vehicle Applications

Household trip characteristics needs to be considered in selecting a driving cycle to be applied to household vehicle applications. Above Table B.4.9 shows that average speeds for potential household EVs range from 25 mph to 29 mph among the four metropolitan areas. Average speeds in the four areas are closer to the LA-92 average speed (24.7 mph) than to the FUDS average speed (19.6 mph). In addition, the LA-92 cycle has been developed to represent the aggressiveness of actual urban driving. Thus, the LA-92 cycle is selected for simulating household vehicle energy consumption.

The NPTS data presented above show some variation in average speeds among the four metropolitan areas. Data on top speeds and acceleration rates are not available for each metropolitan area. To develop or select a specific driving cycle for each area based on the limited data is not feasible. Thus, the LA-92 cycle is applied to each of the four metropolitan areas.

Because of the aggressiveness of the LA-92 cycle relative to the FUDS, use of the LA-92 cycle in EAGLES simulation will result in designed EV performance attributes better than use of the FUDS. Thus, battery size of a given EV type will be larger, causing to higher per-mile EV energy consumption. In this sense, selection of the LA-92 cycle is a little against EV benefits, if EVs are actually driven less aggressively than the LA-92 cycle.

Selected Driving Cycles for Fleet Vehicle Applications

The University of Michigan's survey on fleet vehicle travel patterns reveals the percentage of miles travelled by fleet vehicles with speed greater than 40 mph (Table B.4.14). But the survey does not reveal the average speed of fleet vehicle trips. It is reasonable to assume the fleet cars are driven in the way similar to household cars. Thus, the LA-92 cycle is selected for simulating fleet car energy consumption.

Table B.4.14 shows that fleet cars are generally driven with higher percentages of mileage with speeds exceeding 40 mph than fleet light trucks. This implies that fleet light trucks are driven less aggressively than fleet cars. Since the FUDS is less aggressive than the LA-92 cycle, the FUDS is selected for simulating energy consumption of fleet light trucks.

In summary, since the differences in average speeds among the four metropolitan areas are relatively small, and since data available for each metropolitan are limited, same driving cycles are assumed for the four areas. For household and fleet cars, the LA-92 is selected for EAGLES simulation; and for fleet light trucks, the FUDS is selected.

On the other hand, daily mileage for household cars, fleet cars, and fleet light trucks each is assumed to be different in the four areas (see Table B.4.9 for household car daily mileage and Table B.4.18 for fleet car and light truck mileage). Daily mileage in a given metropolitan area is assumed different among the three vehicle applications--household cars, fleet cars, and fleet light trucks. Daily mileage for each vehicle application and in each metropolitan area will be used later to estimate energy consumption and emissions per day and then per year.

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B.5 EV Battery Recharging Patterns

B.5.1 Introduction

Battery recharge profiles (in the form of hourly electricity input to batteries), starting time of battery recharge during a day, and distribution of battery depth of discharge (DOD), together with daily EV electricity consumption and the total number of EVs, determine hourly electricity demand by EVs during a day in a utility system. This memorandum presents the methodologies and results of establishing EV battery recharge profiles and of calculating the distribution of EV recharge starting time and the distribution of battery DOD. The results presented here will be used for simulating EV impacts on electric utility systems in the EVTECA.

B.5.2 Construction of Battery Recharge Profiles

To maintain designed battery capacity and battery lifetime, battery manufacturers usually recommend certain charge methods for given battery types, which primarily determines the shape of recharge profiles. This section summarizes previously established battery recharge profiles and battery recharge methods. And then, based on recommended recharge methods, battery recharge profiles are established for the four battery types selected in the EVTECA.

Existing Literature

Information on battery recharge profiles is limited. Hamilton (1989) presented three battery recharge profiles (namely motive power, improved state-of-the-art [ISOA] lead-acid battery, and nickel-iron battery) (Figure 1). The profiles are for a full recharge from 100% of battery DOD. The figure implies that the ISOA lead-acid battery is charged with a schedule of four hours of constant current followed by two hours of constant voltage as finishing charge; the nickel-iron battery is charged for five hours of constant current; and the motive power battery is recharged for eight hours of constant voltage. Hamilton maintained that the motive power profile was typical for most EVs then. He used the motive power recharge profile to estimate hourly electricity demand by EVs for a given utility system. Hamilton pointed out that recharge of a partially discharged battery meant entering the recharge profile at an appropriate intermediate point.

Ducat (1989) presented recharging characteristics of a Spiegel/Lucas Chloride charger, which was used for recharging lead-acid battery-equipped Griffon electric vans. The charger was designed with two-stage charge power rating--a high power rating of 5.5 KW for the early charge stage and a low power rating of 3.2 KW for the late charge stage. The low-power charge rate for the late stage was designed to control the gases that may accumulate in lead-acid batteries near the end of the charging cycle.

Battery Charge Methods

Battery manufacturers usually design a battery charge method for a particular battery type by considering factors such as battery characteristics, complication of charge methods (e.g., maintaining constant voltage is more difficult than maintaining constant current), and impacts of charge methods on battery lifetime, capacity, and charge efficiency. Usually, battery chargers can be designed and set to follow the requirements of a given recommended charge method. Depending on characteristics and designs of batteries, battery charge methods could be very different for different battery types. Table B.5.1 presents charge methods for various battery types recommended by battery manufacturers.

Table B.5.1 shows that two charge methods are applied to Pb-acid batteries--a three-step CI/CI/CI method and a three-step CI/CV/CV method (here CI represents constant current, and CV represents constant voltage). Among the three steps of both methods, a high level of current in the first step enables batteries to reach to the majority of their capacity (e.g., 80% of their capacity) quickly; and a low level of current in the third step prevents thermal, gas accumulation, and other adverse effects on batteries during the last stage of charge. Though the CI/CV/CI method may require sophisticated charger design because of the relative difficulty of maintaining constant voltage, the method may have less adverse effects on batteries due to the smooth change in battery energy input during the three steps with the method. The CI/CV/CI method is selected here for Pb-acid batteries.

The table shows that an one-step CI method is recommended for Na-S batteries, which is the easiest method to design and operate. The one-step CI method is selected here for Na-S batteries.

Two charge methods are recommended for Ni-Cd batteries--a three-step CI/CV/CI method and an one-step CI method. Although the CI method is easier to design and operate, it certainly has adverse impacts on Ni-Cd battery charge efficiency and lifetime. Thus, the three-step CI/CV/CI method is selected here for Ni-Cd batteries.

Two charge methods are recommended for Ni-MH batteries--a two-step CI/CI method and a one-step CI method. Because of the potential adverse impacts of the one-step CI method on battery charge efficiency and lifetime, the two-step CI/CI method is selected here for Ni-MH batteries.

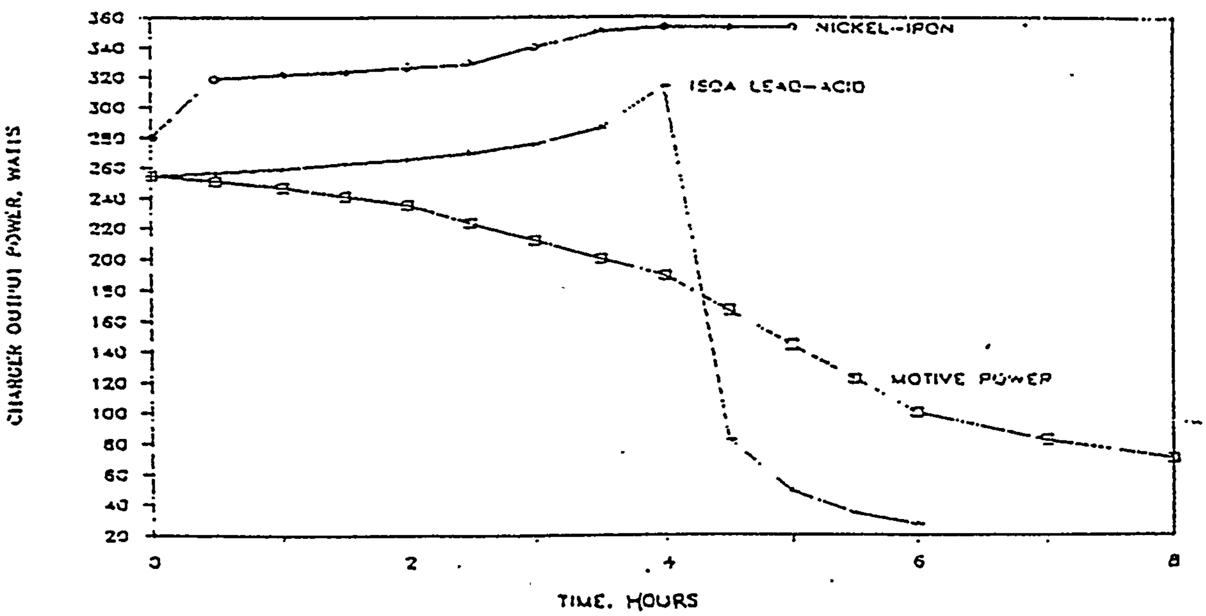

Figure B.5.1 Battery Recharge Profiles (from Hamilton, 1989)

Table B.5.1 Recommended Battery Charge Methods [a]

Battery	Manufacturer	Charge Method[b]	Reference
Tabular Pb-Acid (175 Ah, 6 V)	Chloride EV Systems	CI/CI/CI at 36A/24A/12A to reach 7.2V/7.5V/constant temp. compensated voltage for 2 hours; charge time of 8 hours; 15-20% overcharge	ANL, 1992a
Valve-Regulated Pb-Acid (150 Ah, 6 V)	Sonnenschein of Germany	CI/CV/CI at 38A/7.2V/1.3A; charge time of 8 hours; 10% overcharge	ANL, 1992b
Sealed Pb-Acid (105 Ah, 12 V)	Delco-Remy	CI/CV/CI at 15A/14.8V/1A, 14.8V held till current drops to 2A, and 1A held for 4 hours; 5-10% overcharge	Dickinson et al., 1993
Flooded Pb-Acid (205 Ah, 6 V)	Chloride Motive Power of the U.K.	CI/CI/CI at 36A/24A/12A to reach 7.2V/7.5V/7.9V, and 7.9V held constant till current drops to 6 A; 20% overcharge	Dickinson et al., 1993
Flooded Pb-Acid (200 Ah, 6 V)	EXIDE Motive Power	CI/CV/CI at 25A/7.65V/4A, 7.65V held for 3 hours, and 4A held for 3 hours; 20% overcharge	Dickinson et al., 1993
Flooded Pb-Acid (115 Ah, 12 V)	Johnson Controls, Inc.	CI/CV/CI at 10A/14.8V/1A, 14.8V held till current drops to 2A, and 1A held for 4 hours; 20% overcharge	Dickinson et al., 1993
Na-S (300 Ah, 8.3 V)	CSPL	CI at 30A to voltage of 9.1V. Lasting about 8-10 hours	Burke, 1992
Ni-Cd (190 Ah, 6 V)	SAFT of France	CI/CV/CI at 60A/8V/10A; charge time of 6.5 hours; 20% overcharge	ANL, 1992a
Ni-Cd (44 Ah, 25 V)	Marathon	CI at 8.8A for 7 hours; 40% overcharge	Dickinson et al., 1993
Ni-MH (3.5 Ah, 1.2 V, C-size cell)	Ovonic	CI/CI at 1A/0.35A, 1A held till voltage reaches 1.5V; 9% overcharge	ANL, 1992b
Ni-MH (3.5 Ah, 1.2 V, C-size cell)	Ovonic	CI at 0.88A for 4.67 hours; 17% overcharge	Dickinson et al., 1993
Ni-MH (1.4 Ah, 1.2 V, slightly smaller than C-size cell)	Panasonic	CI at 0.7A for 2.33 hours; 17% overcharge	Dickinson et al., 1993

[a] Charge methods here are for batteries with 100% of depth of discharge (DOD). Here, CI represents constant current, and CV represents constant voltage.
[b] Overcharge applied to batteries is primarily for reaching full charge of each battery module, which helps maintain designed battery life.

Construction of Battery Recharge Profiles

To construct battery recharge profiles, information on time duration of each charge step, changes in voltage (in the case of a constant-current step), and changes in current (in the case of a constant-voltage step) is needed. Precise information on these aspects is usually not available. In order to construct recharge profiles for the four battery types, assumptions about time duration of each charge step, change in voltage, and change in current have to be made. Table 2 presents the assumptions made regarding battery recharge steps for each battery type. Note that the assumptions are for recharging the batteries with 100% of depth of discharge (DOD).

Table B.5.2 Assumptions Made for Constructing Battery Recharge Profiles

Battery Type	Charge Method	Time Duration(hr)	Current Change[a]	Voltage Change[a]
Pb-Acid	CI/CV/CI	4/2/2	C/LD/C	LI/C/C
Na-S	CI	8	C	DI
Ni-Cd	CI/CV/CI	3/2/2	C/LD/C	LI/C/C
Ni-MH	CI/CI	3/3	C/C	LI/C

[a] These are changes within each charge step. Here, C represents constant; LD represents linear decrease over time; LI represents linear increase over time; and DI represents increase with different rates over time.

Using the assumptions in Table 2 and battery current and voltage specifications in Table 1, battery recharge profiles are constructed for each of the four battery types. Specifically, Delco-Remy's sealed Pb-acid battery specifications are used in constructing the recharge profile for Pb-acid batteries; CSPL's Na-S battery specifications for Na-S batteries; SAFT's Ni-Cd battery specifications for Ni-Cd batteries; and Ovonic's Ni-MH battery specifications for Ni-MH batteries. Figures 2-5 present the four recharge profiles constructed for the four battery types.

The entire recharge profiles constructed here are for batteries with 100% of DOD. Recharging a battery with less than 100% of DOD means entering to an intermediate point on the recharge profile. That is, the early part of the recharge profile is skipped. To precisely determine the point at which recharging enters to, the DOD of batteries needs to be calculated.

As the figures show, within each charge step, the constructed recharge profiles are straight lines. This is caused by the assumptions of linear increase or decrease in current or voltage time within a charge step. In practice, current and voltage are changed non-linearly. Thus, the constructed profiles are approximation of actual profiles. To precisely produce actual recharge profiles, changes in battery resistance over time during recharge are needed, which is usually not available. However, by comparing the profiles constructed here to the profiles constructed by Hamilton, one can find that the general shapes of the straight-line recharge profiles here are close to those of Hamilton's recharge profiles. Particularly, the shape of the Pb-acid battery recharge profile is similar to that of Hamilton's ISOA Pb-acid battery recharge profile (both profiles are based on the three-step CI/CV/CI charge method); and the shape of the Na-S battery recharge profile is similar to that of Hamilton's Ni-Fe battery recharge profile (both profiles are based on the one-step CI charge method). Thus, even though the recharge profiles constructed here do not precisely represent actual recharge profiles, they should be adequate enough for simulating utility impacts of EV use.

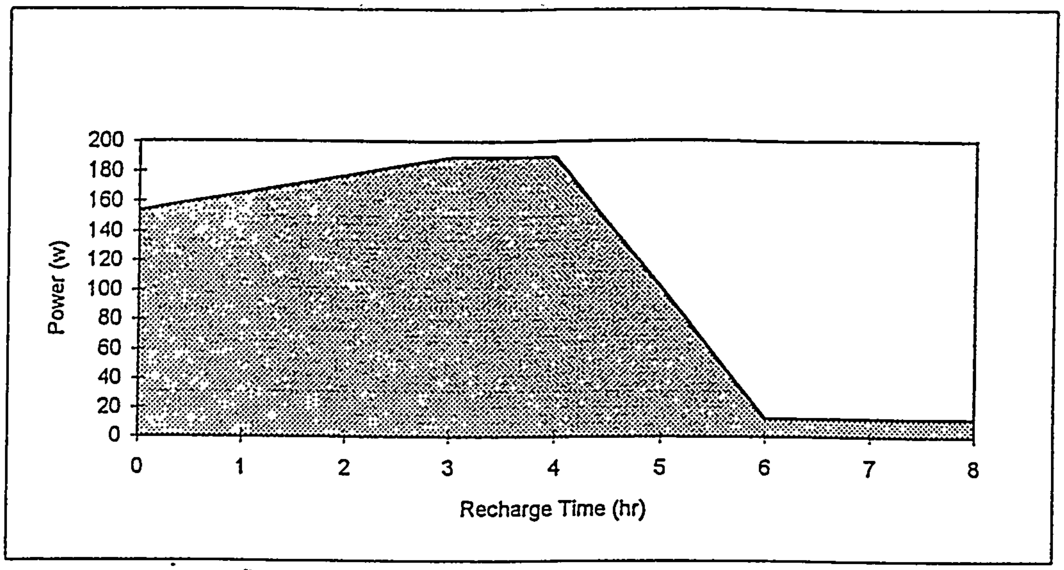

Figure B.5.2 Recharge Profile for Lead-Acid Batteries (for a 1-KWh Battery with 100% of DOD)

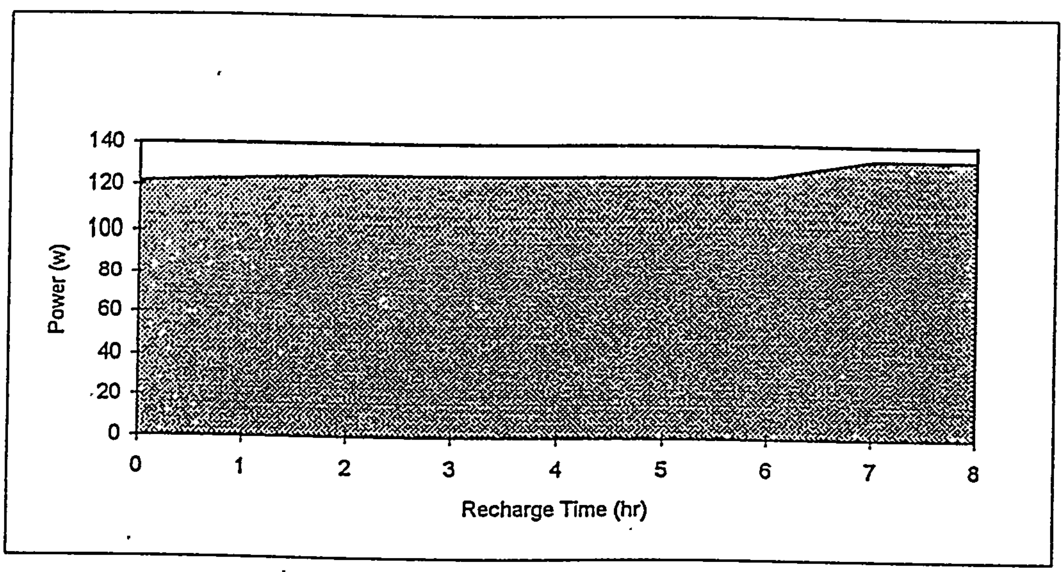

Figure B.5.3 Recharge Profile for Na-S Batteries (for a 1-KWh Battery with 100% of DOD)

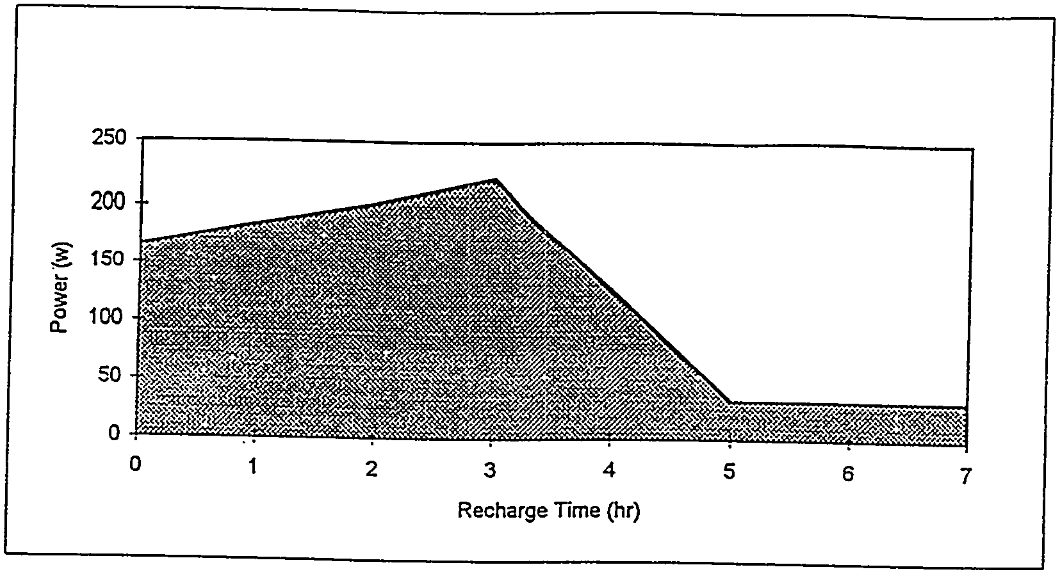

Figure B.5.4 Recharge Profile for Ni-Cd Batteries (for a 1-KWh Battery with 100% of DOD)

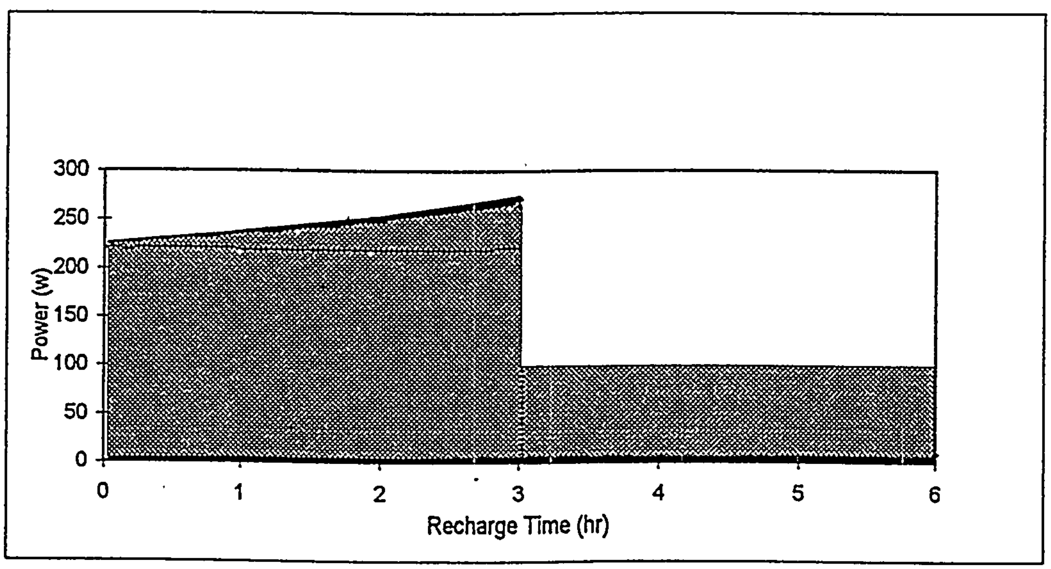

Figure B.5.5 Recharge Profile for Ni-MH Batteries (for a 1-KWh Battery with 100% of DOD)

B.5.3 Starting Time of EV Recharge During a Day

To utilize off-peak electric capacity of an utility system, EVs are preferred to be recharged during the evening. To simulate EV impacts on an utility system, assumptions regarding starting time of EV recharge have to be made.

Electric utility companies may prefer a relatively flat EV electricity demand curve in the evening in order to avoid a sudden increase in electricity demand by EVs. To achieve such a curve, utility companies may control the starting time of EV recharge by offering some incentives to EV users to delay EV recharge. However, under an uncontrolled EV recharge situation, EV users will probably start EV recharge as soon as they get home. To simulate such an uncontrolled recharge situation, the distribution of last trip ending time is used here to represent the distribution of starting time of EV recharge.

Table 3 presents the distribution of last trip ending time for household vehicles in the four metropolitan areas which are included in the EVTECA. The distribution is calculated from the data presented in the 1990 National Personal Travel Survey (NPTS). In calculating the distribution, it is assumed that the earliest ending time of EV last trips is 3:00pm and the latest ending time is 12:00am. Although for some EVs, last trip ending time may be either before 3:00pm or after 12:00am, the 3:00pm--12:00am period should cover the majority of EV trips.

In calculating the distribution for pre-2003 model-year EVs, vehicles with daily mileage less than 75 miles (the driving range of pre-2003 model-year EVs) have been included, while in calculating the distribution for post-2002 model-year EVs, vehicles with daily mileage less than 100 miles (the shortest driving range of post-2002 model-year EVs). Because of this, the distribution of last trip ending time is slightly different between the pre-2003 and post-2002 period.

No data on last trip ending time were found for fleet vehicles. Since fleet vehicles are supposed to be used for business purposes, the majority of fleet vehicles return from business probably around 5:00pm. It is simply assumed here that 50% of fleet vehicles will start to be recharged between 4:00pm and 5:00pm, and the remaining 50% between 5:00pm and 6:00pm.

B.5.4 Distribution of Battery DOD at the Beginning of EV Recharge

The battery DOD at the beginning of battery recharge determines the point on a recharge profile curve at which battery recharge starts. Under the uncontrolled recharge situation, EVs are assumed to be recharged every day after the last trips. For an EV, the battery DOD at the end of the last trip is determined by EV daily mileage, per-mile EV electricity consumption, and EV battery capacity. Specifically, battery DOD at the end of daily trips is calculated with the following formula.

$$\text{DOD} = \text{Daily mileage} \times \text{Kwh/mile} \div \text{Battery Capacity in Kwh}$$

For a given combination of EV type and battery type, per-mile electricity consumption and EV battery are fixed. Battery DOD for the combination varies with daily mileage. For a given number of EVs, there is a distribution of daily mileage, thus, there is a distribution of battery DOD.

Daily Mileage

The following method is used to determine EV daily mileage and its distribution. First, a daily mileage range is selected (i.e., 0-80 miles for pre-2003 model-year EVs, and 0-100 miles for post-2002 model-year EVs). And then, the selected daily mileage is divided into various sub-ranges (e.g., 0-10 miles, 11-20 miles, and so on). Finally, the mid-point of a sub-range is selected to represent the average milage of the sub-range (e.g, 5 miles for 0-10 miles, 15 miles for 11-20 miles, and so on). The mid-point mileage for a sub-range is used in the above formula to calculate the DOD for the sub-range mileage. Furthermore, the mid-point mileage is adjusted to reflect seasonal variation in daily mileage. Based on Mullen (1994), the following seasonal VMT adjustment factors have been determined: 1 for the whole year, 1.019 for the spring, 1.084 for the summer, 0.992 for the fall, and 0.905 for the winter.

Vehicle distribution for a sub-range mileage was obtained from the NPTS. The distribution for the sub-range is then treated as the distribution of the DOD calculated with the mid-point value of the sub-range.

Per-Mile Electricity Consumption

For the purpose of calculating battery DOD, EV electricity consumption in Kwh/mile here is measured from batteries rather than from wall outlets. EV electricity consumption is estimated with the EAGLES--a computer model developed in Argonne National Laboratory--for each vehicle type, in each of the four cities, and for each of the four seasons. Estimated EV electricity consumption is presented in a separate memorandum.

Battery Capacity

Battery capacity is calculated from battery weight for a particular EV type and specific energy of a particular battery type. Battery weight is estimated with EAGLES for meeting a driving range with given battery characteristics, and presented in a separate memorandum. Battery specific energy is assumed in another separate memorandum.

It has been found that ambient temperature has a significant impact on the capacity of lead-acid batteries (see Keller and Whitehead, 1991). As ambient temperature decreases, the capacity of lead-acid batteries decreases. In calculating the DOD of lead-acid batteries, the following equation is used to estimate relative capacity of lead-acid batteries:

$$\text{Capacity} = (27990 + 438.7 \times \text{Temp} - 3.53 \times \text{Temp}^2)/32713$$

This equation is developed here from data presented by Keller and Whitehead (1991). The capacity here is calculated relative to the capacity at ambient temperature of 16.2 °C--the annual average temperature of the four cities which are involved in the EVTECA. Temperature here is ambient temperature in °C.

Calculated distribution of EV battery DOD is presented in the appendix.

Table B.5.3 Distribution of EV Recharge Starting Time

Time Period (pm)	Chicago		Houston		Los Angeles		Washington, D.C.	
	Pre-2003	Post-2002	Pre-2003	Post-2002	Pre-2003	Post-2002	Pre-2003	Post-2002
3:00-3:59	0.111	0.109	0.088	0.085	0.088	0.084	0.033	0.032
4:00-4:59	0.141	0.141	0.113	0.108	0.132	0.127	0.118	0.113
5:00-5:59	0.188	0.198	0.132	0.132	0.170	0.166	0.194	0.186
6:00-6:59	0.102	0.100	0.152	0.168	0.164	0.162	0.156	0.152
7:00-7:59	0.100	0.098	0.189	0.186	0.134	0.144	0.124	0.119
8:00-8:59	0.079	0.078	0.138	0.137	0.092	0.090	0.131	0.125
9:00-9:59	0.120	0.119	0.072	0.073	0.097	0.096	0.114	0.116
10:00-10:59	0.094	0.092	0.071	0.068	0.076	0.078	0.083	0.096
11:00-11:59	0.066	0.065	0.045	0.043	0.048	0.053	0.047	0.060
3:00-11:59	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000

B.5.5 Remaining Issues

Opportunity Charging and Quick Charging

Various options will be available for opportunity and quick charging to meet longer, unexpected trips (for various options, see Moore, 1993). Use of opportunity charging will depend on travel patterns and availability of recharging facilities out of homes. It is difficult to determine pattern of opportunity charging. Quick charging requires quick charging infrastructure, which could be expensive. In the EVTECA, both opportunity and quick charging are excluded.

Electric Utilities' Ability to Affect EV Recharging Patterns

The discussion in this memorandum is based primarily on the presumption that EV recharge patterns will be determined by the convenience to EV users. EV recharge patterns, especially composite utility recharge profiles, can be certainly affected by utility companies who may prefer a flat EV electricity demand curve for efficient use of their available electric capacity. In order to create a relatively flat EV electricity demand curve, utilities can provide some incentives through certain electricity pricing mechanism to influence EV recharge patterns. Technologically speaking, utilities will be able to communicate with EV users and to direct charging profiles with some smart charge systems. Thus, after all, it may not be unreasonable to assume a flat composite utility recharge profile for a given utility system.

Deep Discharge

Some battery types have the ability to remember the previous state of DOD. Such battery types include nickel-based batteries. For these battery types, deep discharge once in a while is necessary for maintaining their capacity. Deep discharge is not necessary for Pb-acid and Na-S batteries. Current Ni-Cd and Ni-MH batteries usually need to be discharged to 100% of DOD once in a while. However, recent advances in nickel-based batteries make deep discharge unnecessary. Thus, in the EVTECA, deep discharge is not assumed.

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B.6 Estimation of Conventional Vehicle Emissions [1]

B.6.1 Introduction

Emissions of baseline conventional vehicles (CVs) need to be estimated for the purpose of comparing emissions between EVs and CVs. Since the EVTECA includes model years between 1998 and 2010, and since the EVTECA analyzes EV emission and energy impacts in 2000 and 2010, emissions of 1998-2010 model-year CVs are estimated in each of the two target years. This memorandum presents procedures, assumptions, and results of CV emission estimation.

CV emissions are estimated for each of the several air pollutants--volatile organic gases (VOC), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), carbon dioxide (CO_2), particulate matter (PM) and methane (CH_4). The following sections present emission estimation for each of the pollutants.

B.6.2 Estimation of VOC, CO, and NO_x Emissions

EPA's Mobile5a is used here to estimate emissions of these three pollutants. Mobile5a has been developed by the EPA to estimate vehicle emission rates in grams per mile in all states except California. In California, EMFAC7G, which has been developed by California Air Resources Board, is used to estimate vehicle emission rates there. Since Mobile5a can generate model-year-specific emission rates which are needed for the EVTECA analysis, Mobile5a is used to generate vehicle emission rates for each of the four cities (Chicago, Houston, Los Angeles, and Washington, D.C.).

Mobile5a requires specifications of input parameters of emission standards, motor fuel requirements, use of certain given emission control technologies, vehicle operation patterns, and ambient temperature. Major input parameters and their values and specifications are presented below.

Vehicle Emission Standards

The 1990 Clean Air Act Amendments establish Tier 1 and Tier 2 emission standards for light-duty vehicles. Tier 1 standards take into effect in 1994. Mobile5a includes Tier 1 emission standards. Adoption of Tier 2 standards will depend on the need for further motor vehicle emission reductions, which will be determined by the EPA in the later 1990s. Since the outcome of adopting Tier 2 standards is not certain, it is decided here that Tier 2 standards are not included in Mobile5a runs for Chicago, Houston, and Washington, D.C.

On the other hand, in California, the California Air Resources Board has adopted a low-emission vehicle (LEV) program which establishes stringent emission standards for light-duty vehicles to be sold in California. For same model year vehicles, LEV standards are more stringent than Tier 1 or Tier 2 standards. Mobile5a has an option of including the LEV program. The LEV program is included in Mobile5a runs for Los Angeles.

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[1] This section was prepared by Michael Wang, Argonne National Laboratory, in August 1994. It was modified in December 1996 to include the discussion of methane.

Federal and California Reformulated Gasoline (RFG) Requirements

The EPA has adopted requirements of producing RFG which has low emission characteristics. In California, the California Air Resources Board has adopted its own RFG requirements. California's RFG requirements are more stringent than EPA's RFG requirements.

Nationwide, the EPA has established Phase 1 and Phase 2 RFG requirements. Phase 1 requirements take into effect beginning in January 1, 1995, and Phase 2 requirements in January 1, 2000. To estimate vehicle emissions in the two target years--2000 and 2010, federal Phase 2 RFG requirements are included in Mobile5a runs for Chicago, Houston, and Washington, D.C.

The California Air Resources Board has established California Phase 1 and Phase 2 RFG requirements. The California Phase 1 RFG requirements have taken into effect in 1992, and the Phase 2 requirements will take into effect in 1996. To estimate vehicle emissions in Los Angeles, the California Phase 2 requirements should be included in Mobile5a runs. However, Mobile5a does not have an option of taking California's RFG requirements. Thus, federal Phase 2 RFG requirements are included in Mobile5a runs for Los Angeles.

Stage II and On-Board Vehicle Refueling Emission Control Systems

Emissions that occur in gasoline service stations during vehicle refueling can be controlled by the stage II technology or the on-board technology. The stage II technology engages a gasoline vapor recovery system installed on a gasoline pump nozzle. During vehicle refueling, the system returns gasoline vapor accumulated in vehicle tanks back into under-ground storage tanks. The on-board control technology engages a canister system installed on a vehicle. During vehicle refueling, the on-board system takes the gasoline vapor accumulated in a vehicle gas tank to the canister. As the engine is started, the vapor stored in the canister is taken into the engine. Among the four cities, Los Angles and Washington, D.C. have already implemented the stage II technology; and Chicago and Houston will implement the technology in November of 1994 (Passavent, 1994). Thus, the stage II technology is included in Mobile5a run for the four cities.

Recently, EPA adopts a requirement of installing the on-board technology on future new vehicles (JAWMA, 1994). According to the EPA's requirement, the on-board technology will be phased-in between 1998 to 2000 model years for passenger cars, and between 2000 to 2003 model years for light trucks. The on-board technology is included in Mobile5a runs.

Both the stage II and on-board technology are included in Mobile5a, and vehicle refueling emissions are double-controlled. In practice, this is reasonable because even after the on-board technology is installed on vehicles, it is unlikely that states and local air quality control agencies will withdraw the stage II technology requirement, and it is very unlikely that gasoline service station operators will take the stage II system out of the stations since the vapor recovered by the system contributes to fuel savings in stations.

Driving Cycles

Two driving cycles have been selected in the EVTECA--the LA-92 cycle for cars and the federal urban driving schedule (FUDS) for vans. Mobile5a uses speed correction factors to simulate emissions under different driving cycles. The LA-92 has been developed very recently, and LA-92 emission test results have not been used in developing mobile5a's speed correction factors. Speed correction factors currently incorporated in Mobile5a may not represent emission characteristics of the LA-92. In fact, Mobile5a simulation shows decreases in emissions from the FUDS to the LA-92, while real world emissions are actually increased from the FUDS to the LA-92. Because of the concern of Mobile5a's inability of handling the LA-92, vehicle emissions under the LA-92 are estimated outside of Mobile5a. Specifically, FUDS emissions are estimated with Mobile5a first. And then, FUDS emissions are adjusted to LA-92 emissions, using emission differences between the FUDS and the LA-92.

Recent emission tests by the California Air Resources Board show that from the FUDS to the LA-92, emissions are increased by 12.5% for VOC, by 50% for CO, and by 31.4% for NO_x (Gammariello and Long, 1993). These emission differences are used to adjust Mobile5a-estimated FUDS emissions to LA-92 emissions.

Enhanced Inspection/Maintenance (I/M) Program

The EPA has adopted an enhanced I/M program for vehicle emission inspection (U.S. EPA, 1992). The enhanced program, known as the IM240 program, requires that vehicles be inspected and tested every two years. Vehicles are driven for 240 seconds on dynamometers during emission tests, as opposite to the current I/M program under which vehicles are tested at idling. The enhanced program will take into effect beginning in 1995 in 83 cities with the worst air quality (Automotive News, 1994). All four cities included in the EVTECA are among the covered cities. Thus, the enhanced I/M program is included in Mobile5a runs for the four cities.

Effect of Using Air Conditioning (A/C) Systems

Use of vehicle A/C systems increases vehicle emissions because of the extra load added to engines by A/C systems. Use of A/C systems is included in Mobile5a runs of estimating summertime vehicle emissions. In determining the intensity of A/C usage in each of the four cities, data of ambient temperature and humidity were collected and fed in Mobile5a.

Simulation

With the above input parameters, Mobile5a is run to generate vehicle emissions. Emissions are estimated for passenger cars and light-duty trucks, for each of the four seasons, in each of the four cities, by model year, and in the two target years. Estimated emissions of VOC include exhaust, diurnal evaporative, hot soak evaporative, refueling, running loss, and resting loss emissions.

B.6.3 Estimation of CO_2 Emissions

Vehicle CO_2 emissions are estimated by assuming that all carbon contained in gasoline is converted into CO_2 and CO emissions. A small amount of carbon is converted into VOC emissions, and this amount is ignored. Specifically, the following formula is used to calculate CO_2 emissions:

$$CO_2 = (2749 \times 83.3\% \div MPG - CO \times 12 \div 28) \times 44 \div 12$$

Where:

CO_2	CO_2 emissions in grams per mile
2749	RFG density in grams per gallon (from DeLucchi, 1993)
83.3%	carbon content of RFG (DeLucchi, 1993)
MPG	Vehicle fuel economy in miles per gallon (estimated in a separate memorandum)

CO	CO emissions in grams per mile (estimated with Mobile5a)
12	molecular weight of carbon
28	molecular weight of CO
44	molecular weight of CO_2

B.6.4 Estimation of SO_x Emissions

Vehicle SO_x emissions are estimated by assuming all sulfur contained in gasoline is converted into SO_2. Specifically, the following formula is used to calculate SO_2 emissions:

$$SO_2 = 2749 \times S\% \times 64 \div 32 \div MPG$$

Where:

SO_2	SO_2 emissions in grams per mile
2749	RFG density in grams per gallon (from DeLucchi, 1993)
S%	sulfur content of RFG (assuming 40 ppm for Los Angeles and 170 ppm for Chicago, Houston, and Washington, D.C.)
64	molecular weight of SO_2
32	molecular weight of sulfur

B.6.5 PM Emissions

Two types of PM emissions are related to vehicle operations--tirewear and exhaust emissions. Both EVs and GVs produce tirewear emissions. Since EVs are usually heavier than comparable CVs, EVs may produce higher grams-per-mile PM emissions than comparable CVs. However, there are no quantitative data on the difference of tirewere PM emissions between EVs and CVs. EV and GV tirewear PM emissions are treated same here, thus, tirewear PM emissions become irrelevant for estimating EV emission reductions. Estimates of exhaust PM emissions for gasoline vehicles are rarely available. An EPA report presents 0.017 grams-per-mile exhaust emissions of organic component PM and 0.001 of sulfate component PM for gasoline light-duty vehicles (U.S. EPA, 1985). Total exhaust PM emissions of 0.018 grams per mile are assumed here for all model-year light-duty vehicles.

B.6.6 CH_4 Emissions

Methane emissions from CVs were estimated using a CHG and criteria pollutant model developed by M. Wang, ANL (see reference list). MOBILE5a calculates both total HC emissions and nonmethane HC emissions for each vehicle. The difference between the two is total CH_4 emissions. Because CH_4 emissions from CV operation are generally considered unimportant, we did not calculate this delta for each CV in the EVTECA.

Instead we assumed that the CH_4 emissions estimated for a model year 2000 CV operating in 2005, as estimated in Wang's model from MOBILE5a estimates, were appropriate for all CVs included in the EVTECA. Wang's estimate is that CH_4 emissions are equal to 7.3% of total VOC emissions. We applied this percentage estimate to the VOC emission totals generated for each CV as discussed above in Sec. B.6.2. Note that the CH_4 emissions are not part of the VOC emissions; heir total is simply equal to 7.3% of the VOC emissions.

B.6.7 Results

With the above estimation procedures and assumptions, grams-per-mile emissions are estimated for model-year 1998-2010 passenger cars and light-duty trucks, in 2000 and 2010, for each of the four seasons, and in each of the four cities. The estimated vehicle emission results are presented in Appendix B.7.

B.6.8 References for Appenidx B.6

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B.7 Estimated Emission Rates for Conventional Vehicles

Table B.7.1 provides emission rates (in grams per mile) for conventional vehicles for the four metropolitan areas in the EVTECA. Emission rates for all four metropolitan areas of VOC, CO, and NOx are presented first in Section (1) of the tables. Section (2) provides particular matter emission rates. Section (3) provides SO_2 rates. And Section (4) provides CO_2 rates. Emission rates vary by metropolitan area model year (MY), projection year (2000 versus 2010), type of vehicle (cars versus vans), and season.

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles

1) Emissions of VOC, CO, and NOx:

1.1) Chicago:

1.1.1) Target Year 2000:

	Spring:			Summer:			Fall:			Winter:		
MY	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx
Household and Fleet Cars:												
1998	0.561	7.245	0.498	0.532	4.212	0.436	0.581	6.753	0.485	0.577	10.374	0.570
1999	0.504	6.527	0.392	0.470	3.675	0.344	0.521	6.042	0.381	0.526	9.480	0.448
2000	0.455	6.048	0.323	0.422	3.325	0.284	0.472	5.568	0.314	0.477	8.877	0.369
Fleet Vans:												
1998	0.555	6.572	0.521	0.507	3.212	0.387	0.561	5.956	0.505	0.634	10.136	0.604
1999	0.501	5.983	0.404	0.451	2.783	0.351	0.507	5.377	0.393	0.578	9.381	0.469
2000	0.445	5.588	0.328	0.396	2.501	0.285	0.451	4.989	0.319	0.523	8.867	0.380

1.1.2) Target Year 2010:

	Spring:			Summer:			Fall:			Winter:		
MY	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx
Household and Fleet Cars:												
1998	1.234	11.075	1.079	1.387	7.064	0.943	1.367	10.545	1.050	0.819	15.157	1.238
1999	1.176	11.067	1.079	1.281	7.062	0.943	1.292	10.539	1.050	0.823	15.143	1.238
2000	1.105	11.058	1.079	1.182	7.061	0.943	1.206	10.529	1.050	0.811	15.123	1.238
2001	1.050	11.045	1.079	1.105	7.059	0.943	1.138	10.518	1.050	0.816	15.099	1.236
2002	0.975	10.715	1.025	1.008	6.809	0.897	1.049	10.191	0.997	0.792	14.693	1.176
2003	0.888	10.243	0.949	0.902	6.449	0.830	0.949	9.722	0.924	0.755	14.114	1.088
2004	0.797	9.737	0.869	0.791	6.065	0.761	0.844	9.219	0.845	0.720	13.487	0.996
2005	0.706	9.185	0.783	0.676	5.654	0.686	0.737	8.672	0.762	0.687	12.797	0.897
2006	0.612	8.541	0.692	0.555	5.197	0.607	0.626	8.037	0.674	0.662	11.969	0.794
2007	0.570	7.914	0.598	0.520	4.719	0.524	0.585	7.416	0.582	0.612	11.199	0.685

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

2008	0.526	7.245	0.498	0.484	4.212	0.436	0.543	6.753	0.485	0.560	10.374	0.570
2009	0.483	6.527	0.392	0.445	3.675	0.344	0.499	6.042	0.381	0.509	9.480	0.448
2010	0.455	6.048	0.323	0.422	3.325	0.284	0.472	5.568	0.314	0.477	8.877	0.369
Fleet Vans:												
1998	1.286	10.062	1.262	1.394	5.792	1.090	1.396	9.401	1.225	0.955	14.581	1.470
1999	1.229	10.055	1.262	1.292	5.791	1.089	1.327	9.395	1.224	0.959	14.568	1.470
2000	1.150	9.920	1.233	1.191	5.691	1.064	1.236	9.262	1.196	0.932	14.397	1.436
2001	1.070	9.604	1.162	1.093	5.452	1.003	1.143	8.949	1.127	0.895	14.001	1.353
2002	0.930	9.271	1.087	0.992	5.198	0.938	1.048	8.619	1.054	0.857	13.583	1.265
2003	0.898	8.911	1.006	0.889	4.927	0.869	0.948	8.263	0.976	0.817	13.131	1.171
2004	0.809	8.520	0.921	0.782	4.635	0.796	0.845	7.877	0.894	0.777	12.638	1.071
2005	0.715	8.093	0.830	0.669	4.321	0.717	0.740	7.456	0.805	0.739	12.091	0.990
2006	0.621	7.615	0.733	0.553	3.982	0.634	0.628	6.985	0.711	0.710	11.465	0.852
2007	0.566	7.115	0.630	0.496	3.614	0.545	0.573	6.492	0.612	0.667	10.826	0.732
2008	0.521	6.572	0.521	0.459	3.212	0.451	0.524	5.956	0.505	0.612	10.136	0.604
2009	0.474	5.983	0.404	0.419	2.783	0.351	0.479	5.377	0.393	0.556	9.381	0.469
2010	0.445	5.588	0.328	0.396	2.501	0.285	0.451	4.989	0.319	0.523	8.867	0.380

1.2) Houston:

1.2.1) Target Year 2000:

	Spring:			Summer:			Fall:			Winter:		
MY	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx
Household and Fleet Cars:												
1998	0.659	5.055	0.445	0.537	3.980	0.434	0.609	4.587	0.440	0.645	6.988	0.485
1999	0.586	4.392	0.351	0.469	3.482	0.342	0.539	3.987	0.346	0.579	6.233	0.382
2000	0.533	5.454	0.289	0.424	3.158	0.281	0.490	3.593	0.285	0.527	5.727	0.315
Fleet Vans:												
1998	0.614	3.908	0.460	0.500	3.034	0.366	0.575	3.499	0.454	0.605	6.127	0.506
1999	0.550	3.378	0.357	0.444	2.635	0.338	0.512	3.019	0.353	0.548	5.511	0.393
2000	0.490	3.025	0.291	0.390	2.375	0.283	0.455	2.702	0.287	0.489	5.097	0.319

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

1.2.2) Target Year 2010:

	Spring:			Summer:			Fall:			Winter:		
MY	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx
Household and Fleet Cars:												
1998	1.793	8.594	0.962	1.363	6.627	0.940	1.642	7.784	0.950	1.562	11.028	1.053
1999	1.652	8.589	0.962	1.243	6.627	0.940	1.512	7.781	0.950	1.471	11.019	1.051
2000	1.523	8.583	0.962	1.148	6.627	0.940	1.393	7.778	0.950	1.369	11.009	1.051
2001	1.417	8.576	0.962	1.073	6.627	0.940	1.297	7.773	0.950	1.290	10.995	1.051
2002	1.288	8.267	0.915	0.981	6.393	0.894	1.179	7.494	0.903	1.183	10.647	1.000
2003	1.145	7.826	0.846	0.769	6.059	0.827	1.050	7.092	0.837	1.068	10.149	0.925
2004	0.998	7.352	0.775	0.775	5.700	0.757	0.917	6.663	0.766	0.942	9.614	0.846
2005	0.845	6.841	0.699	0.667	5.320	0.683	0.779	6.203	0.691	0.818	9.030	0.763
2006	0.682	6.260	0.619	0.551	4.899	0.604	0.633	5.684	0.611	0.686	8.351	0.675
2007	0.643	5.676	0.535	0.518	4.452	0.522	0.595	5.151	0.528	0.644	7.692	0.583
2008	0.601	5.055	0.445	0.482	3.980	0.434	0.555	4.587	0.440	0.600	6.988	0.485
2009	0.560	4.392	0.351	0.444	3.482	0.342	0.513	3.987	0.346	0.555	6.233	0.382
2010	0.533	3.954	0.289	0.424	3.158	0.281	0.490	3.593	0.285	0.527	5.727	0.315
Fleet Vans:												
1998	1.781	7.095	1.112	1.360	5.434	1.085	1.637	6.384	1.097	1.573	9.792	1.227
1999	1.650	7.091	1.112	1.248	5.434	1.085	1.516	6.382	1.097	1.491	9.785	1.227
2000	1.521	6.969	1.086	1.151	5.341	1.060	1.396	6.270	1.072	1.385	9.644	1.198
2001	1.393	6.676	1.023	1.058	5.117	0.999	1.278	6.004	1.010	1.279	9.312	1.129
2002	1.260	6.367	0.957	0.960	4.881	0.934	1.158	5.723	0.945	1.168	8.961	1.056
2003	1.123	6.034	0.887	0.863	4.627	0.866	1.034	5.420	0.875	1.053	8.583	0.978
2004	0.979	5.675	0.812	0.760	4.355	0.792	0.903	5.095	0.801	0.931	8.172	0.895
2005	0.831	5.286	0.732	0.653	4.064	0.714	0.769	4.742	0.722	0.807	7.723	0.807
2006	0.674	4.857	0.647	0.539	3.750	0.631	0.628	4.358	0.638	0.675	7.220	0.713
2007	0.603	4.402	0.556	0.486	3.409	0.543	0.561	3.947	0.549	0.610	6.695	0.613
2008	0.561	3.908	0.460	0.452	3.034	0.449	0.523	3.499	0.454	0.566	6.127	0.506
2009	0.517	3.378	0.357	0.413	2.635	0.348	0.480	3.019	0.353	0.518	5.511	0.393
2010	0.490	3.025	0.291	0.390	2.375	0.283	0.462	2.702	0.287	0.489	5.097	0.319

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

1.3) Los Angeles:

1.3.1) Target Year 2000:

	Spring:			Summer:			Fall:			Winter:		
MY	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx
Household and Fleet Cars:												
1998	0.458	4.479	0.390	0.373	3.199	0.364	0.437	3.485	0.373	0.439	4.847	0.398
1999	0.355	3.092	0.215	0.281	2.024	0.202	0.341	2.249	0.208	0.335	3.445	0.221
2000	0.289	1.896	0.143	0.221	0.996	0.134	0.278	1.176	0.137	0.268	2.238	0.146
Fleet Vans:												
1998	0.443	3.859	0.403	0.361	2.488	0.375	0.420	2.777	0.384	0.429	4.310	0.413
1999	0.348	2.763	0.235	0.276	1.567	0.219	0.332	1.808	0.224	0.333	3.199	0.241
2000	0.273	1.820	0.159	0.213	0.762	0.148	0.263	0.964	0.151	0.258	2.244	0.162

1.3.2) Target Year 2010:

	Spring:			Summer:			Fall:			Winter:		
MY	T-VOC	CO	NOx	T-VOC	CO	NOx	T-VOC	CO	NOx	T-VOC	CO	NOx
Household and Fleet Cars:												
1998	1.213	9.104	0.844	0.918	7.008	0.787	1.174	7.526	0.807	1.104	9.536	0.863
1999	1.007	9.405	0.595	0.756	7.265	0.556	0.989	7.794	0.569	0.924	9.842	0.608
2000	0.850	9.681	0.478	0.625	7.500	0.447	0.835	8.042	0.459	0.773	10.119	0.490
2001	0.755	9.378	0.464	0.558	7.271	0.434	0.738	7.794	0.444	0.688	9.803	0.474
2002	0.675	8.859	0.442	0.500	6.840	0.413	0.659	7.338	0.422	0.618	9.276	0.452
2003	0.557	7.688	0.386	0.417	5.894	0.361	0.544	6.331	0.371	0.513	8.075	0.396
2004	0.479	6.936	0.353	0.362	5.270	0.331	0.465	5.672	0.339	0.442	7.313	0.363
2005	0.397	6.134	0.319	0.304	4.607	0.298	0.384	4.968	0.306	0.369	6.500	0.327
2006	0.311	5.255	0.283	0.245	3.886	0.264	0.297	4.205	0.271	0.293	5.607	0.289
2007	0.298	4.349	0.243	0.232	3.125	0.227	0.286	3.400	0.234	0.277	4.691	0.250
2008	0.282	3.393	0.202	0.219	2.319	0.189	0.271	2.553	0.194	0.264	3.725	0.208
2009	0.267	2.388	0.159	0.206	1.467	0.150	0.258	1.658	0.152	0.250	2.709	0.163
2010	0.259	1.742	0.131	0.200	0.915	0.124	0.252	1.077	0.126	0.242	2.055	0.134

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

Fleet Vans:												
1998	1.218	8.148	0.973	0.938	6.013	0.903	1.183	6.515	0.927	1.131	8.669	0.998
1999	1.025	8.518	0.730	0.773	6.323	0.678	1.000	6.842	0.696	0.947	9.044	0.749
2000	0.864	8.644	0.591	0.632	6.431	0.549	0.845	6.956	0.563	0.793	9.173	0.606
2001	0.772	7.998	0.551	0.611	5.909	0.512	0.752	6.400	0.525	0.708	8.509	0.565
2002	0.688	7.455	0.515	0.510	5.459	0.478	0.669	5.924	0.491	0.635	7.958	0.528
2003	0.583	6.690	0.467	0.436	4.848	0.434	0.567	5.273	0.445	0.539	7.170	0.479
2004	0.502	6.080	0.428	0.377	4.344	0.398	0.485	4.740	0.408	0.467	6.551	0.439
2005	0.417	5.424	0.386	0.318	3.804	0.359	0.401	4.167	0.368	0.390	5.884	0.395
2006	0.330	4.714	0.341	0.257	3.224	0.317	0.314	3.551	0.325	0.314	5.162	0.349
2007	0.296	3.960	0.293	0.233	2.598	0.273	0.282	2.889	0.280	0.282	4.396	0.301
2008	0.281	3.151	0.243	0.220	1.921	0.226	0.268	2.175	0.231	0.266	3.575	0.249
2009	0.264	2.295	0.189	0.205	1.201	0.176	0.254	1.417	0.180	0.251	2.706	0.193
2010	0.256	1.741	0.153	0.195	0.731	0.143	0.247	0.923	0.147	0.240	2.145	0.157

1.4) Washington, DC:

1.4.1) Target Year 2000:

	Spring:			Summer:			Fall:			Winter:		
MY	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx
Household and Fleet Cars:												
1998	0.592	6.449	0.477	0.472	3.980	0.431	0.565	5.819	0.465	0.504	8.229	0.531
1999	0.532	5.744	0.376	0.413	3.482	0.340	0.504	5.165	0.367	0.456	7.494	0.418
2000	0.483	5.274	0.309	0.370	3.158	0.280	0.457	4.733	0.302	0.409	7.002	0.344
Fleet Vans:												
1998	0.568	5.579	0.496	0.448	3.034	0.446	0.543	4.921	0.484	0.528	7.825	0.559
1999	0.512	5.006	0.386	0.397	2.635	0.338	0.487	4.393	0.376	0.481	7.214	0.434
2000	0.456	4.623	0.313	0.345	2.375	0.282	0.431	4.041	0.306	0.427	6.801	0.352

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

1.4.2) Target Year 2010:

	Spring:			Summer:			Fall:			Winter:		
MY	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx	VOC	CO	NOx
Household and Fleet Cars:												
1998	1.444	10.214	1.033	1.141	6.627	0.933	1.401	9.302	1.008	0.894	12.100	1.151
1999	1.359	10.206	1.033	1.056	6.627	0.933	1.313	9.296	1.008	0.871	12.090	1.151
2000	1.266	10.199	1.033	0.980	6.627	0.933	1.221	9.290	1.008	0.833	12.078	1.151
2001	1.193	10.187	1.033	0.923	6.627	0.933	1.148	9.282	1.008	0.813	12.063	1.151
2002	1.095	9.861	0.982	0.848	6.393	0.887	1.053	8.979	0.958	0.860	11.737	1.095
2003	0.985	9.396	0.908	0.765	6.059	0.821	0.946	8.546	0.887	0.717	11.271	1.013
2004	0.873	8.895	0.832	0.678	5.700	0.752	0.836	8.082	0.812	0.665	10.767	0.926
2005	0.755	8.352	0.750	0.589	5.320	0.678	0.720	7.579	0.732	0.613	10.215	0.836
2006	0.634	7.725	0.664	0.531	4.899	0.600	0.603	7.005	0.648	0.567	9.549	0.740
2007	0.594	7.107	0.573	0.553	4.452	0.518	0.565	6.429	0.560	0.525	8.910	0.639
2008	0.551	6.449	0.477	0.462	3.980	0.431	0.523	5.819	0.465	0.482	8.229	0.531
2009	0.509	5.744	0.376	0.390	3.482	0.340	0.481	5.165	0.367	0.436	7.494	0.418
2010	0.483	5.274	0.309	0.370	3.158	0.280	0.457	4.733	0.302	0.409	7.002	0.344
Fleet Vans:												
1998	1.466	8.991	1.202	1.152	5.434	1.077	1.419	8.074	1.171	0.986	11.330	1.358
1999	1.386	8.986	1.202	1.072	5.434	1.077	1.337	8.070	1.171	0.964	11.322	1.357
2000	1.289	8.854	1.174	0.991	5.341	1.052	1.240	7.949	1.144	0.915	11.188	1.326
2001	1.191	8.544	1.107	0.914	5.117	0.991	1.145	7.661	1.078	0.862	10.876	1.249
2002	1.088	8.216	1.035	0.834	4.881	0.927	1.045	7.356	1.008	0.808	10.547	1.168
2003	0.981	7.862	0.959	0.752	4.627	0.859	0.941	7.028	0.934	0.754	10.194	1.082
2004	0.870	7.480	0.877	0.668	4.355	0.786	0.831	6.674	0.855	0.698	9.807	0.990
2005	0.797	7.062	0.791	0.580	4.064	0.709	0.719	6.288	0.770	0.645	9.380	0.892
2006	0.634	6.597	0.699	0.487	3.750	0.627	0.601	5.863	0.681	0.591	8.895	0.787
2007	0.572	6.109	0.601	0.438	3.409	0.539	0.541	5.412	0.585	0.548	8.387	0.677
2008	0.529	5.579	0.496	0.405	3.043	0.446	0.502	4.921	0.484	0.503	7.825	0.559
2009	0.483	5.006	0.386	0.368	2.635	0.347	0.458	4.393	0.376	0.457	7.214	0.434
2010	0.456	4.623	0.313	0.345	2.375	0.282	0.431	4.041	0.306	0.427	6.801	0.352

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

2) Particulate Matter Emissions:

0.017	Organic component of total PM
0.001	Sulfate component of total PM
0.018	Total PM

3) SO2 emissions:

3.1) Pre-2003 Model Years:

		Chicago:				Houston:				Los Angeles:				Washington,DC:			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
HH	2-Seater	0.028	0.030	0.028	0.030	0.028	0.031	0.028	0.030	0.007	0.007	0.007	0.007	0.028	0.031	0.028	0.030
	Compact	0.034	0.040	0.034	0.038	0.034	0.041	0.034	0.037	0.008	0.009	0.008	0.009	0.034	0.041	0.034	0.037
Fleet	Compact	0.034	0.040	0.034	0.038	0.034	0.041	0.034	0.037	0.008	0.009	0.008	0.009	0.034	0.041	0.034	0.037
	Mi-MiniVan	0.033	0.041	0.033	0.038	0.033	0.043	0.033	0.036	0.008	0.010	0.008	0.008	0.033	0.042	0.033	0.037
	MiniVan	0.043	0.054	0.043	0.050	0.043	0.056	0.043	0.047	0.010	0.013	0.010	0.011	0.043	0.055	0.043	0.048
	Full-Size Van	0.068	0.087	0.068	0.078	0.068	0.090	0.068	0.074	0.016	0.020	0.016	0.017	0.068	0.088	0.068	0.075

3.2) Model Years 2003-2007:

		Chicago:				Houston:				Los Angeles:				Washington,DC:			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
HH	Mini Compact	0.028	0.032	0.028	0.031	0.028	0.033	0.028	0.030	0.007	0.008	0.007	0.007	0.028	0.032	0.028	0.030
	Compact	0.034	0.040	0.034	0.038	0.034	0.041	0.034	0.037	0.008	0.009	0.008	0.009	0.034	0.041	0.034	0.037
Fleet	Compact	0.034	0.040	0.034	0.038	0.034	0.041	0.034	0.037	0.008	0.009	0.008	0.009	0.034	0.041	0.034	0.037
	MiniVan	0.043	0.054	0.043	0.050	0.043	0.056	0.043	0.047	0.010	0.013	0.010	0.011	0.043	0.055	0.043	0.048
	Full-Size Van	0.068	0.087	0.068	0.078	0.068	0.090	0.068	0.074	0.016	0.020	0.016	0.017	0.068	0.088	0.068	0.075

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

3.3) Model Years 2008-2010:

		Chicago:				Houston:				Los Angeles:				Washington, DC:			
		Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
HH	Mini Compact	0.026	0.030	0.026	0.028	0.026	0.031	0.026	0.028	0.006	0.007	0.006	0.006	0.026	0.030	0.026	0.028
	Compact	0.032	0.038	0.032	0.036	0.032	0.039	0.032	0.035	0.008	0.009	0.008	0.008	0.032	0.038	0.032	0.035
Fleet	Compact	0.032	0.038	0.032	0.036	0.032	0.039	0.032	0.035	0.008	0.009	0.008	0.008	0.032	0.038	0.032	0.035
	MiniVan	0.040	0.052	0.040	0.047	0.040	0.054	0.040	0.044	0.009	0.012	0.009	0.010	0.040	0.053	0.040	0.045
	Full-Size Van	0.063	0.081	0.063	0.074	0.063	0.084	0.063	0.069	0.015	0.019	0.015	0.016	0.063	0.082	0.063	0.071

4) CO2 Emissions:

4.1) Target Year 2000:

	Chicago:				Houston:				Los Angeles:				Washington, DC:			
MY	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter
HH 2-Seater:																
1998	235.9	265.4	236.8	251.6	239.9	269.4	240.7	252.8	240.9	267.4	242.8	256.3	237.3	267.3	238.5	252.1
1999	237.2	266.4	238.1	253.3	241.1	270.3	241.8	254.2	243.5	269.5	245.0	258.9	238.6	268.2	239.7	253.4
2000	238.1	267.0	238.9	254.4	239.2	270.9	242.6	255.1	245.7	271.4	247.0	261.1	239.5	268.8	240.5	254.3
HH and Fleet Compact:																
1998	296.5	352.9	297.4	322.9	300.6	361.4	301.4	319.6	301.6	355.0	303.4	322.7	298.0	356.6	299.2	320.2
1999	297.9	353.9	298.8	324.5	301.8	362.3	302.5	321.0	304.2	357.1	305.7	325.3	299.3	357.5	300.4	321.6
2000	298.7	354.5	299.6	325.6	299.8	362.9	303.2	321.9	306.4	359.0	307.7	327.5	300.2	358.1	301.2	322.5
Fleet Mini-Minivan:																
1998	284.6	364.5	285.8	324.0	289.5	377.5	290.3	312.8	289.6	366.1	291.6	314.6	286.5	369.9	287.7	315.2
1999	285.7	365.3	286.8	325.4	290.5	378.2	291.2	314.0	291.6	367.8	293.4	316.6	287.5	370.7	288.6	316.3
2000	286.4	365.8	287.5	326.3	291.1	378.7	291.7	314.7	293.4	369.3	294.9	318.4	288.2	371.1	289.3	317.1
Fleet Minivan:																
1998	373.1	481.7	374.2	429.7	378.0	500.0	378.7	410.7	378.1	483.5	380.1	411.9	374.9	489.3	376.1	415.4
1999	374.2	482.5	375.3	431.1	379.0	500.7	379.6	411.9	380.1	485.2	381.8	413.9	376.0	490.0	377.1	416.6
2000	374.9	483.0	376.0	432.1	379.6	501.2	380.2	412.6	381.8	486.7	383.4	415.7	376.7	490.5	377.7	417.3
Fleet Full-Size Van:																
1998	596.4	775.4	597.5	685.7	601.3	806.5	602.0	653.9	601.4	777.5	603.3	654.0	598.2	788.2	599.4	662.5
1999	597.5	776.2	598.6	687.1	602.2	807.3	602.9	655.1	603.4	779.2	605.1	656.0	599.3	788.9	600.4	663.6
2000	598.2	776.7	599.3	688.1	602.9	807.7	603.5	655.8	605.1	780.7	606.7	657.8	600.0	789.4	601.0	664.3

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

4.2) Target Year 2010:

MY	Chicago: Spring	Summer	Fall	Winter	Houston: Spring	Summer	Fall	Winter	Los Angeles: Spring	Summer	Fall	Winter	Washington,DC: Spring	Summer	Fall	Winter
HH 2-Seater:																
1998	228.8	260.2	229.8	242.8	233.4	264.5	234.9	245.4	232.5	260.4	235.4	247.7	230.4	262.4	232.1	245.0
1999	228.9	260.2	229.8	242.9	233.4	264.5	234.9	245.4	231.9	259.9	234.9	247.2	230.4	262.4	232.1	245.0
2000	228.9	260.2	229.8	242.9	233.4	264.5	234.9	245.5	231.4	259.5	234.4	246.6	230.5	262.4	232.1	245.0
2001	228.9	260.2	229.9	243.0	233.4	264.5	234.9	245.5	232.0	259.9	234.9	247.2	230.5	262.4	232.1	245.0
2002	229.5	260.6	230.5	243.7	234.0	265.0	235.4	246.1	232.9	260.7	235.7	248.2	231.1	262.9	232.7	245.6
HH Mini-Compact:																
2003	230.4	277.5	231.3	248.3	234.8	284.5	236.1	248.4	235.1	278.6	237.5	251.6	231.9	280.8	233.5	248.5
2004	231.3	278.2	232.2	249.4	235.7	285.2	236.9	249.4	236.4	279.8	238.8	253.0	232.8	281.4	234.3	249.4
2005	232.3	278.9	233.3	250.7	236.6	285.9	237.8	250.5	237.9	281.0	240.0	254.5	233.8	282.1	235.3	250.4
2006	233.5	279.8	234.4	252.2	237.7	286.7	238.7	251.7	239.5	282.3	241.4	256.1	235.0	282.9	236.3	251.7
2007	234.6	280.6	235.6	253.6	238.7	287.5	239.7	252.9	241.2	283.7	242.9	257.8	236.1	283.7	237.4	252.8
2008	217.4	261.8	218.3	235.5	221.4	268.4	222.3	234.6	224.4	265.4	226.0	240.0	218.8	264.8	220.0	234.5
2009	218.7	262.8	219.6	237.1	222.6	269.3	223.4	236.0	226.3	267.0	227.6	241.9	220.1	265.7	221.2	235.8
2010	219.6	263.4	220.5	238.2	223.4	269.9	224.1	237.0	227.5	268.0	228.7	243.1	221.0	266.3	222.0	236.8
HH and Fleet Compact:																
1998	289.5	347.7	290.5	314.1	294.1	356.5	295.6	312.2	293.1	348.0	296.0	314.1	291.1	351.8	292.8	313.1
1999	289.5	347.7	290.5	314.2	294.1	356.5	295.6	312.2	292.6	347.5	295.5	313.6	291.1	351.8	292.8	313.1
2000	289.6	347.7	290.5	314.2	294.1	356.5	295.6	312.2	292.1	347.1	295.1	313.1	291.1	351.8	292.8	313.2
2001	289.6	347.7	290.5	314.2	294.1	356.5	295.6	312.3	292.6	347.5	295.5	313.6	291.2	351.8	292.8	313.2
2002	290.2	348.1	291.1	315.0	294.7	357.0	296.1	312.9	293.6	348.3	296.4	314.6	291.8	352.2	293.4	313.8
2003	291.0	348.8	292.0	316.0	295.5	357.6	296.8	313.8	295.7	350.0	298.2	316.8	292.6	352.8	294.2	314.6
2004	292.0	349.5	292.9	317.2	296.4	358.2	297.6	314.8	297.1	351.2	299.4	318.2	293.5	353.5	295.0	315.6
2005	293.0	350.2	293.9	318.5	297.3	358.9	298.5	315.9	298.6	352.4	300.7	319.7	294.5	354.1	295.9	316.6
2006	294.2	351.1	295.1	320.0	298.4	359.7	299.4	317.1	300.2	353.7	302.1	321.3	295.7	354.9	297.0	317.8
2007	295.3	352.0	296.2	321.4	299.4	360.5	300.4	318.3	301.9	355.1	303.6	323.0	296.8	355.7	298.0	319.0
2008	275.3	332.1	276.2	300.7	279.3	340.7	280.1	297.3	282.3	335.8	283.9	302.4	276.7	335.8	277.9	297.9
2009	276.6	333.0	277.5	302.4	280.5	341.7	281.2	298.7	284.2	337.3	285.5	304.3	278.0	336.8	279.1	299.3
2010	277.4	333.7	278.3	303.5	281.3	342.2	281.9	299.6	285.3	338.3	286.6	305.5	278.9	337.4	279.9	300.2

Table B.7.1 Estimated Grams-Per-Mile Emissions of Conventional Vehicles (continued)

Fleet Mini-Minivan:																
1998	278.2	359.7	279.5	315.9	283.7	373.1	285.0	306.1	281.8	359.7	284.7	306.6	280.2	365.5	281.9	308.8
1999	278.3	359.7	279.5	315.9	283.7	373.1	285.0	306.1	281.1	359.1	284.1	305.9	280.2	365.5	281.9	308.8
2000	278.5	359.9	279.7	316.2	283.9	373.3	285.2	306.4	280.8	358.9	283.9	305.7	280.5	365.7	282.1	309.1
2001	279.1	360.4	280.3	316.9	284.5	373.7	285.7	307.0	282.0	359.9	285.0	306.9	281.0	366.1	282.6	309.6
2002	279.7	360.8	280.9	317.7	285.0	374.1	286.2	307.6	283.0	360.7	285.8	307.9	281.6	366.6	283.2	310.2
Fleet Minivan:																
1998	366.7	477.0	367.9	421.6	372.1	495.6	373.5	404.0	370.2	477.0	373.2	403.9	368.7	484.9	370.4	409.0
1999	366.7	477.0	367.9	421.6	372.2	495.6	373.5	404.0	369.5	476.5	372.6	403.2	368.7	484.9	370.4	409.0
2000	367.0	477.2	368.2	421.9	372.4	495.8	373.7	404.3	369.3	476.3	372.4	403.0	368.9	485.1	370.6	409.3
2001	367.5	477.6	368.7	422.6	372.9	496.2	374.1	404.9	370.5	477.2	373.4	404.2	369.5	485.5	371.1	409.8
2002	368.2	478.1	369.4	423.4	373.5	496.6	374.7	405.5	371.5	478.1	374.3	405.2	370.1	485.9	371.7	410.4
2003	368.8	478.6	370.0	424.2	374.1	497.1	375.2	406.2	372.9	479.2	375.5	406.6	370.7	486.4	372.3	411.1
2004	369.5	479.1	370.7	425.1	374.8	497.6	375.8	407.0	374.0	480.1	376.5	407.8	371.4	486.9	372.9	411.8
2005	370.3	479.7	371.5	426.1	375.5	498.1	376.5	407.8	375.2	481.1	377.5	409.0	372.2	487.4	373.6	412.6
2006	371.2	480.3	372.3	427.3	376.2	498.7	377.2	408.7	376.5	482.2	378.6	410.3	373.1	488.0	374.4	413.5
2007	372.1	481.0	373.3	428.5	377.1	499.3	377.9	409.7	377.9	483.3	379.9	411.7	374.0	488.6	375.2	414.4
2008	349.9	459.3	351.0	404.2	354.7	478.1	355.5	385.8	356.1	462.2	357.9	388.4	351.7	467.1	352.9	390.3
2009	350.9	460.1	352.1	405.6	355.7	478.8	356.4	387.0	357.7	463.5	359.3	390.0	352.7	467.8	353.9	391.4
2010	351.7	460.6	352.8	406.5	356.4	479.3	357.0	387.7	358.7	464.4	360.2	391.0	353.4	468.3	354.5	392.2
Fleet Full-Size Van:																
1998	590.0	770.7	591.2	677.6	595.4	802.1	596.7	647.2	593.5	771.1	596.5	646.0	591.9	783.8	593.6	656.0
1999	590.0	770.7	591.2	677.6	595.4	802.1	596.7	647.2	592.8	770.5	595.9	645.3	592.0	783.8	593.6	656.1
2000	590.2	770.9	591.5	677.9	595.7	802.3	596.9	647.5	592.6	770.3	595.7	645.1	592.2	783.9	593.9	656.3
2001	590.8	771.3	592.0	678.6	596.2	802.7	597.4	648.1	593.8	771.3	596.7	646.3	592.8	784.3	594.4	656.9
2002	591.4	771.8	592.6	679.4	596.8	803.2	597.9	648.8	594.8	772.1	597.6	647.3	593.4	784.8	594.9	657.5
2003	592.1	772.3	593.3	680.2	597.4	803.6	598.5	649.4	596.2	773.2	598.8	648.8	594.0	785.2	595.5	658.1
2004	592.8	772.8	594.0	681.1	598.0	804.1	599.1	650.2	597.3	774.1	599.7	649.9	594.7	785.7	596.2	658.8
2005	593.6	773.4	594.8	682.2	598.7	804.7	599.7	651.0	598.5	775.1	600.8	651.1	595.5	786.3	596.9	659.6
2006	594.5	774.0	595.6	683.3	599.5	805.2	600.4	651.9	599.8	776.2	601.9	652.4	596.3	786.8	597.7	660.5
2007	595.4	774.7	596.5	684.5	600.4	805.9	601.2	652.9	601.2	777.3	603.1	653.8	597.2	787.5	598.5	661.4
2008	555.3	720.7	556.4	643.9	560.2	749.3	560.9	611.1	561.5	723.8	563.3	612.5	557.1	732.4	558.3	619.9
2009	556.4	721.5	557.5	645.3	561.1	750.1	561.8	612.2	563.1	725.1	564.7	614.0	558.1	733.2	559.3	621.0
2010	557.1	722.0	558.2	646.3	561.8	750.5	562.4	613.0	564.1	726.0	565.6	615.1	558.8	733.6	559.9	621.8

APPENDIX C
Details of the Electric Utility Analysis[1]

Appendix C provides considerable detail on the methodology for the electric utility simulations used in the EVTECA. Results of the utility analysis are also included. The appendix discusses: Base Case load profiles (C.1), utility dispatch (C.2), simulation of EV loads (C.3), an example of the computational procedure (C.4), a summary of the results (C.5), and conclusions (C.6).

C.1 Developing Base Case Load Profiles for Utilities in the Four Metropolitan Areas

Incremental emissions resulting from EV charging is greatly affected by the temporal shape of native load. Native loads are loads other than those of EV charging which the utility is obligated to serve in the future. Therefore, we had to pay careful attention to the synthesis of data to formulate temporal shapes of system load.

The change in the temporal shape of load due to DSM and purchases and sales were another area of concern. In some instances, data from the utilities conflicted with other information. For example, Consolidated Edison (CE) has a total installed nuclear capacity of 10,030 MW. The system minimum load in 1992 (night time load) was on the order of 9,000 MW. Under the assumption that no nuclear units are down for maintenance, the nuclear units have to be cycled (output reduced) during low load periods. Any utility wants to avoid having to cycle nuclear generating units. The projected loads for the years 2000 and 2010 assumed a certain demand growth. In spite of this load growth, the minimum load in the data obtained from CE was lower than the 1992 minimum load. Therefore, the cycling problem of nuclear units would be exacerbated. As this situation appeared unrealistic, we modified the temporal data to keep the minimum load at the present value while the total energy consumed (the area under the temporal load curve) matched the forecast values for those years.

Difficulties in reconciling the data obtained from the Texas Public Utilities Commission and the California Energy Commission were similar in nature. In the case of the latter, we had to find an acceptable way to synthesize the temporal profiles of purchases and sales. Firm purchases were assumed to be "on peak," and other purchases and sales were treated as energy assigned units (EAU) in the simulation. For instance, the purchases were aggregated with other EAUs and a suitable position in the merit order of loading was found.

In the case of VEPCO, we could not obtain the temporal hourly data from any source. Therefore, we assumed it to be a similarity transformation of Potomac Electric Co. loads, suitably scaled to obtain the projected peak loads and annual energy use in future years.

In some instances, the utility and its regulator did not agree on the amount of demand-side management (DSM) that could be procured. Consequently, the resource expansion and the temporal load shape obtained from the commission and the utility were not in agreement.

An example is that of CE that has two affected units under the provisions of the CAAA. The Illinois Public Utilities Commission had ordered CE to install scrubbers to bring the SO_2 emission to a lower level.

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[1]This Appendix was written by Narayan S. Rau, Stephen T. Adelman and David M. Kline of, or formerly of, the National Renewable Energy Laboratory, Golden, Colorado.

Such an action by CE would entail the use of Midwestern coal. CE won a legal battle to overturn this commission order. Therefore, it is unclear at present if CE intends to install cleaning equipment, purchase allowances, or resort to emission constrained dispatch. In 2010, CE's SO_2 emission will be more than that allowed by the Environmental Protection Agency (EPA) (Federal Register, 1994). Consequently, we considered both economic dispatch as well as emission constrained dispatch in our study.

C.2 The Dispatch of Utility Generation Resources

In the literature, mathematical models that simulate the operating procedure are well documented. It is not our intent to describe the simulation procedure and its mathematical underpinnings, but rather to describe the rudiments of certain concepts and the manner in which they impinge on the final results.

We will illustrate these concepts via the use of a simple and illustrative mix of generation and load.

C.2.1 Least Cost Dispatch

Consider an illustrative three-machine system shown in Table C.3.1 that is to be dispatched to meet a demand of 35 MW in a particular hour.

Table C.2.1 Illustrative Example

Unit Number	Capacity (MW)	Cost ($/MWh)	SO2 (lb/MWh)
1	5	20	7
2	20	22	6
3	30	25	1

A least-cost dispatch strategy dictates full outputs from the first two machines of the table and an output of 10 MW from the third machine. Note that the SO_2 emission in that particular hour is 165 lb. (5x7 +20x6 + 10x1). If we now take into account that some of the machines may not be available as a result of random outages, the remaining machines will have to be dispatched to meet the load. If the 5 MW machine is down, the contributions from the other two machines will be 20 and 15 MW respectively. If the 30 MW machine is on an outage, the contributions from the first two machines are 5 MW and 20 MW with a load curtailment of 10 MW.

The dispatch simulation procedure (Baleriaux et al. 1967, Rau et al. 1980, and Rau and Necsalescu, 1983) considers the temporal shape of the load during a year or season and the probability of machine outages.[2]

[2] The mathematical underpinnings of the procedures used in the references (Baleriaux et al. 1967, Rau et al. 1980, and Rau and Necsalescu, 1983) are all identical. The simulation procedure in the EPRI EGEAS program is also similar to these. Therefore, the results of the dispatch procedure produced by any of these procedures will be the same within a tolerance bound arising from small idiosyncracies of different procedures. We used the algorithm from the 1983 work (Rau and Necsalescu, 1983) in our simulations.

The result of the simulation gives the expected energy generation from each machine and the expected energy curtailed for a year or season under simulation. Note that the results are mathematical expectations.

An important observation is that the units are dispatched in order of increasing cost as load increases. Although the actual dispatching of units in operating practice is somewhat different,[3] this approximation for simulation purposes is acceptable. The ordering of machines according to the incremental cost of energy production is called the merit order. Machines with higher incremental cost used to serve higher demands are called machines of higher merit order. Machines higher in the merit order generate energy for a shorter period during the day; hence, their load factor is lower than the machines lower in the merit order. Consequently, machines that are very high in the order are used only during peak load periods. As a consequence, the incremental cost of energy production in the system increases with the demand and is a nondecreasing function of demand.

C.2.2 The Dispatch of Energy Assigned Units

The value of their energy injected into the system is higher during periods of high incremental cost of production (e.g., system peak hours). Consequently, the dispatcher attempts to dispatch them during times of high marginal cost of energy production. This procedure is simulated in the dispatch algorithm we used in our analysis.

C.2.3 Emission-Constrained Dispatch

A brief summary of Title VI of the CAAA as it pertains to sulfur dioxide emissions can be in the shaded box on the following page. Although the affected utilities only are required to limit emission under Phase 1 of the implementation of CAAA, all the utilities are required by law to limit the tonnage of effluent during the period January 1 to December 31 in any year after 2000 to be below a certain cap. For SO_2 emission, the annual allowance permitted by the EPA is based on average fuel burns in the 1985-1987 period. Utilities that desire to emit more than the annual limit have to purchase additional allowances from the allowance market. On the other hand, a utility can over comply and sell allowances in the market. If the utility installs mitigative measures, such as coal washing or scrubbing the effluent, to comply with the provisions of the CAAA, the economic dispatch procedure results in minimum cost while honoring the annual emission cap. Of course, there are additional costs associated with the building of cleaning equipment. If no mitigative measures are undertaken and if the traditional economic dispatch violates the annual SO_2 emission cap, the utility has to resort to a dispatch procedure constrained by the emission cap. Such a dispatch procedure is called emission constrained dispatch. The total cost of energy production from a constrained dispatch is higher than that of economic dispatch.

The simulation of emission constrained dispatch involves complex nonlinear minimization techniques described in "Operating Strategies Under Emission Constraints" (Rau and Adelman, 1995). In contrast, consider the minimum emission dispatch to supply a load of 35 MW from the system of Table C.2.1. The strategy is to dispatch outputs of 30 MW and 5 MW from the third and the second machines respectively. This procedure results in an SO_2 emission of 60 lb. per hour (1x30 + 5x6). The merit order of dispatch in this case is different from that of economic dispatch. However, under emission constrained dispatch, the object is still

[3] The economic dispatch procedure in operating practice entails the loading of the generating units such that the incremental cost of production from all the units under economic dispatch is the same.

to minimize the cost and honor the annual emission cap. The merit order of dispatch under this procedure will be that neither of the economic dispatch nor of minimum emission dispatch.

Summary of Title IV, SO_2 Allowance System

CAAA-90 requires emission reductions from electric utilities. It addresses pollutants such as SO_2, NO_x, hazardous air pollutants, and particulate matter. One part of the CAAA's requirements for utilities -- the Title IV SO_2 reduction requirements, including the system for SO_2 allowance trading and the phased reduction in nationwide SO_2 emissions -- is described below.

Title IV established a market-based system for limiting SO_2 emissions from electric utilities. Under this system, utilities will be required to obtain and surrender one SO_2 allowance per ton of SO_2 emitted annually. Allowances may be obtained through automatic allocations, allowance transfers, or auction and sales. Utility units that were in operation during 1985-1987 will automatically receive an annual allowance allocation based on their average annual emissions during those years. However, new units will not receive these free allocations. Allowances may be transferred among units within a utility system. Purchase of allowances from EPA or from other sellers may occur at an annual auction, or private sales may be negotiated at any time. Allowances may be banked for future use. Allowances from past or future years may be purchased or transferred, but may not be used to "pay" for emissions in advance of the year for which they are issued.

SO_2 emissions will be reduced in two phases. During Phase I, January 1, 1995, to December 31, 1999, only the highest-emitting 110 plants in the United States must comply (Phase-I affected units). Phase I allowance allocations permit a national average emissions rate of 2.5 lb SO_2/million Btu of energy input to the generating unit as reported in the DOE Form 767 based on the 1985-1987 level of generation. Incentive programs, to encourage flue gas desulfuriztion and conservation, grant allowances for emissions exceeding this basic rate. In Phase II, almost all utility* with nameplate capacities over 25 MWe must comply, and the permitted national average emissions rate is lowered to 1.2 lb SO_2/million Btu based on 1985-1987 level of generation. However, repowering allowances and bonus allowances** permit emissions above this rate.

Annual allowances allocated to Phase I-affected units will be 5.55 million tons (EPRI 1993), but additional allowances during Phase I will be available as follows:

• EPA Auction and sales	150,000 tons/yr
• Flue gas desulfurization incentives	Variable number of allowances
• Phase II plants brought into Phase I***	3,500,000 tons total, Phase I
• Conservation and renewable energy	300,000 tons total, Phases I & II

* Units not affected by Title IV include certain independent power producers, solid waste incinerators, and cogenerating facilities.

** Bonus allowances are allocated to utility units with baseline emissions between 1.2 and 2.5 lb/million Btu and baseline capacity factors below 60%. Bonus allowances also may be allocated in states with low average emissions.

*** Phase II units become subject to Phase I requirements if generation is transferred from a Phase I unit to a Phase II unit. In this case, the Phase II unit must be designated a substitution unit and receives an allowance allocation.

Summary of Title IV, SO_2 Allowance System (cont.)

The total number of Phase I allowances annually could be 6.42 million, assuming that incentive allowances were distributed evenly over the applicable phases and without accounting for Phase II plants entering the program early.

During Phase II, January 1, 2000, to December 31, 2009, virtually all generators with capacities over 25 MWe must comply with the program. Annual allowances allocated will increase to 9.15 million, but this reflects the lower national average emissions rate as indicated above. During Phase II, additional allowances above the 9.15 million allocations will still be available, as follows:

- EPA auctions and sales 250,000 tons/yr
- Repowering allowances[7] 500,000 tons total (estimated)
- Conservation and renewable energy incentives 300,000 total, Phase I and II

The total number of Phase II allowances annually could be 9.47 million, assuming an even distribution incentive allowances over the applicable phases.

After January 1, 2010, the total allowance allocation will stabilize at 8.95 million tons/year.

Emission constrained dispatch addresses the amount of power output from each machine for a given annual emission cap. For example, if the hourly emission is to be limited to 100 lb., the constrained dispatch simulation determines the outputs from the three generating units at minimum cost. Evidently, the cost of production is higher than under economic dispatch, and lower than under minimum emission dispatch.

An approximate procedure to simulate constrained dispatch procedure is to add a proxy cost of emission to the generating cost and to conduct an economic dispatch procedure. For example, if the proxy cost[8] of emission is \$1.0/lb., the cost of energy production from the first machine will be \$(20 + 1 x 7) = \$27/MWh. Similarly, the cost of production from the second and the third machines will be \$28 and \$26 per MWh respectively. Then, for an economic dispatch procedure that includes the proxy cost, the merit order will be the third machine, followed by the first and the second machines. However, there is no a priori guidance as to what annual emissions will be produced from an economic dispatch using this proxy cost. Inevitably, this leads to a trial and error or an iterative procedure in which different proxy costs are tried, and the one that results in the desired annual emissions is selected. A more sophisticated and direct approach is described in our 1995 paper (Rau and Adelman, 1995). In our studies, we used the approximate trial and error procedure for a majority of cases. However, for Chicago, since Commonwealth Edison (CE) is likely to use emission constrained dispatch in the years after 2010, we checked our results with the prior, more sophisticated approach.

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[7] Repowering allowances are available from January 1, 2000 until December 2003.

[8] The proxy cost could be taken as the market trading price of allowances, which could be different from the internal cost of controlling emissions. It is difficult to estimate the future prices of allowances with any certainty.

C.3 Simulation of EV Loads

The following is a description of a model used to simulate the charging loads of EVs that are presented to the utility system. In developing this model, the intent was to make it flexible to accommodate different driving patterns, battery types, and times of charging by suitable changes to the data inputs. Such a flexibility in the model permits the study of different policy cases (constrained charging scenarios) as will become evident later.

C.3.1 Basic Principle

The basic principle of the model can be understood from Figure C.3.1. This figure shows a hypothetical arrival distribution for three types of EVs. Each column in the distribution represents the number of EVs that arrive to their final destination and begin charging at that time. These columns are at five minute intervals, which is also the computational time step used in the model.

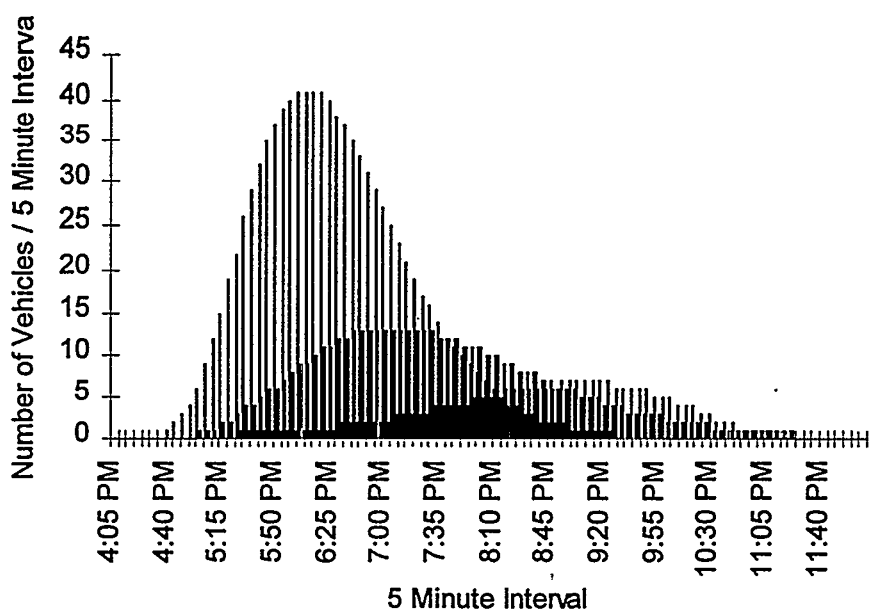

Figure C.3.1 Arrival Distribution of Vehicles

The figure illustrates only three vehicle types. The actual data as received from Argonne National Laboratory (ANL) consisted of up to thirty-two different vehicle types. Vehicle type categorization was based on fleet use, household use, battery types and sizes, vans, cars, and their combinations.

C.3.2 Battery Characteristics

The electric vehicle load presented to the system is dependent on the number of vehicles charging at a given time. The load is further dependent on the characteristics of the batteries in these vehicles and the batteries' state of discharge.

Figure C.3.2 shows the charging characteristic of the lead acid (Pb-Acid) battery.[1] If a vehicle is fitted with such a battery, based on the driving pattern, let the energy drained at the time of arrival in its final destination for the day be, for example, 64%. We assume that when it is plugged in for charging, the load presented to the system is the profile abcdefg plus an appropriate amount to account for the charging efficiency. Here, the position of line ab is calculated such that 64% of the area of the charging profile lies to its right-hand side. At the instant of plugging in for charging, the demand of the vehicle on the system is represented by the ordinate ab. As time progresses, the demand on the system is given by the ordinate of the profile to the right of ab. Clearly, if the battery is fully discharged, the charging load presented to the system is the complete profile abcdefgh.

The charging profiles for the batteries were provided by ANL (see Appendix B).

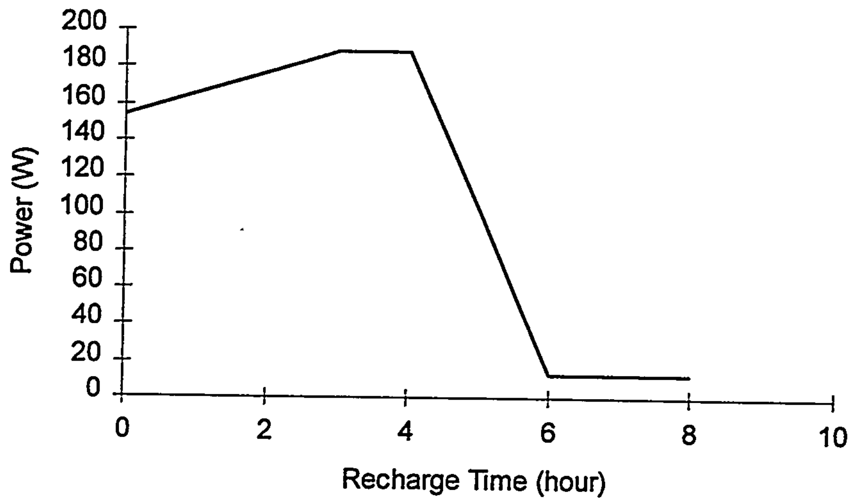

Figure C.3.2 Charging Profile for 1 kWh PbAc Battery (100% DOD) (Adopted from profile obtained from ANL)

C.3.3 Computation of Charging Load

From a knowledge of the battery depth of discharge (DOD), type of battery, time of plug-in, and the number of vehicles plugged in, the aggregate load presented to the utility's system can be computed. The computer program developed for this purpose calculated these loads at different times to produce a composite daily demand profile as follows. For a given charging profile associated with a particular vehicle and battery type, the demand on the system was computed at five minute intervals. By a similar set of calculations for different vehicles and their number at any given time, the aggregate load on the system was computed. The aggregate demand was computed for all the five week days and week end days.

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[1] The charging profiles for all battery types, the states of their discharge based on driving patterns, and all other battery parameters were provided by Argonne National Laboratory (ANL).

The **charging demand** computed for a week was assumed to repeat for other weeks during the season. However, we used detailed load profiles for every day of the season. The total system demand was computed by adding the system demand to that of the EV demand.

For the study of unconstrained charging, it was assumed that the vehicles were plugged in at their times of arrival. Therefore, the distribution of plugging in for charging is a one-to-one transformation of the arrival distribution shown in Figure C.3.1. For constrained charging cases, the charging of the vehicles was delayed from the times of their arrival. The plugging in distribution for this case was obtained by a suitable modification of the arrival distribution depending on the assumptions regarding delayed charging. It is important to ensure that plugging in the vehicles that abstained from charging during the waiting period all at once did not produce a secondary peak demand on the system.[2] Consequently, we had to use some guiding principles and judgement in determining the plugging in distributions for off-peak charging scenarios.

Structure of Data Input

An example of the input data structure will further explain how the EV simulation proceeds. Table C.3.1 represents the input data for the Chicago high penetration scenario in the summer of 2010. In the interest of brevity, this example includes the input for the fleet vehicle category only and some of the nonessential inputs have been removed.

The first part of the input data (Table C.3.1, section (a)) pertains to the vehicles for fleet use, twenty-two types in all. These vehicle types are differentiated by their battery technology, size of battery, and by whether it is a fleet car, or a fleet van. Note that there are four battery types. Section (a) inputs the battery technology, the size of the batteries, their charging efficiencies, and the number of each vehicle type.

The next section of input (section (b)) begins the process of entering the vehicle arrival demographics that are necessary to calculate a temporal load profile. The first input specifies the number of hours over which the fleet vehicles arrive to their final destination (2 hours) and begin charging. The next inputs provide the start time of these two durations (4:00 p.m. to 5:00 p.m. and 5:00 p.m. to 6:00 p.m.) and the distribution of the vehicles across these two hours (50% of the total numbers of vehicles in each hour). The model assumes a uniform distribution of arrivals over 5 minute intervals for the vehicles that begin charging in each hour.

The last sections of Table C.3.1(sections (c) & (d)) provide a DOD distribution for the different vehicle types. Section (c) indicates three values of DOD assuming a three-point probability distributions for each vehicle type. Section (d) provides the distribution of vehicle numbers at each DOD distribution point. For example, for all of the fleet vehicles that arrive during the one hour interval starting at 4:00 p.m., 24.56 percent of the vans will have a DOD associated with the first point of the three point distributions. To illustrate further, 24.56 percent of vehicle type 22, which is a van, will have a 15.66 percent DOD.

Results

Figure C.3.3 shows a set of sample results. In this figure, the composition of the charging load in terms of the constituent battery types, and vehicle classifications (fleet, or household vehicles) are indicated.

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[2] In Demand Side Management (DSM) literature, this effect is called the "pay back."

The model is general in nature with a capability to handle any required variation, be it the battery characteristics, driving habits affecting the DOD, or different times of charging.

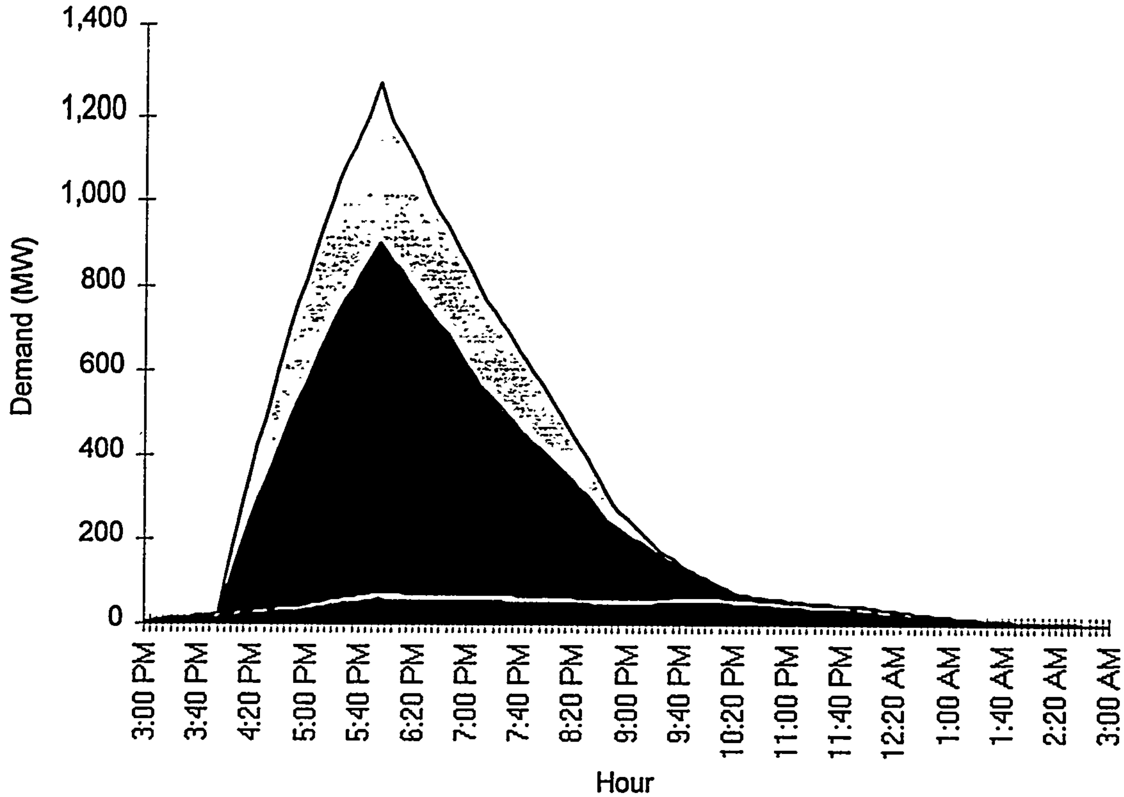

Figure C.3.3 Power Demand by Battery Technology for Fleet and Household Vehicles CE-Summer 2010-High Penetration Scenario

Table C.3.1 Example of Input Data to EV Load Model

Section (a)

6) Number of Fleet Vehicle/Battery Combinations 22

7) Fleet Vehicle/Battery Descriptions

Vehicle	Battery Type	Battery Size (kWh)	Battery Charging Efficiency (%)	Charger Efficiency (%)	Total Number of Fleet Vehicles by Vehicle/Battery Combination
VEH1	1	18.6	78.0	87.5	8228
VEH2	2	22.4	85.0	87.5	2977
VEH3	2	16.9	80.0	87.5	3970
VEH4	1	29.6	78.0	87.5	2977
VEH5	2	36.0	89.0	87.5	24643
VEH6	3	41.3	74.0	87.5	24643
VEH7	4	36.8	78.0	87.5	24643
VEH8	2	36.7	89.0	87.5	7383
VEH9	3	35.0	74.0	87.5	7383
VEH10	4	32.4	78.0	87.5	7383
VEH11	2	62.1	89.0	87.5	1846
VEH12	3	56.9	74.0	87.5	1846
VEH13	4	52.6	78.0	87.5	1846
VEH14	2	32.1	89.0	90.0	17510
VEH15	3	35.1	74.0	90.0	17510
VEH16	4	31.7	78.0	90.0	17510
VEH17	2	32.4	89.0	90.0	5246
VEH18	3	29.6	74.0	90.0	5246
VEH19	4	27.6	78.0	90.0	5246
VEH20	2	54.8	89.0	90.0	1312
VEH21	3	48.1	74.0	90.0	1312
VEH22	4	44.8	78.0	90.0	1312

Battery Technology in Fleet Vehicles (1=Pb-Acid, 2=NA-S, 3=Ni=Cd, 4=Ni-MH)

Section (b)

8) Number of Hours during Which Fleet Vehicles Arrive at Final Destinations 2

9) Percentage of Vehicles Arriving during Each Hour

Hour	Percentage
4	50.0
5	50.0

Table C.3.1 Example of Input Data to EV Load Model (cont'd.)

Section (c)				
10) Distribution of Battery DOD by Vehicle Type and Hour				
	3 Point Distribution for DOD			
VEH	Hour	1	2	3
VEH1	DOD	26.11	58.74	93.98
VEH2	DOD	16.92	38.07	59.23
VEH3	DOD	22.48	50.59	78.69
VEH4	DOD	23.58	53.06	82.53
VEH5	DOD	15.55	34.98	55.97
VEH6	DOD	13.35	30.04	48.06
VEH7	DOD	13.58	30.55	48.89
VEH8	DOD	16.07	36.15	56.24
VEH9	DOD	15.19	34.17	53.16
VEH10	DOD	15.40	34.65	53.90
VEH11	DOD	15.50	34.87	54.24
VEH12	DOD	15.04	33.85	52.65
VEH13	DOD	15.26	34.34	53.42
VEH14	DOD	15.51	34.91	55.85
VEH15	DOD	13.66	30.72	49.16
VEH16	DOD	13.79	31.03	49.65
VEH17	DOD	16.08	36.18	56.27
VEH18	DOD	15.59	35.08	54.57
VEH19	DOD	15.77	35.49	55.21
VEH20	DOD	15.48	34.84	54.19
VEH21	DOD	15.46	34.79	54.12
VEH22	DOD	15.66	35.23	54.81

Section (d)				
Fleet Car DOD Percentages				
4	DIST	7.64	49.93	45.43
5	DIST	7.64	46.93	45.43
Fleet Van DOD Percentages				
4	DIST	24.56	52.46	22.98
5	DIST	24.56	52.46	22.98

C.4 Details of the Computational Procedure: An Example Simulation for One Metropolitan Area (Chicago)

The study of the four regions consisted of two snapshot years, 2000 and 2010. In addition, scenarios of high and low penetration of EVs in each of the regions were considered. In regions where emission constrained dispatch might be required, such a dispatch procedure as well as the economic dispatch were simulated in order to account for uncertainties regarding mitigation measures.

In the following discussion, we outline the details of one study, that of Chicago for the summer season of 2010 simulating the scenario of high EV penetration. Our purpose in these discussions is not to comment on the actual quantities obtained as results, but rather it is to clarify the details of all the procedures of our simulation and to point out the reasons for obtaining certain results. Computational procedures identical to the one used in this example were used for all the other regions. Of course, there are some minor differences. For example, in California, emission constrained dispatch is not required. Such differences are pointed out in the text.

The nomenclature for our studies is as follows. By base case we mean the simulation of the utilities for the year, or season, under reference without consideration of EVs. The unconstrained case considers the penetration of EVs which are assumed to be plugged-in for charging immediately upon arrival at their final destination. Such charging behavior is not constrained by any policy measures such as direct load control, or indirect methods such as time of day pricing.

C.4.1 Load Modification Arising from EVs

Figures C.4.1 and C.4.2 show the effect EVs have on the load pattern for a representative day of winter and summer months. Recall that our study is conducted for a season and not a single day. These figures are provided for illustrative purposes to explain the underlying concept of the addition of system load and charging load. We computed the week-day and week end charging profiles as described in Section C.3. This charging load was then added to the load of each appropriate day during the season under study. Consequently, the charging demand for all the week-days in every week of the season was assumed to be the same as the representative week simulated in our studies. The same holds for week end loads during the season.

The peak load during summer months occurs around 4:00 p.m. (Figure C.4.2) while, during winter, it occurs around 6:00 p.m. For the assumed driving patterns in the unconstrained charging case, the charging load for the high penetration scenario increases the system peak.

C.4.2 System Dispatch

Base Case Emissions

Table C.4.1 indicates simulation results for the base case system dispatch. The expected generation from each generating unit for the summer season is indicated therein. Additionally, the expected unserved energy (EUSE) and the loss of load probability are also indicated. These are reliability measures of system performance.

The ordering of the units in Table C.4.1 and all other tables portraying economic dispatch is the merit order of loading. Therefore, the cost of production from unit #20, say, is less than that from unit #21.

Table C.4.2 shows the resulting emissions from each generating unit. These are obtained by multiplying the expected generation by the emission coefficients of different pollutants supplied as input data. The total $S0_2$ emission for the summer season is 42,647 tons. The total of $S0_2$ emissions in all four seasons was 184,851 tons. Seasonal emissions of other pollutants are also shown in the table.

Table C.4.3 provides the results of dispatching the units to constrain $S0_2$ emissions to be 142,690 tons per year. This is the allowance for CE in 2010 and thereafter as shown by EPA (Federal Register, Part 40). Table C.4.4 shows the corresponding emissions from generating units.

The focus of emission constrained dispatch as required by CAAA is that of annual So_2 emission cap. Note that the $S0_2$ emission for the summer season in the constrained dispatch case has decreased from 42,647 tons to 34,770 tons. However, the sum of $S0_2$ emissions of the four seasons is 142,690 tons, the annual emission cap. We used $0.3014/lb. as the proxy value[1] for the cost of emissions to obtain the results in the base case. The use of the proxy value is as follows. Instead of modeling a sophisticated constrained dispatch as in reference (Rau and Adelman, 1995), the proxy value multiplied by the $S0_2$ emission per kWh is added to the incremental cost of producing 1 kWh from that unit. Then the dispatch merit order of the units is obtained by sorting the generators on the basis of total cost obtained. As can be seen by a comparison of Tables C.4.3 and C.4.1, the merit order of units for economic dispatch and constrained dispatch are different.

The proxy value for emissions changes if there are changes to the load shape or to the inventory of generating equipment. The degree of penetration of EVs changes the load shape and the required capacity addition. Therefore, the proxy value of emissions changes for the different scenarios studied. The values used for the high EV penetration case for CC and CT unit additions are: $0.5027/lb., and $0.315/lb. respectively. As indicated earlier, these values were obtained from an iterative procedure.

EV Penetration Cases: Incremental, Average and Marginal Emissions

Average System Emissions (ASEs) and Incremental System Emissions (ISEs) are computed as follows. ASEs are computed by dividing the emissions of any pollutant by the total energy produced in the system. For cases in which EV penetration is considered, the total system demand is increased to include EV charging energy. ISEs are obtained by the difference in system emissions with and without EV charging, and is expressed in units of tons. In these computations, the additional generation required to meet the demand of EVs was included in the system resource list only when the EV demand was added to the system demand. Marginal emissions were obtained in a similar manner to that of ISE. But the important difference is that the additional generator was included in the system resources both when the EV demand was added to the system demand and when excluded from the system demand. This means that the added generating unit was considered a *fait accompli*. The resulting emissions were expressed as a ratio of emissions to the charging demand (lb/MWh). Clearly, the marginal emissions trace the charging energy to the source supplying the energy in the simulation of dispatch procedure.

- *Incremental Emissions*

Table C.4.5 portrays the expected values of generation from generating units when the system is economically dispatched under the scenario of high EV penetration. Two important points are to be noted.

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[1] This proxy value was determined iteratively. The effect of assuming different values on the annual SO_2 emissions was examined. A suitable proxy value was chosen that resulted in the desired annual emission.

First, an IGCC unit of 417 MW capacity, unit #15[2], had to be added to meet the additional load of EVs and achieve the same reliability in terms of EUSE as in the base case (Table C.4.1).[3] Secondly, because of the relatively lower cost of energy production from the CC unit, it occupies the fifteenth position in the merit order and contributes energy into the system in addition to that consumed by the EVs.

Table C.4.6 indicates the resulting emissions caused by the EVs when the system is economically dispatched. The results of C.4.7 are obtained by subtracting Table C.4.6 from base case emissions of Table C.4.2. Table C.4.7 indicates the changes in emissions from each generator due to EV charging. Note that emissions from many generators have decreased. Importantly, the generation from the nuclear units has not changed at all. The total changes to the emissions of some pollutants shown at the bottom of Table C.4.7 have also decreased.

At first glance, the result that emissions decrease after the penetration of EVs may appear counter intuitive. A closer examination will reveal the reason for the decrease, which is the increased utilization of the CC units to meet the system load. This unit (unit #15) supplies about 801 GWh into the system. The total EV charging energy, given by the total of energy changes in each unit in Table 6.4.7, is only 273 GWh. Because this IGCC unit is much cleaner than the other older units, the emissions have decreased. Therefore, it is natural to ask what the incremental emissions would be if a generating unit of a different technology were to be chosen to meet the EV demand.

Table C.4.8 shows the result of dispatching the system with an added CT unit of 417 MW capacity (unit #44) instead of a CC unit. Its merit order position of 44 reflects its higher cost of energy production. Table C.4.9 shows the resulting emissions.

Table C.4.10 shows the change in emissions. They are the differences between the emissions in the base case Table C.4.2, and Table C.4.9. The incremental emissions are all positive indicating that the CT unit, in spite of being clean, is not dispatched to supply the system demand because of its higher cost of production. The CT unit generates about 39 GWh (Table C.4.9) in contrast with the EV demand of 273 Gwh.

We now examine the results of emission constrained dispatch for the cases of CC and CT unit addition.

For the case of an IGCC unit addition, Tables C.4.11, C.4.12, and C.4.13 show the energy production, emissions, and incremental emissions for the scenario of a CC unit addition. Table C.4.13 is obtained by subtracting the results of Table C.4.12 from those of Table C.4.3. Although most of the incremental emissions in this season are negative under constrained dispatch, this cannot be the case in all the seasons. The purpose

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[2] The capacity of the unit was determined by reliability considerations. We used three different technologies: CT, CC, or IGCC. The cost of generation from that generator varies depending on the type of technology. The cost associated with the IGCC unit results in the fifteenth position in the dispatch loading order. A choice of other technologies would yield a different position in the order.

[3] Note that we do not make the approximation of a fixed reserve margin which is commonly found in some studies. Under a fixed reserve margin assumption, the resources required are a fixed percent of the peak load, such as 120 %. Under such an assumption, if the peak load does not change by the charging of EVs, no additional resources would be required. As explained in Chapter 4, the use of a reliability criteria requires additional generating resources even if the EVs are not charged on peak.

of the emission constrained dispatch is to comply with the CAAA, which stipulates an annual cap on $S0_2$ emissions. Because the machines on maintenance and the load profile change from season to season, the emission constrained dispatch strategy can give positive incremental emissions for SO_2 in some seasons, although in other seasons, the incremental emissions can be negative. The incremental annual $S0_2$ emission is, of course, zero.

The utility has no interest in reducing incremental emission in any particular season. Its concern is to comply with the CAAA and limit its annual emissions at minimum cost. In the interest of air quality, a particular region might want to reduce the emission in the worst air quality season. Without further regional or federal regulation, this cannot necessarily be guaranteed under Title IV regulations of the CAAA.

Tables C.4.14, C.4.15, and C.4.16 indicate the dispatch, the emissions, and the incremental emissions for the case of adding a CT unit under emission constrained dispatch. In this case, the marginal emissions (Table C.4.16) are all positive. However, as in the previous case, the annual incremental $S0_2$ emission is approximately zero.

- *Marginal Emissions*

The procedure for calculating marginal emissions for IGCC addition is as follows.

Table C.4.17 shows the base case dispatch simulation (without EV load) of the system but with the IGCC added (471 MW in position 15). Table C.4.18 shows the emissions corresponding to this dispatch.

Recall that Table C.4.6 gives the emissions for the high EV penetration case in 2010 with IGCC addition. A subtraction of emissions in Table C.4.18 from those in Table C.4.6 gives the results shown in Table C.4.19 for the marginal emissions.

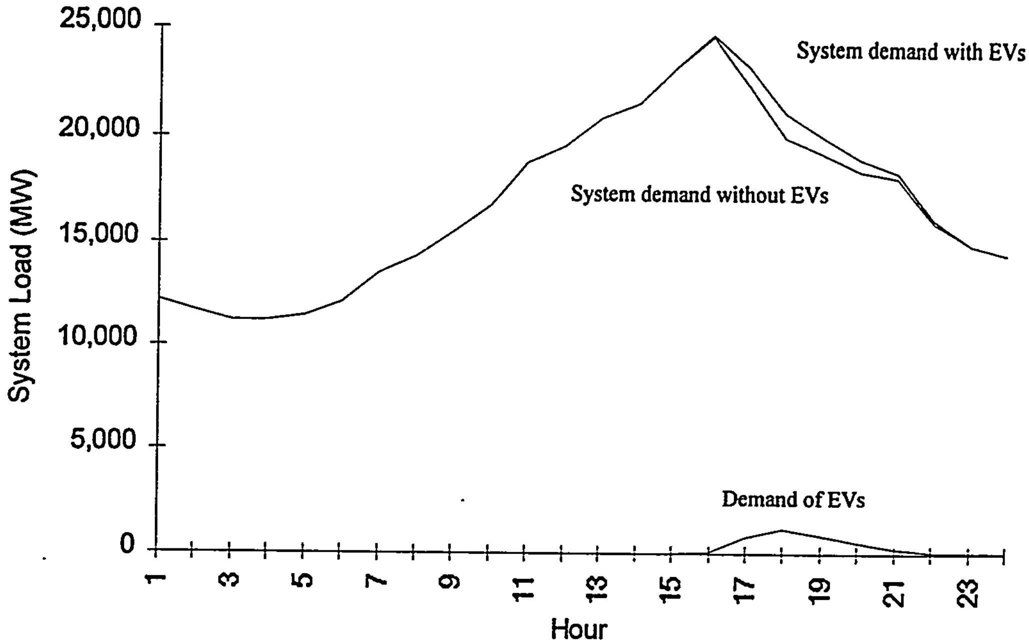

Figure C.4.1 Chicago Summer 2010 Peak Day Temporal Profile With/Without EV Unconstrained Charging

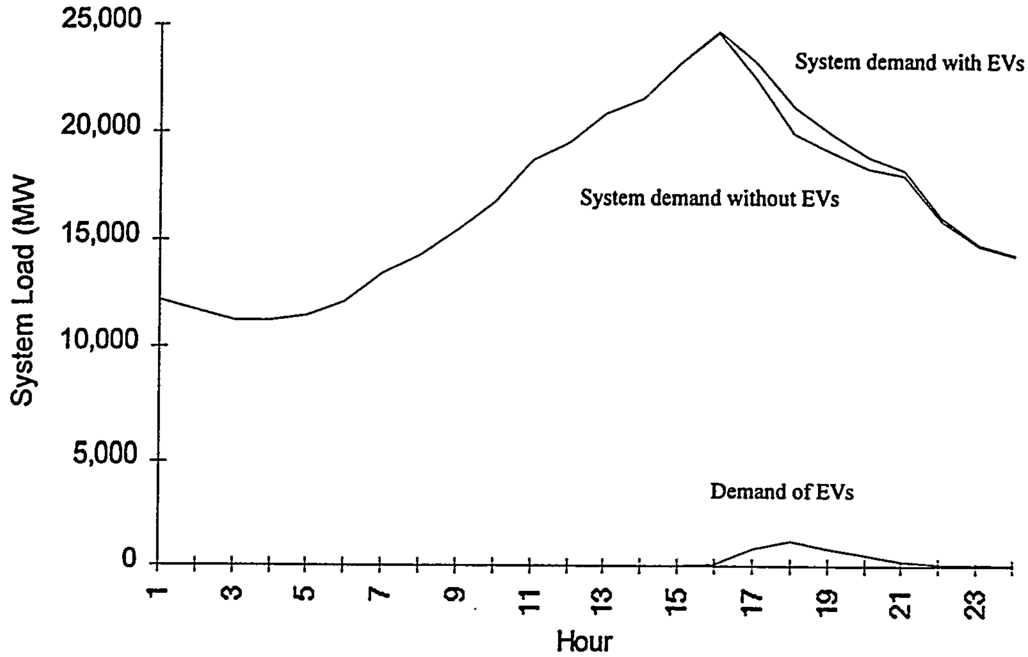

Figure C.4.2 Chicago Winter 2010 Peak Day Temporal Profile With/Without EV Unconstrained Charging

Table C.4.1 Results of ASE Calculation for Commonwealth Edison Summer 2010 - Economic Dispatch - Base Case Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Dispatch Order	Unit Name	Tech-nology	CAP	CAP SUM	Expected Generation(MWh)	Adjusted Capacity	Energy Factor(%)
1	La Salle 2	NB	1048.0	1048.0	2152005.12000	93.00	100.00
2	La Salle 1	NB	967.4	2015.4	1986497.85600	93.00	100.00
3	Zion 1	NP	720.0	2735.4	1478476.80000	93.00	100.00
4	Zion 2	NP	1040.0	3775.4	2135577.60000	93.00	100.00
5	Byron 1	NP	1120.0	4895.4	2299852.80000	93.00	100.00
6	Byron 2	NP	1120.0	6015.4	2299852.80000	93.00	100.00
7	Braidwood 1	NP	1006.2	7021.6	2066171.32800	93.00	100.00
8	Dresden 3	NB	773.0	7794.6	1587309.12000	93.00	100.00
9	Quad Cities 2	NB	577.0	8371.6	1196973.55312	93.95	101.02
10	Quad Cities 1	NB	487.4	8859.0	1015397.32867	94.35	101.45
11	Braidwood 2	NP	1090.0	9949.0	2263940.78905	94.07	101.15
12	Waukegan 7	ST	328.0	10277.0	648302.46839	89.52	99.46
13	CC 1	CC	420.0	10697.0	869060.16624	93.71	97.62
14	CC 2	CC	420.0	11117.0	841740.50758	90.77	94.55
99	CC 3	CC	999.9	9999.9	0.00000	99.99	99.99
15	Waukegan 8	ST	297.0	11414.0	538000.62457	82.04	91.16
16	Joliet 7	ST	499.0	11913.0	858978.43881	77.96	86.62
17	Will County 4	ST	470.8	12383.8	751788.85242	72.32	80.36
18	Joliet 8	ST	518.0	12901.8	752650.37040	65.81	73.12
19	Joliet 6	ST	269.5	13171.3	360251.38449	60.54	67.27
20	HScoal	ST	750.0	13921.3	936116.05486	56.53	58.88
21	Fisk 19	ST	316.0	14237.3	316122.03865	45.31	50.34
22	State Line 4	ST	279.7	14517.0	255940.77634	41.44	46.05
23	Will County 3	ST	251.0	14768.0	211418.95945	38.15	42.39
24	Powerton 5	ST	592.3	15360.3	432016.55841	33.03	36.70
25	Will County 2	ST	148.0	15508.3	95851.20582	29.33	32.59
26	Crawford 8	ST	319.0	15827.3	189579.87577	26.92	29.91
27	State Line 3	ST	187.0	16014.3	101633.80911	24.61	27.35
28	Kincaid 2	ST	554.0	16568.3	260353.22177	21.28	23.65
29	Will County 1	ST	151.0	16719.3	62437.86757	18.73	20.81
30	Powerton 6	ST	700.0	17419.3	241821.35795	15.65	17.38
31	Kincaid 1	ST	511.4	17930.7	138337.78780	12.25	13.61
32	Waukegan 6	ST	100.0	18030.7	24010.96126	10.87	12.08
33	Crawford 7	ST	213.0	18243.7	47763.75891	10.16	11.28
34	New NG Pkr 1	UN	280.0	18523.7	60320.84130	9.76	10.16
35	New NG Pkr 2	UN	280.0	18803.7	53292.25212	8.62	8.98
36	New NG Pkr 3	UN	118.5	18922.2	20704.03241	7.91	8.24
37	New NG Pkr 4	UN	280.0	19202.2	44918.41328	7.27	7.57
38	New NG Pkr 5	UN	140.0	19342.2	20613.07385	6.67	6.95
39	New NG Pkr 6	UN	258.8	19601.0	35178.75785	6.16	6.41
40	New NG Pkr 7	UN	280.0	19881.0	34351.44956	5.56	5.79
41	New NG Pkr 8	UN	280.0	20161.0	31055.04487	5.02	5.23
42	New NG Pkr 9	UN	280.0	20441.0	28218.26506	4.56	4.75
43	New NG Pkr 10	UN	140.0	20581.0	13174.40196	4.26	4.44
44	New NG Pkr 11	UN	280.0	20861.0	24607.51791	3.98	4.15
45	New NG Pkr 12	UN	280.0	21141.0	22507.74801	3.64	3.79
46	New NG Pkr 13	UN	140.0	21281.0	10531.00881	3.41	3.55
47	New NG Pkr 14	UN	280.0	21561.0	19651.75166	3.18	3.31
48	New NG Pkr 15	UN	118.5	21679.5	7787.90328	2.98	3.10
49	New NG Pkr 16	UN	280.0	21959.5	17149.78661	2.77	2.89
50	New NG Pkr 17	UN	140.0	22099.5	7952.22348	2.57	2.68
51	New NG Pkr 18	UN	280.0	22379.5	14657.28580	2.37	2.47
52	New NG Pkr 19	UN	140.0	22519.5	6737.88771	2.18	2.27
53	New NG Pkr 20	UN	280.0	22799.5	12296.56623	1.99	2.07
54	New NG Pkr 21	UN	280.0	23079.5	10806.50968	1.75	1.82
55	New NG Pkr 22	UN	280.0	23359.5	9396.65599	1.52	1.58
56	New NG Pkr 23	UN	280.0	23639.5	8079.59422	1.31	1.36
57	Collins 1-3	ST	1638.0	25277.5	24696.25347	0.68	0.76
58	Collins 4-5	ST	1060.0	26337.5	6393.37414	0.27	0.30
59	Old Oil Pkr's	GT	426.0	26763.5	1337.27334	0.14	0.17
60	Old NG Pkr's	GT	602.0	27365.5	1210.01239	0.09	0.11

Total Expected Generation	29963858.02638
Total Energy Demand	29946973.16792
Final EUSE	1548.84031
Difference	18433.69877
Final LOLP	0.85733E-03

Table C.4.2 Results of Base Case Dispatch Calculation for Commonwealth Edison Summer 2010 - Economic Dispatch - Base Case Scenario

Utility	Date	Case #
ComEd	Apr13'94	sum2010

Average Emission calculation for file baseDISPATCH.DAT.

Dispatch Order	Unit Name	Expected Generation(MWh)	CO	NOx	SO2	TSP	VOC	CO2
			-----Generation Emissions in Tons---					
1	La Salle 2	2152005.12000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	1986497.85600	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	1478476.80000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	2135577.60000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	2066171.32800	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	1587309.12000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	1196973.55312	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	1015397.32867	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	2263940.78905	0.00	0.00	0.00	0.00	0.00	0.00
12	Waukegan 7	648302.46839	104.04	1118.43	2405.92	325.12	16.26	692513.46
13	CC 1	869060.16624	7.57	227.09	333.06	378.48	18.92	806153.25
14	CC 2	841740.50758	7.33	219.95	322.59	366.58	18.33	780811.12
15	Waukegan 8	538000.62457	87.80	856.07	1975.54	274.38	13.72	584430.08
16	Joliet 7	858978.43881	147.88	2218.23	3789.47	462.13	23.11	984337.75
17	Will County 4	751788.85242	118.72	1484.03	2819.66	371.01	18.55	790246.61
18	Joliet 8	752650.37040	132.47	1552.34	3394.45	413.96	20.70	881729.91
19	Joliet 6	360251.38449	63.75	2010.12	1414.46	199.22	9.96	424336.50
20	CC 3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
21	HScoal	936116.05486	149.78	1872.23	3557.24	468.06	23.40	996963.60
22	Fisk 19	316122.03865	52.20	880.84	1207.08	163.12	8.16	347443.41
23	State Line 4	255940.77634	42.30	1393.32	872.48	132.19	6.61	281571.97
24	Will County 3	211418.95945	35.11	504.74	822.95	109.73	5.49	233717.32
25	Powerton 5	432016.55841	72.58	2211.38	1564.98	226.81	11.34	483102.52
26	Will County 2	95851.20582	15.98	534.34	344.58	49.94	2.50	106368.96
27	Crawford 8	189579.87577	32.27	564.80	796.77	100.86	5.04	214824.33
28	State Line 3	101633.80911	17.27	101.46	372.38	53.97	2.70	114950.89
29	Kincaid 2	260353.22177	47.16	1989.36	9696.28	147.36	7.37	313876.64
30	Will County 1	62437.86757	11.20	370.96	237.98	35.00	1.75	74542.38
31	Powerton 6	241821.35795	43.72	1817.17	929.08	136.63	6.83	291019.91
32	Kincaid 1	138337.78780	25.83	928.28	5311.38	80.72	4.04	171933.81
33	Waukegan 6	24010.96126	5.19	115.81	108.67	16.22	0.81	34547.33
34	Crawford 7	47763.75891	9.06	102.73	215.08	28.30	1.42	60279.06
35	New NG Pkr 1	60320.84130	38.15	40.93	0.21	4.51	2.77	41274.54
36	New NG Pkr 2	53292.25212	33.71	36.16	0.18	3.98	2.45	36465.22
37	New NG Pkr 3	20704.03241	13.10	14.05	0.07	1.55	0.95	14166.73
38	New NG Pkr 4	44918.41328	28.41	30.48	0.15	3.36	2.07	30735.42
39	New NG Pkr 5	20613.07385	13.04	13.99	0.07	1.54	0.95	14104.50
40	New NG Pkr 6	35178.75785	22.25	23.87	0.12	2.63	1.62	24071.07
41	New NG Pkr 7	34351.44956	21.73	23.31	0.12	2.57	1.58	23504.98
42	New NG Pkr 8	31055.04487	19.64	21.07	0.11	2.32	1.43	21249.41
43	New NG Pkr 9	28218.26506	17.85	19.15	0.10	2.11	1.30	19308.35
44	New NG Pkr 10	13174.40196	8.33	8.94	0.05	0.98	0.61	9014.58
45	New NG Pkr 11	24607.51791	15.56	16.70	0.08	1.84	1.13	16837.69
46	New NG Pkr 12	22507.74801	14.24	15.27	0.08	1.68	1.04	15400.93
47	New NG Pkr 13	10531.00881	6.66	7.15	0.04	0.79	0.48	7205.84
48	New NG Pkr 14	19651.75166	12.43	13.33	0.07	1.47	0.90	13446.71
49	New NG Pkr 15	7787.90328	4.93	5.28	0.03	0.58	0.36	5328.87
50	New NG Pkr 16	17149.78661	10.85	11.64	0.06	1.28	0.79	11734.74
51	New NG Pkr 17	7952.22348	5.03	5.40	0.03	0.59	0.37	5441.31
52	New NG Pkr 18	14657.28580	9.27	9.94	0.05	1.10	0.67	10029.25
53	New NG Pkr 19	6737.88771	4.26	4.57	0.02	0.50	0.31	4610.40
54	New NG Pkr 20	12296.56623	7.78	8.34	0.04	0.92	0.57	8413.93
55	New NG Pkr 21	10806.50968	6.84	7.33	0.04	0.81	0.50	7394.35
56	New NG Pkr 22	9396.65599	5.94	6.38	0.03	0.70	0.43	6429.66
57	New NG Pkr 23	8079.59422	5.11	5.48	0.03	0.60	0.37	5528.46
58	Collins 1-3	24696.25347	4.94	33.96	118.39	0.46	0.15	18367.84
59	Collins 4-5	6393.37414	1.37	11.99	32.90	1.11	0.17	6939.37
60	Old Oil Pkr's	1337.27334	1.32	5.26	0.01	0.14	0.09	1304.91
61	Old NG Pkr's	1210.01239	1.18	3.94	2.40	0.29	0.24	1597.58
Storage Units								
N/A	CAES A	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES B	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES C	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES D	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES E	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
	Totals	30203858.02640	1615.92	23534.20	42647.80	4586.43	255.12	10106727.45
	Average Emissions (lb/MWh)		0.11	1.56	2.82	0.30	0.02	669.22

Table C.4.3 Results of Dispatch Calculation for Commonwealth Edison Summer 2010 - Emission Constrained Dispatch - Base Case Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Dispatch Order	Unit Name	Tech-nology	CAP	CAP SUM	Expected Generation(MWh)	Adjusted Capacity	Energy Factor(%)		
1	La Salle 2	NB	1048.0	1048.0	2152005.12000	93.00	100.00	.37090E-04	0.00000
2	La Salle 1	NB	967.4	2015.4	1986497.85600	93.00	100.00	.38980E-04	0.00000
3	Zion 1	NP	720.0	2735.4	1478476.80000	93.00	100.00	.39310E-04	0.00000
4	Zion 2	NP	1040.0	3775.4	2135577.60000	93.00	100.00	.39930E-04	0.00000
5	Byron 1	NP	1120.0	4895.4	2299852.80000	93.00	100.00	.41470E-04	0.00000
6	Byron 2	NP	1120.0	6015.4	2299852.80000	93.00	100.00	.42130E-04	0.00000
7	Braidwood 1	NP	1006.2	7021.6	2066171.32800	93.00	100.00	.42580E-04	0.00000
8	Dresden 3	NB	773.0	7794.6	1587309.12000	93.00	100.00	.38680E-04	0.00000
9	Quad Cities 2	NB	577.0	8371.6	1196973.55312	93.95	101.02	.40650E-04	0.00000
10	Quad Cities 1	NB	487.4	8859.0	1015397.32867	94.35	101.45	.40700E-04	0.00000
11	Braidwood 2	NP	1090.0	9949.0	2263940.78905	94.07	101.15	.43520E-04	0.00000
12	CC 1	CC	420.0	10369.0	883535.58039	95.27	99.24	.10963E-03	0.82000
13	CC 2	CC	420.0	10789.0	862768.52396	93.03	96.91	.10963E-03	0.82000
14	Waukegan 7	ST	328.0	11117.0	612799.03785	84.61	94.02	.11549E-03	0.72000
15	Waukegan 8	ST	297.0	11414.0	538000.62457	82.04	91.16	.11488E-03	0.71000
16	Will County 4	ST	470.8	11884.8	812231.27988	78.13	86.82	.12999E-03	0.74000
17	HScoal	ST	750.0	12634.8	1248495.57893	75.39	78.53	.13023E-03	0.08800
18	Joliet 6	ST	269.5	12904.3	378367.04703	63.59	70.65	.11933E-03	0.08800
19	Joliet 7	ST	499.0	13403.3	639149.91173	58.01	64.46	.12170E-03	0.76000
20	State Line 4	ST	279.7	13683.0	325375.71712	52.69	58.54	.12740E-03	0.66000
21	Powerton 5	ST	592.3	14275.3	607527.93136	46.45	51.62	.12672E-03	0.75000
22	Will County 2	ST	148.0	14423.3	136900.61828	41.89	46.55	.12785E-03	0.76000
23	Fisk 19	ST	316.0	14739.3	271134.38009	38.86	43.18	.12962E-03	0.79000
24	Joliet 8	ST	518.0	15257.3	386769.45686	33.82	37.57	.12170E-03	0.68000
25	Will County 3	ST	251.0	15508.3	165182.71838	29.81	33.12	.12968E-03	0.69000
26	State Line 3	ST	187.0	15695.3	114061.91725	27.62	30.69	.12832E-03	0.69000
27	Crawford 8	ST	319.0	16014.3	177151.76764	25.15	27.95	.13115E-03	0.69000
28	Will County 1	ST	151.0	16165.3	77132.25516	23.13	25.70	.12641E-03	0.68000
29	Powerton 6	ST	700.0	16865.3	301077.51390	19.48	21.64	.12641E-03	6.58000
30	Waukegan 6	ST	100.0	16965.3	37201.17237	16.85	18.72	.11334E-03	6.58000
31	Crawford 7	ST	213.0	17178.3	74198.31525	15.78	17.53	.13023E-03	0.74000
32	Kincaid 2	ST	554.0	17732.3	163828.86266	13.39	14.88	.30518E-03	0.67000
33	New NG Pkr 1	UN	280.0	18012.3	74648.91091	12.07	12.58	.30833E-03	0.76000
34	New NG Pkr 2	UN	280.0	18292.3	65809.54531	10.64	11.09	.30833E-03	0.76700
35	New NG Pkr 3	UN	118.5	18410.8	25495.30276	9.74	10.15	.30833E-03	0.76800
36	New NG Pkr 4	UN	280.0	18690.8	55084.78588	8.91	9.28	.30833E-03	0.00060
37	New NG Pkr 5	UN	140.0	18830.8	25144.41582	8.13	8.47	.30833E-03	0.00060
38	New NG Pkr 6	UN	258.8	19089.6	42651.98926	7.46	7.78	.30833E-03	0.00060
39	New NG Pkr 7	UN	280.0	19369.6	41274.54918	6.68	6.95	.30833E-03	0.00060
40	New NG Pkr 8	UN	280.0	19649.6	36954.99180	5.98	6.23	.30833E-03	0.00060
41	New NG Pkr 9	UN	280.0	19929.6	33280.70862	5.38	5.61	.30833E-03	0.00060
42	New NG Pkr 10	UN	140.0	20069.6	15450.06260	5.00	5.21	.30833E-03	0.00060
43	New NG Pkr 11	UN	280.0	20349.6	28736.77513	4.65	4.84	.30833E-03	0.00060
44	New NG Pkr 12	UN	280.0	20629.6	26203.27083	4.24	4.41	.30833E-03	0.00060
45	New NG Pkr 13	UN	140.0	20769.6	12256.35072	3.96	4.13	.30833E-03	0.00060
46	New NG Pkr 14	UN	280.0	21049.6	22914.05019	3.71	3.86	.30833E-03	0.00060
47	New NG Pkr 15	UN	118.5	21168.1	9110.31233	3.48	3.63	.30833E-03	0.00060
48	New NG Pkr 16	UN	280.0	21448.1	20166.38273	3.26	3.40	.30833E-03	0.00060
49	Kincaid 1	ST	511.4	21959.5	30166.68036	2.67	2.97	.30518E-03	0.00060
50	New NG Pkr 17	UN	140.0	22099.5	7952.22348	2.57	2.68	.30833E-03	0.00060
51	New NG Pkr 18	UN	280.0	22379.5	14657.28580	2.37	2.47	.30833E-03	0.00060
52	New NG Pkr 19	UN	140.0	22519.5	6737.88771	2.18	2.27	.30833E-03	0.00060
53	New NG Pkr 20	UN	280.0	22799.5	12296.56623	1.99	2.07	.30833E-03	0.00060
54	New NG Pkr 21	UN	280.0	23079.5	10806.50968	1.75	1.82	.30833E-03	0.00060
55	New NG Pkr 22	UN	280.0	23359.5	9396.65599	1.52	1.58	.30833E-03	0.00060
56	New NG Pkr 23	UN	280.0	23639.5	8079.59422	1.31	1.36	.30833E-03	0.00060
57	Collins 1-3	ST	1638.0	25277.5	24696.25347	0.68	0.76	.33183E-03	0.00060
58	Collins 4-5	ST	1060.0	26337.5	6393.37414	0.27	0.30	.40427E-03	0.00060
59	Old Oil Pkr's	GT	426.0	26763.5	1337.27334	0.14	0.17	.59299E-03	0.00060
60	Old NG Pkr's	GT	602.0	27365.5	1210.01239	0.09	0.11	.67359E-03	0.24300

Total Expected Generation	29963858.02638
Total Energy Demand	29946973.16792
Final EUSE	1548.84031
Difference	18433.69877
Final LOLP	0.85733E-03
Total Prod Cost w/eta($)	0.22424E+09
Tot Prod Cost w/o eta($)	0.19985E+09

Table C.4.4 Results of ASE Calculation for Commonwealth Edison Summer 2010 - Emission constrained dispatch - Base Case Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Average Emission calculation for file .

Dispatch Order	Unit Name	Expected Generation(MWh)	CO	NOx	SO2	TSP	VOC	CO2
			-----Generation Emissions in Tons---					
1	La Salle 2	2152005.12000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	1986497.85600	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	1478476.80000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	2135577.60000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	2066171.32800	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	1587309.12000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	1196973.55312	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	1015397.32867	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	2263940.78905	0.00	0.00	0.00	0.00	0.00	0.00
12	CC 1	883535.58039	7.70	230.87	338.61	384.78	19.24	819580.86
13	CC 2	862768.52396	7.51	225.44	330.65	375.74	18.79	800317.02
14	CC 3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
15	Waukegan 7	612799.03785	98.34	1057.18	2274.16	307.32	15.37	654588.87
16	Waukegan 8	538000.62457	87.80	856.07	1975.54	274.38	13.72	584430.08
17	Will County 4	812231.27988	128.27	1603.34	3046.35	400.84	20.04	853780.97
18	HScoal	1248495.57893	199.76	2496.99	4744.28	624.25	31.21	1329647.79
19	Joliet 6	378367.04703	66.96	2111.20	1485.58	209.24	10.46	445674.76
20	Joliet 7	639149.91173	110.04	1650.54	2819.67	343.86	17.19	732427.45
21	State Line 4	325375.71712	53.78	1771.32	1109.17	168.06	8.40	357960.47
22	Powerton 5	607527.93136	102.06	3109.78	2200.77	318.95	15.95	679368.11
23	Will County 2	136900.61828	22.82	763.18	492.14	71.33	3.57	151922.72
24	Fisk 19	271134.38009	44.77	755.49	1035.30	139.91	7.00	297998.37
25	Joliet 8	386769.45686	68.07	797.71	1744.33	212.72	10.64	453100.42
26	Will County 3	165182.71838	27.43	394.36	642.97	85.73	4.29	132604.54
27	State Line 3	114061.91725	19.38	113.87	417.91	60.57	3.03	129007.45
28	Crawford 8	177151.76764	30.16	527.77	744.53	94.24	4.71	200741.30
29	Will County 1	77132.25516	13.83	458.27	293.98	43.23	2.16	92085.50
30	Powerton 6	301077.51390	54.43	2262.45	1156.74	170.11	8.51	362331.73
31	Waukegan 6	37201.17237	8.04	179.42	168.37	25.13	1.26	53525.60
32	Crawford 7	74198.31525	14.07	159.58	334.12	43.96	2.20	93640.13
33	Kincaid 2	163828.86266	29.67	1251.82	6101.45	92.73	4.64	197508.80
34	New NG Pkr 1	74648.91091	46.80	50.21	0.26	5.53	3.40	50634.36
35	New NG Pkr 2	65809.54531	41.30	44.30	0.23	4.88	3.00	44677.77
36	New NG Pkr 3	25495.30276	16.01	17.18	0.09	1.89	1.16	17323.80
37	New NG Pkr 4	55084.78588	34.63	37.15	0.19	4.09	2.52	37462.34
38	New NG Pkr 5	25144.41582	15.82	16.97	0.09	1.87	1.15	17115.30
39	New NG Pkr 6	42651.98926	26.86	28.81	0.15	3.17	1.95	29057.73
40	New NG Pkr 7	41274.54918	26.02	27.91	0.14	3.07	1.89	28143.88
41	New NG Pkr 8	36954.99180	23.31	25.01	0.13	2.76	1.70	25220.49
42	New NG Pkr 9	33280.70862	21.01	22.54	0.11	2.48	1.53	22732.72
43	New NG Pkr 10	15450.06260	9.76	10.47	0.05	1.15	0.71	10562.51
44	New NG Pkr 11	28736.77513	18.18	19.50	0.10	2.15	1.32	19663.14
45	New NG Pkr 12	26203.27083	16.59	17.79	0.09	1.96	1.21	17945.18
46	New NG Pkr 13	12256.35072	7.77	8.33	0.04	0.92	0.56	8400.99
47	New NG Pkr 14	22914.05019	14.53	15.59	0.08	1.72	1.06	15719.84
48	New NG Pkr 15	9110.31233	5.78	6.20	0.03	0.68	0.42	6255.41
49	New NG Pkr 16	20166.38273	12.81	13.74	0.07	1.51	0.93	13858.84
50	Kincaid 1	30166.68036	5.63	202.43	1158.23	17.60	0.88	37492.81
51	New NG Pkr 17	7952.22348	5.06	5.42	0.03	0.60	0.37	5469.70
52	New NG Pkr 18	14657.28580	9.33	10.01	0.05	1.10	0.68	10090.30
53	New NG Pkr 19	6737.88771	4.29	4.60	0.02	0.51	0.31	4642.47
54	New NG Pkr 20	12296.56623	7.84	8.41	0.04	0.93	0.57	8479.77
55	New NG Pkr 21	10806.50968	6.89	7.40	0.04	0.81	0.50	7458.65
56	New NG Pkr 22	9396.65599	6.00	6.44	0.03	0.71	0.44	6491.16
57	New NG Pkr 23	8079.59422	5.17	5.54	0.03	0.61	0.38	5590.96
58	Collins 1-3	24696.25347	4.94	33.96	118.39	0.46	0.15	18367.84
59	Collins 4-5	6393.37414	1.37	11.99	32.90	1.11	0.17	6939.37
60	Old Oil Pkr's	1337.27334	1.32	5.26	0.01	0.14	0.09	1304.91
61	Old NG Pkr's	1210.01239	1.18	3.94	2.40	0.29	0.24	1597.58
Storage Units								
N/A	CAES A	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES B	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES C	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES D	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES E	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
	Totals	30203858.02638	1643.91	23500.39	34770.92	4518.03	255.49	10008062.78
	Average Emissions (lb/MWh)		0.11	1.56	2.30	0.30	0.02	662.70

Table C.4.5 Results of Dispatch Calculation for Commonwealth Edison Summer 2010 - Economic Dispatch - Integrated Gasification Combined Cycle Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Dispatch Order	Unit Name	Tech-nology	CAP	CAP SUM	Expected Generation(MWh)	Adjusted Capacity	Energy Factor(%)
1	La Salle 2	NB	1048.0	1048.0	2152005.12000	93.00	100.00
2	La Salle 1	NB	967.4	2015.4	1986497.85600	93.00	100.00
3	Zion 1	NP	720.0	2735.4	1478476.80000	93.00	100.00
4	Zion 2	NP	1040.0	3775.4	2135577.60000	93.00	100.00
5	Byron 1	NP	1120.0	4895.4	2299852.80000	93.00	100.00
6	Byron 2	NP	1120.0	6015.4	2299852.80000	93.00	100.00
7	Braidwood 1	NP	1006.2	7021.6	2066171.32800	93.00	100.00
8	Dresden 3	NB	773.0	7794.6	1587309.12000	93.00	100.00
9	Quad Cities 2	NB	577.0	8371.6	1196918.98253	93.95	101.02
10	Quad Cities 1	NB	487.4	8859.0	1014463.23744	94.27	101.36
11	Braidwood 2	NP	1090.0	9949.0	2259123.69311	93.87	100.93
12	Waukegan 7	ST	328.0	10277.0	646798.39946	89.31	99.23
13	CC 1	CC	420.0	10697.0	867572.10092	93.55	97.45
14	CC 2	CC	420.0	11117.0	841557.86922	90.75	94.53
15	CC 3	ST	417.0	11534.0	801410.17896	87.04	90.67
16	Waukegan 8	ST	297.0	11831.0	511642.32468	78.02	86.69
17	Joliet 7	ST	499.0	12330.0	809828.15247	73.50	81.67
18	Will County 4	ST	470.8	12800.8	702167.42714	67.55	75.05
19	Joliet 8	ST	518.0	13318.8	697334.32749	60.97	67.74
20	Joliet 6	ST	269.5	13588.3	332116.43422	55.81	62.01
21	HScoal	ST	750.0	14338.3	858930.60023	51.87	54.03
22	Fisk 19	ST	316.0	14654.3	289185.43522	41.45	46.05
23	State Line 4	ST	279.7	14934.0	233986.82844	37.89	42.10
24	Will County 3	ST	251.0	15185.0	193254.07480	34.87	38.74
25	Powerton 5	ST	592.3	15777.3	395056.22084	30.21	33.56
26	Will County 2	ST	148.0	15925.3	87714.99848	26.84	29.82
27	Crawford 8	ST	319.0	16244.3	173597.33571	24.65	27.38
28	State Line 3	ST	187.0	16431.3	93134.69034	22.56	25.06
29	Kincaid 2	ST	554.0	16985.3	238912.05499	19.53	21.70
30	Will County 1	ST	151.0	17136.3	57374.87901	17.21	19.12
31	Powerton 6	ST	700.0	17836.3	222753.03026	14.41	16.01
32	Kincaid 1	ST	511.4	18347.7	127965.62874	11.33	12.59
33	Waukegan 6	ST	100.0	18447.7	22266.36387	10.08	11.20
34	Crawford 7	ST	213.0	18660.7	44363.59756	9.43	10.48
35	New NG Pkr 1	UN	280.0	18940.7	56171.02125	9.09	9.46
36	New NG Pkr 2	UN	280.0	19220.7	49785.08326	8.05	8.39
37	New NG Pkr 3	UN	118.5	19339.2	19384.90930	7.41	7.72
38	New NG Pkr 4	UN	280.0	19619.2	42145.56492	6.82	7.10
39	New NG Pkr 5	UN	140.0	19759.2	19378.99957	6.27	6.53
40	New NG Pkr 6	UN	258.8	20018.0	33122.85601	5.80	6.04
41	New NG Pkr 7	UN	280.0	20298.0	32388.02606	5.24	5.46
42	New NG Pkr 8	UN	280.0	20578.0	29293.04887	4.74	4.94
43	New NG Pkr 9	UN	280.0	20858.0	26601.09916	4.30	4.48
44	New NG Pkr 10	UN	140.0	20998.0	12406.09495	4.01	4.18
45	New NG Pkr 11	UN	280.0	21278.0	23134.50291	3.74	3.90
46	New NG Pkr 12	UN	280.0	21558.0	21102.51499	3.41	3.56
47	New NG Pkr 13	UN	140.0	21698.0	9850.40132	3.19	3.32
48	New NG Pkr 14	UN	280.0	21978.0	18335.15481	2.97	3.09
49	New NG Pkr 15	UN	118.5	22096.5	7248.73484	2.77	2.89
50	New NG Pkr 16	UN	280.0	22376.5	15924.73301	2.58	2.68
51	New NG Pkr 17	UN	140.0	22516.5	7366.96423	2.38	2.48
52	New NG Pkr 18	UN	280.0	22796.5	13550.05992	2.19	2.28
53	New NG Pkr 19	UN	140.0	22936.5	6217.54782	2.01	2.10
54	New NG Pkr 20	UN	280.0	23216.5	11330.45456	1.83	1.91
55	New NG Pkr 21	UN	280.0	23496.5	9943.96764	1.61	1.68
56	New NG Pkr 22	UN	280.0	23776.5	8641.30361	1.40	1.46
57	New NG Pkr 23	UN	280.0	24056.5	7431.29947	1.20	1.25
58	Collins 1-3	ST	1638.0	25694.5	22852.36579	0.63	0.70
59	Collins 4-5	ST	1060.0	26754.5	6018.56549	0.26	0.29
60	Old Oil Pkr's	GT	426.0	27180.5	1277.49135	0.14	0.16
61	Old NG Pkr's	GT	602.0	27782.5	1169.36006	0.09	0.10

Total Expected Generation	30237244.41530
Total Energy Demand	30223908.12956
Final EUSE	1549.76440
Difference	14886.05014
Final LOLP	0.83371E-03
Final numEUSE	1550.50459
Final numLOLP	0.87881E-03

Table C.4.6 Results of ASE Calculation for Commonwealth Edison
Summer 2010 - Economic Dispatch - Integrated Gasification Combined Cycle
Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Average Emission calculation for file !.

Dispatch Order	Unit Name	Expected Generation(MWh)	-----Generation Emissions in Tons--- CO	NOx	SO2	TSP	VOC	CO2
1	La Salle 2	2152005.12000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	1986497.85600	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	1478476.80000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	2135577.60000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	2299352.80000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	2066171.32800	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	1587309.12000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	1196918.98253	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	1014463.23744	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	2259123.69311	0.00	0.00	0.00	0.00	0.00	0.00
12	Waukegan 7	646798.39946	103.80	1115.83	2400.33	324.37	16.22	690906.82
13	CC 1	867572.10092	7.56	226.70	332.49	377.83	18.89	804772.89
14	CC 2	841557.86922	7.33	219.90	322.52	366.50	18.32	780641.70
15	CC 3	801410.17896	6.98	209.41	307.13	349.01	17.45	743400.10
16	Waukegan 8	511642.32468	83.50	814.13	1878.75	260.94	13.05	555797.06
17	Joliet 7	809828.15247	139.42	2091.30	3572.64	435.69	21.78	928014.47
18	Will County 4	702167.42714	110.89	1386.08	2633.55	346.52	17.33	738086.80
19	Joliet 8	697334.32749	122.73	1438.25	3144.98	383.53	19.18	816927.16
20	Joliet 6	332116.43422	58.77	1853.13	1303.99	183.66	9.18	391196.63
21	HScoal	858930.60023	137.43	1717.86	3263.94	429.47	21.47	914761.09
22	Fisk 19	289185.43522	47.75	805.79	1104.23	149.22	7.46	317837.93
23	State Line 4	233986.82844	38.67	1273.80	797.64	120.85	6.04	257419.44
24	Will County 3	193254.07480	32.10	461.37	752.24	100.30	5.01	213636.58
25	Powerton 5	395056.22084	66.37	2022.19	1431.09	207.40	10.37	441771.62
26	Will County 2	87714.99848	14.62	488.98	315.33	45.70	2.29	97339.97
27	Crawford 8	173597.33571	29.55	517.18	729.59	92.35	4.62	196713.56
28	State Line 3	93134.69034	15.83	92.97	341.24	49.45	2.47	105338.13
29	Kincaid 2	238912.05499	43.27	1825.53	8897.75	135.22	6.76	288027.60
30	Will County 1	57374.87901	10.29	340.88	218.68	32.16	1.61	68497.86
31	Powerton 6	222753.03026	40.27	1673.88	855.82	125.86	6.29	258072.13
32	Kincaid 1	127965.62874	23.89	858.68	4913.15	74.67	3.73	159042.72
33	Waukegan 6	22266.36387	4.81	107.39	100.77	15.04	0.75	32037.18
34	Crawford 7	44363.59756	8.41	95.42	199.77	26.29	1.31	55987.97
35	New NG Pkr 1	56171.02125	35.53	38.11	0.19	4.20	2.58	38435.02
36	New NG Pkr 2	49785.08326	31.49	33.78	0.17	3.72	2.29	34065.44
37	New NG Pkr 3	19384.90930	12.26	13.15	0.07	1.45	0.89	13264.12
38	New NG Pkr 4	42145.56492	26.66	28.60	0.15	3.15	1.94	28838.10
39	New NG Pkr 5	19378.99957	12.26	13.15	0.07	1.45	0.89	13260.08
40	New NG Pkr 6	33122.85601	20.95	22.47	0.11	2.48	1.52	22664.31
41	New NG Pkr 7	32388.02606	20.49	21.98	0.11	2.42	1.49	22161.51
42	New NG Pkr 8	29293.04887	18.53	19.88	0.10	2.19	1.35	20043.77
43	New NG Pkr 9	26601.09916	16.83	18.05	0.09	1.99	1.22	18201.80
44	New NG Pkr 10	12406.09495	7.85	8.42	0.04	0.93	0.57	8488.87
45	New NG Pkr 11	23134.50291	14.63	15.70	0.08	1.73	1.06	15829.78
46	New NG Pkr 12	21102.51499	13.35	14.32	0.07	1.58	0.97	14439.40
47	New NG Pkr 13	9850.40132	6.23	6.68	0.03	0.74	0.45	6740.14
48	New NG Pkr 14	18335.15481	11.60	12.44	0.06	1.37	0.84	12545.83
49	New NG Pkr 15	7248.73484	4.58	4.92	0.03	0.54	0.33	4959.95
50	New NG Pkr 16	15924.73301	10.07	10.80	0.05	1.19	0.73	10896.50
51	New NG Pkr 17	7366.96423	4.66	5.00	0.03	0.55	0.34	5040.85
52	New NG Pkr 18	13550.05992	8.57	9.19	0.05	1.01	0.62	9271.63
53	New NG Pkr 19	6217.54782	3.93	4.22	0.02	0.46	0.29	4254.36
54	New NG Pkr 20	11330.45456	7.17	7.69	0.04	0.85	0.52	7752.86
55	New NG Pkr 21	9943.96764	6.29	6.75	0.03	0.74	0.46	6804.16
56	New NG Pkr 22	8641.30361	5.47	5.86	0.03	0.65	0.40	5912.81
57	New NG Pkr 23	7431.29947	4.70	5.04	0.03	0.56	0.34	5084.87
58	Collins 1-3	22852.36579	4.57	31.42	109.55	0.43	0.14	16995.45
59	Collins 4-5	6018.56549	1.29	11.29	30.97	1.05	0.16	6532.55
60	Old Oil Pkr's	1277.49135	1.26	5.03	0.01	0.14	0.08	1246.58
61	Old NG Pkr's	1169.36006	1.14	3.81	2.32	0.28	0.23	1543.91
Storage Units								
N/A	CAES A	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES B	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES C	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES D	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES E	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
	Totals	30477244.41530	1519.39	22071.04	39962.40	4676.10	258.17	10278623.05
	Average Emissions (lb/MWh)		0.10	1.45	2.62	0.31	0.02	674.51

Table C.4.7 Results of ISE Calculation for Commonwealth Edison
Summer 2010 - Economic Dispatch - Integrated Gasification Combined Cycle
Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Marginal Emission calculation between files DISPATCH.DAT and baseDISPATCH.DAT.

Dispatch Order	Unit Name	Expected Generation(MWh)	CO	NOx	SO2	TSP	VOC	CO2
			-----Generation Emissions in Tons---					
1	La Salle 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	-54.57059	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	-934.09123	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	-4817.09594	0.00	0.00	0.00	0.00	0.00	0.00
12	Waukegan 7	-1504.06893	-0.24	-2.59	-5.58	-0.75	-0.04	-1506.64
13	CC 1	-1438.06532	-0.01	-0.39	-0.57	-0.65	-0.03	-1330.35
14	CC 2	-182.63836	0.00	-0.05	-0.07	-0.03	0.00	-159.42
15	CC 3	801410.17896	6.98	209.41	307.13	349.01	17.45	743400.10
16	Waukegan 8	-26358.29989	-4.30	-41.94	-96.79	-13.44	-0.67	-29633.02
17	Joliet 7	-49150.28634	-3.46	-126.93	-216.83	-26.44	-1.32	-56323.28
18	Will County 4	-49621.42528	-7.84	-97.95	-186.11	-24.49	-1.22	-52159.81
19	Joliet 8	-55316.04291	-9.74	-114.09	-249.48	-30.42	-1.52	-64802.74
20	Joliet 6	-28134.95027	-4.98	-156.99	-110.47	-15.56	-0.78	-33139.83
21	HScoal	-77185.45463	-12.35	-154.37	-293.30	-38.59	-1.93	-82202.51
22	Fisk 19	-26936.60343	-4.45	-75.06	-102.85	-13.90	-0.69	-29605.48
23	State Line 4	-21953.94790	-3.63	-119.52	-74.84	-11.34	-0.57	-24152.53
24	Will County 3	-18164.88465	-3.02	-43.37	-70.71	-9.43	-0.47	-20080.74
25	Powerton 5	-36960.33757	-6.21	-189.19	-133.89	-19.40	-0.97	-41330.90
26	Will County 2	-8136.20734	-1.36	-45.36	-29.25	-4.24	-0.21	-9028.99
27	Crawford 8	-15982.54006	-2.72	-47.62	-67.17	-8.50	-0.43	-18110.78
28	State Line 3	-8499.11877	-1.44	-8.48	-31.14	-4.51	-0.23	-9612.76
29	Kincaid 2	-21441.16678	-3.88	-163.83	-798.53	-12.14	-0.61	-25849.04
30	Will County 1	-5062.98855	-0.91	-30.08	-19.30	-2.84	-0.14	-6044.52
31	Powerton 6	-19068.32769	-3.45	-143.29	-73.26	-10.77	-0.54	-22947.78
32	Kincaid 1	-10372.15906	-1.94	-69.60	-398.23	-6.05	-0.30	-12891.09
33	Waukegan 6	-1744.59739	-0.38	-8.41	-7.90	-1.13	-0.06	-2510.15
34	Crawford 7	-3400.16135	-0.64	-7.31	-15.31	-2.01	-0.10	-4291.09
35	New NG Pkr 1	-4149.82005	-2.62	-2.82	-0.01	-0.31	-0.19	-2939.51
36	New NG Pkr 2	-3507.16886	-2.22	-2.38	-0.01	-0.26	-0.16	-2399.78
37	New NG Pkr 3	-1319.12311	-0.83	-0.90	0.00	-0.10	-0.06	-902.61
38	New NG Pkr 4	-2772.84836	-1.75	-1.88	-0.01	-0.21	-0.13	-1897.32
39	New NG Pkr 5	-1234.07428	-0.78	-0.84	0.00	-0.09	-0.06	-844.42
40	New NG Pkr 6	-2055.90184	-1.30	-1.39	-0.01	-0.15	-0.09	-1406.75
41	New NG Pkr 7	-1963.42350	-1.24	-1.33	-0.01	-0.15	-0.09	-1343.47
42	New NG Pkr 8	-1761.99600	-1.11	-1.20	-0.01	-0.13	-0.08	-1205.65
43	New NG Pkr 9	-1617.16590	-1.02	-1.10	-0.01	-0.12	-0.07	-1106.55
44	New NG Pkr 10	-768.30701	-0.49	-0.52	0.00	-0.06	-0.04	-525.71
45	New NG Pkr 11	-1473.01500	-0.93	-1.00	-0.01	-0.11	-0.07	-1007.91
46	New NG Pkr 12	-1405.23302	-0.89	-0.95	0.00	-0.11	-0.06	-961.53
47	New NG Pkr 13	-680.60749	-0.43	-0.46	0.00	-0.05	-0.03	-465.71
48	New NG Pkr 14	-1316.59685	-0.83	-0.89	0.00	-0.10	-0.06	-900.88
49	New NG Pkr 15	-539.16844	-0.34	-0.37	0.00	-0.04	-0.02	-368.93
50	New NG Pkr 16	-1225.05360	-0.77	-0.83	0.00	-0.09	-0.06	-838.24
51	New NG Pkr 17	-585.25925	-0.37	-0.40	0.00	-0.04	-0.03	-400.46
52	New NG Pkr 18	-1107.22588	-0.70	-0.75	0.00	-0.08	-0.05	-757.62
53	New NG Pkr 19	-520.33989	-0.33	-0.35	0.00	-0.04	-0.02	-356.04
54	New NG Pkr 20	-966.11167	-0.61	-0.66	0.00	-0.07	-0.04	-661.06
55	New NG Pkr 21	-862.54204	-0.55	-0.59	0.00	-0.06	-0.04	-590.19
56	New NG Pkr 22	-755.35238	-0.48	-0.51	0.00	-0.06	-0.03	-516.85
57	New NG Pkr 23	-648.29475	-0.41	-0.44	0.00	-0.05	-0.03	-443.60
58	Collins 1-3	-1843.88768	-0.37	-2.54	-8.84	-0.03	-0.01	-1371.39
59	Collins 4-5	-374.80865	-0.08	-0.70	-1.93	-0.07	-0.01	-406.82
60	Old Oil Pkr's	-59.78199	-0.06	-0.24	0.00	-0.01	0.00	-58.34
61	Old NG Pkr's	-40.65233	-0.04	-0.13	-0.08	-0.01	-0.01	-53.67
Storage Units								
N/A	CAES A	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES B	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES C	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES D	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES E	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	Totals	273386.38890	-96.53	-1463.16	-2685.40	89.67	3.05	171895.60
	Average Marginal Emissions (lb/MWh)		-0.71	-10.70	-19.65	0.66	0.02	1257.53
	Actual Emissions Responsibility (tons)		13.63	197.98	358.47	41.95	2.32	92201.11
	Average Actual Emissions (lb/MWh)		0.10	1.45	2.62	0.31	0.02	674.51

Table C.4.8 Results of Dispatch Calculation for Commonwealth Edison Summer 2010 - Economic Dispatch - Combustion Turbine Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Dispatch Order	Unit Name	Tech-nology	CAP	CAP SUM	Expected Generation(MWh)	Adjusted Capacity	Energy Factor(%)
1	La Salle 2	NB	1048.0	1048.0	2152005.12000	93.00	100.00
2	La Salle 1	NB	967.4	2015.4	1986497.85600	93.00	100.00
3	Zion 1	NP	720.0	2735.4	1478476.80000	93.00	100.00
4	Zion 2	NP	1040.0	3775.4	2135577.60000	93.00	100.00
5	Byron 1	NP	1120.0	4895.4	2299852.80000	93.00	100.00
6	Byron 2	NP	1120.0	6015.4	2299852.80000	93.00	100.00
7	Braidwood 1	NP	1006.2	7021.6	2066171.32800	93.00	100.00
8	Dresden 3	NB	773.0	7794.6	1587309.12000	93.00	100.00
9	Quad Cities 2	NB	577.0	8371.6	1196918.98253	93.00	100.00
10	Quad Cities 1	NB	487.4	8859.0	1014463.23744	93.95	101.02
11	Braidwood 2	NP	1090.0	9949.0	2259123.69311	94.27	101.36
12	Waukegan 7	ST	328.0	10277.0	646798.39946	93.87	100.93
13	CC 1	CC	420.0	10697.0	867572.10092	89.31	99.23
14	CC 2	CC	420.0	11117.0	841557.86922	93.55	97.45
15	Waukegan 8	ST	297.0	11414.0	538977.59963	90.75	94.53
16	Joliet 7	ST	499.0	11913.0	863210.63875	82.19	91.32
17	Will County 4	ST	470.8	12383.8	759115.96767	78.35	87.05
18	Joliet 8	ST	518.0	12901.8	764634.97766	73.03	81.14
19	Joliet 6	ST	269.5	13171.3	367958.23175	66.85	74.28
20	HScoal	ST	750.0	13921.3	964046.17588	61.84	68.71
21	Fisk 19	ST	316.0	14237.3	328658.52502	58.22	60.64
22	State Line 4	ST	279.7	14517.0	267455.49463	47.10	52.34
23	Will County 3	ST	251.0	14768.0	221954.41324	43.31	48.12
24	Powerton 5	ST	592.3	15360.3	457052.07096	40.05	44.50
25	Will County 2	ST	148.0	15508.3	102039.74531	34.95	38.83
26	Crawford 8	ST	319.0	15827.3	202716.15545	31.23	34.69
27	State Line 3	ST	187.0	16014.3	109174.79412	28.78	31.98
28	Kincaid 2	ST	554.0	16568.3	281709.10355	26.44	29.38
29	Will County 1	ST	151.0	16719.3	67990.51845	23.03	25.59
30	Powerton 6	ST	700.0	17419.3	265508.62433	20.39	22.66
31	Kincaid 1	ST	511.4	17930.7	153411.28380	17.18	19.09
32	Waukegan 6	ST	100.0	18030.7	26733.13277	13.59	15.10
33	Crawford 7	ST	213.0	18243.7	53273.21362	12.11	13.45
34	New NG Pkr 1	UN	280.0	18523.7	67411.28676	11.33	12.59
35	New NG Pkr 2	UN	280.0	18803.7	59614.81995	10.90	11.36
36	New NG Pkr 3	UN	118.5	18922.2	23153.11847	9.64	10.04
37	New NG Pkr 4	UN	280.0	19202.2	50161.42747	8.85	9.22
38	New NG Pkr 5	UN	140.0	19342.2	22964.67794	8.11	8.45
39	New NG Pkr 6	UN	258.8	19601.0	39064.12440	7.43	7.74
40	New NG Pkr 7	UN	280.0	19881.0	37935.82171	6.84	7.12
41	New NG Pkr 8	UN	280.0	20161.0	34068.65801	6.14	6.39
42	New NG Pkr 9	UN	280.0	20441.0	30744.51072	5.51	5.74
43	New NG Pkr 10	UN	140.0	20581.0	14284.11770	4.97	5.18
44	CT 1	CT	417.0	20998.0	38648.05708	4.62	4.81
45	New NG Pkr 11	UN	280.0	21278.0	23134.50291	4.20	4.37
46	New NG Pkr 12	UN	280.0	21558.0	21102.51499	3.74	3.90
47	New NG Pkr 13	UN	140.0	21698.0	9850.40132	3.41	3.56
48	New NG Pkr 14	UN	280.0	21978.0	18335.15481	3.19	3.32
49	New NG Pkr 15	UN	118.5	22096.5	7248.73484	2.97	3.09
50	New NG Pkr 16	UN	280.0	22376.5	15924.73301	2.77	2.89
51	New NG Pkr 17	UN	140.0	22516.5	7366.96423	2.58	2.68
52	New NG Pkr 18	UN	280.0	22796.5	13550.05992	2.38	2.48
53	New NG Pkr 19	UN	140.0	22936.5	6217.54782	2.19	2.28
54	New NG Pkr 20	UN	280.0	23216.5	11330.45456	2.01	2.10
55	New NG Pkr 21	UN	280.0	23496.5	9943.96764	1.83	1.91
56	New NG Pkr 22	UN	280.0	23776.5	8641.30361	1.61	1.68
57	New NG Pkr 23	UN	280.0	24056.5	7431.29947	1.40	1.46
58	Collins 1-3	ST	1638.0	25694.5	22852.36579	1.20	1.25
59	Collins 4-5	ST	1060.0	26754.5	6018.56549	0.63	0.70
60	Old Oil Pkr's	GT	426.0	27180.5	1277.49135	0.26	0.29
61	Old NG Pkr's	GT	602.0	27782.5	1169.36006	0.14	0.16
						0.09	0.10

Total Expected Generation	30237244.41530
Total Energy Demand	30223908.12956
Final EUSE	1549.76440
Difference	14886.05014
Final LOLP	0.83371E-03
Final numEUSE	1550.50459
Final numLOLP	0.87881E-03

Table C.4.9 Results of ASE Calculation for Commonwealth Edison Summer 2010 - Economic Dispatch - Combustion Turbine Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Average Emission calculation for file !.

Dispatch Order	Unit Name	Expected Generation(MWh)	-----Generation Emissions in Tons--- CO	NOx	SO2	TSP	VOC	CO2
1	La Salle 2	2152005.12000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	1986497.85600	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	1478476.80000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	2135577.60000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	2066171.32800	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	1587309.12000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	1196918.98253	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	1014463.23744	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	2259123.69311	0.00	0.00	0.00	0.00	0.00	0.00
12	Waukegan 7	646798.39946	103.80	1115.83	2400.33	324.37	16.22	690906.82
13	CC 1	867572.10092	7.56	226.70	332.49	377.83	18.89	804772.89
14	CC 2	841557.86922	7.33	219.90	322.52	366.50	18.32	780641.70
15	Waukegan 8	538977.59963	87.96	857.62	1979.13	274.88	13.74	585491.37
16	Joliet 7	863210.63875	143.61	2229.16	3808.14	464.41	23.22	989187.60
17	Will County 4	759115.96767	119.88	1498.49	2847.14	374.62	18.73	797948.54
18	Joliet 8	764634.97766	134.58	1577.06	3448.50	420.55	21.03	895769.98
19	Joliet 6	367958.23175	65.11	2053.12	1444.71	203.48	10.17	433414.32
20	HScoal	964046.17588	154.25	1928.09	3663.38	482.02	24.10	1025709.18
21	Fisk 19	328658.52502	54.27	915.77	1254.95	169.59	8.48	361222.01
22	State Line 4	267455.49463	44.21	1456.00	911.73	138.14	6.91	294239.83
23	Will County 3	221954.41324	36.86	529.89	863.96	115.19	5.76	245363.95
24	Powerton 5	457052.07096	76.78	2339.54	1655.67	239.95	12.00	521098.48
25	Will County 2	102039.74531	17.01	568.84	366.82	53.16	2.66	113236.57
26	Crawford 8	202716.15545	34.51	603.93	851.98	107.84	5.39	229709.84
27	State Line 3	109174.79412	18.55	108.99	400.01	57.97	2.90	123479.97
28	Kincaid 2	281709.10355	51.02	2152.54	10491.64	159.45	7.97	339622.86
29	Will County 1	67990.51845	12.19	403.95	259.14	38.11	1.91	82171.50
30	Powerton 6	265508.62433	48.00	1995.16	1020.08	150.01	7.50	319526.35
31	Kincaid 1	153411.28380	28.64	1029.43	5890.12	89.52	4.48	190667.98
32	Waukegan 6	26733.13277	5.78	128.94	120.99	18.06	0.90	38464.03
33	Crawford 7	53273.21362	10.10	114.58	239.89	31.56	1.58	67232.13
34	New NG Pkr 1	67411.28676	42.27	45.34	0.23	5.00	3.07	45725.08
35	New NG Pkr 2	59614.81995	37.41	40.13	0.20	4.42	2.72	40472.20
36	New NG Pkr 3	23153.11847	14.54	15.60	0.08	1.72	1.06	15732.31
37	New NG Pkr 4	50161.42747	31.53	33.83	0.17	3.73	2.29	34114.03
38	New NG Pkr 5	22964.67794	14.45	15.50	0.08	1.71	1.05	15631.60
39	New NG Pkr 6	39064.12440	24.60	26.39	0.13	2.91	1.79	26613.41
40	New NG Pkr 7	37935.82171	23.91	25.65	0.13	2.83	1.74	25867.30
41	New NG Pkr 8	34068.65801	21.49	23.06	0.12	2.54	1.56	23250.67
42	New NG Pkr 9	30744.51072	19.41	20.82	0.11	2.29	1.41	21000.35
43	New NG Pkr 10	14284.11770	9.03	9.68	0.05	1.07	0.66	9765.41
44	CT 1	38648.05708	24.44	26.22	0.13	2.89	1.78	26444.93
45	New NG Pkr 11	23134.50291	14.63	15.70	0.08	1.73	1.06	15829.78
46	New NG Pkr 12	21102.51499	13.36	14.33	0.07	1.58	0.97	14451.95
47	New NG Pkr 13	9850.40132	6.24	6.70	0.03	0.74	0.45	6751.86
48	New NG Pkr 14	18335.15481	11.63	12.47	0.06	1.37	0.85	12578.56
49	New NG Pkr 15	7248.73484	4.60	4.94	0.03	0.54	0.33	4977.20
50	New NG Pkr 16	15924.73301	10.12	10.85	0.06	1.20	0.74	10943.87
51	New NG Pkr 17	7366.96423	4.68	5.02	0.03	0.55	0.34	5067.15
52	New NG Pkr 18	13550.05992	8.62	9.25	0.05	1.02	0.63	9328.06
53	New NG Pkr 19	6217.54782	3.96	4.25	0.02	0.47	0.29	4283.95
54	New NG Pkr 20	11330.45456	7.22	7.75	0.04	0.85	0.53	7813.54
55	New NG Pkr 21	9943.96764	6.34	6.81	0.03	0.75	0.46	6863.33
56	New NG Pkr 22	8641.30361	5.52	5.92	0.03	0.65	0.40	5969.37
57	New NG Pkr 23	7431.29947	4.75	5.10	0.03	0.56	0.35	5142.35
58	Collins 1-3	22852.36579	4.57	31.42	109.55	0.43	0.14	16996.45
59	Collins 4-5	6018.56549	1.29	11.29	30.97	1.05	0.16	6532.55
60	Old Oil Pkr's	1277.49135	1.26	5.03	0.01	0.14	0.08	1246.58
61	Old NG Pkr's	1169.36006	1.14	3.81	2.32	0.28	0.23	1543.91
Storage Units								
N/A	CAES A	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES B	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES C	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES D	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES E	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
	Totals	30477244.41530	1692.85	24553.03	44718.43	4708.46	263.85	10397935.53
	Average Emissions (lb/MWh)		0.11	1.61	2.93	0.31	0.02	682.34

Table C.4.10 Results of ISE Calculation for Commonwealth Edison Summer 2010 - Economic Dispatch - Combustion Turbine Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Marginal Emission calculation between files evDISPATCH.DAT and baseDISPATCH.DAT.

Dispatch Order	Unit Name	Expected Generation(MWh)	CO	NOx	SO2	TSP	VOC	CO2
			------Generation Emissions in Tons---					
1	La Salle 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	-54.57059	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	-934.09123	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	-4817.09594	0.00	0.00	0.00	0.00	0.00	0.00
12	Waukegan 7	-1504.06893	-0.24	-2.59	-5.53	-0.75	-0.04	-1506.54
13	CC 1	-1488.06532	-0.01	-0.39	-0.57	-0.65	-0.03	-1380.35
14	CC 2	-182.63836	0.00	-0.05	-0.07	-0.08	0.00	-159.42
15	Waukegan 8	976.97506	0.15	1.55	3.59	0.50	0.02	1061.29
16	Joliet 7	4232.19994	0.73	10.93	13.67	2.23	0.11	4849.85
17	Will County 4	7327.11525	1.16	14.46	27.43	3.62	0.19	7701.93
18	Joliet 8	11984.60725	2.11	24.72	54.05	6.59	0.33	14039.97
19	Joliet 6	7706.84726	1.36	43.00	30.25	4.26	0.21	9077.82
20	HScoal	27930.12102	4.47	55.86	106.13	13.97	0.70	29745.53
21	Fisk 19	12536.48537	2.07	34.93	47.87	6.47	0.32	13778.60
22	State Line 4	11514.71829	1.90	62.69	39.25	5.95	0.30	12567.86
23	Will County 3	10535.45379	1.75	25.15	41.01	5.47	0:27	11646.63
24	Powerton 5	25035.51255	4.21	128.15	90.69	13.14	0.66	27995.96
25	Will County 2	6188.53949	1.03	34.50	22.25	3.22	0.16	6867.61
26	Crawford 8	13136.27968	2.24	39.14	55.21	6.99	0.35	14835.51
27	State Line 3	7540.98501	1.28	7.53	27.63	4.00	0.20	8529.08
28	Kincaid 2	21355.88178	3.87	163.18	795.35	12.09	0.60	25746.22
29	Will County 1	5552.65088	1.00	32.99	21.16	3.11	0.16	6629.12
30	Powerton 6	23687.26638	4.23	178.00	91.01	13.38	0.67	28506.44
31	Kincaid 1	15073.49600	2.81	101.15	578.74	8.80	0.44	18734.17
32	Waukegan 6	2722.17151	0.59	13.13	12.32	1.84	0.09	3916.70
33	Crawford 7	5509.45471	1.04	11.85	24.81	3.26	0.16	6953.07
34	New NG Pkr 1	7090.44546	4.45	4.77	0.02	0.53	0.32	4809.45
35	New NG Pkr 2	6322.56783	3.97	4.26	0.02	0.47	0.29	4292.36
36	New NG Pkr 3	2449.08606	1.54	1.65	0.01	0.18	0.11	1664.13
37	New NG Pkr 4	5243.01419	3.30	3.54	0.02	0.39	0.24	3565.70
38	New NG Pkr 5	2351.60409	1.48	1.59	0.01	0.17	0.11	1600.69
39	New NG Pkr 6	3885.36655	2.45	2.62	0.01	0.29	0.18	2647.00
40	New NG Pkr 7	3584.37215	2.26	2.42	0.01	0.27	0.16	2444.08
41	New NG Pkr 8	3013.61314	1.90	2.04	0.01	0.22	0.14	2056.69
42	New NG Pkr 9	2526.24566	1.60	1.71	0.01	0.19	0.12	1725.58
43	New NG Pkr 10	1109.71574	0.70	0.75	0.00	0.08	0.05	758.66
44	CT 1	38648.05708	24.44	26.22	0.13	2.89	1.78	25444.93
45	New NG Pkr 11	-1473.01500	-0.93	-1.00	-0.01	-0.11	-0.07	-1007.91
46	New NG Pkr 12	-1405.23302	-0.89	-0.95	0.00	-0.11	-0.06	-962.37
47	New NG Pkr 13	-680.60749	-0.43	-0.46	0.00	-0.05	-0.03	-466.52
48	New NG Pkr 14	-1316.59685	-0.83	-0.90	0.00	-0.10	-0.06	-903.23
49	New NG Pkr 15	-539.16844	-0.34	-0.37	0.00	-0.04	-0.02	-370.21
50	New NG Pkr 16	-1225.05360	-0.78	-0.83	0.00	-0.09	-0.06	-841.89
51	New NG Pkr 17	-585.25925	-0.37	-0.40	0.00	-0.04	-0.03	-402.55
52	New NG Pkr 18	-1107.22588	-0.70	-0.76	0.00	-0.08	-0.05	-762.23
53	New NG Pkr 19	-520.33989	-0.33	-0.36	0.00	-0.04	-0.02	-358.52
54	New NG Pkr 20	-966.11167	-0.62	-0.66	0.00	-0.07	-0.04	-666.24
55	New NG Pkr 21	-862.54204	-0.55	-0.59	0.00	-0.07	-0.04	-595.33
56	New NG Pkr 22	-755.35238	-0.48	-0.52	0.00	-0.06	-0.04	-521.79
57	New NG Pkr 23	-648.29475	-0.41	-0.44	0.00	-0.05	-0.03	-448.61
58	Collins 1-3	-1843.88768	-0.37	-2.54	-8.84	-0.03	-0.01	-1371.39
59	Collins 4-5	-374.80865	-0.08	-0.70	-1.93	-0.07	-0.01	-406.82
60	Old Oil Pkr's	-59.78199	-0.06	-0.24	0.00	-0.01	0.00	-58.34
61	Old NG Pkr's	-40.65233	-0.04	-0.13	-0.08	-0.01	-0.01	-53.67
Storage Units								
N/A	CAES A	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES B	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES C	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES D	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES E	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	Totals	273386.38890	77.65	1019.60	2070.63	122.11	8.78	291983.65
	Average Marginal Emissions (lb/MWh)		0.57	7.46	15.15	0.89	0.06	2136.09
	Actual Emissions Responsibility (tons)		15.19	220.25	401.13	42.24	2.37	93271.36
	Average Actual Emissions (lb/MWh)		0.11	1.61	2.93	0.31	0.02	682.34

Table C.4.11 Results of Dispatch Calculation for Commonwealth Edison Summer 2010 - Integrated Gasification Combined Cycle Emission Constrained Dispatch - Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Dispatch Order	Unit Name	Tech-nology	CAP	CAP SUM	Expected Generation(MWh)	Adjusted Capacity	Energy Factor(%)		
1	La Salle 2	NB	1043.0	1043.0	2152005.12000	93.00	100.00	.37090E-04	0.00000
2	La Salle 1	NB	967.4	2010.4	1986497.85600	93.00	100.00	.38980E-04	0.00000
3	Zion 1	NP	720.0	2735.4	1478476.80000	93.00	100.00	.39210E-04	0.00000
4	Zion 2	NP	1040.0	3775.4	2135577.60000	93.00	100.00	.39930E-04	0.00000
5	Byron 1	NP	1120.0	4895.4	2299852.80000	93.00	100.00	.41470E-04	0.00000
6	Byron 2	NP	1120.0	6015.4	2299852.80000	93.00	100.00	.42130E-04	0.00000
7	Braidwood 1	NP	1006.2	7021.6	2066171.32800	93.00	100.00	.42580E-04	0.00000
8	Dresden 3	NB	773.0	7794.6	1587309.12000	93.00	100.00	.35660E-04	0.00000
9	Quad Cities 2	NB	577.0	8371.6	1196918.98253	93.95	101.02	.40650E-04	0.00000
10	Quad Cities 1	NB	487.4	8859.0	1014463.23744	94.27	101.36	.40700E-04	0.00000
11	Braidwood 2	NP	1090.0	9949.0	2259123.69311	93.87	100.93	.43520E-04	0.00000
12	CC 1	CC	420.0	10369.0	831536.24614	95.06	99.02	.10960E-03	0.82000
13	CC 2	CC	420.0	10789.0	861547.78966	92.90	96.77	.10960E-03	0.82000
14	CC 3	CC	417.0	11206.0	827442.00474	89.87	93.61	.10960E-03	0.72000
15	Waukegan 7	ST	328.0	11534.0	586812.50802	81.03	90.03	.11522E-03	0.71000
16	Waukegan 8	ST	297.0	11831.0	511642.32463	78.02	86.69	.11462E-03	0.74000
17	Will County 4	ST	470.8	12301.8	765993.79695	73.69	81.87	.12972E-03	0.08300
18	HScoal	ST	750.0	13051.8	1163695.39418	70.27	73.20	.12996E-03	0.08300
19	Joliet 6	ST	269.5	13321.3	349696.69489	58.77	65.30	.11807E-03	0.08900
20	Joliet 7	ST	499.0	13820.3	588053.66665	53.37	59.30	.12141E-03	0.76000
21	State Line 4	ST	279.7	14100.0	298410.03038	48.32	53.69	.12716E-03	0.65000
22	Powerton 5	ST	592.3	14692.3	555921.59016	42.51	47.23	.12647E-03	0.75000
23	Will County 2	ST	148.0	14840.3	125165.93490	38.30	42.56	.12760E-03	0.75000
24	Fisk 19	ST	316.0	15156.3	247844.91868	35.52	39.47	.12935E-03	0.79000
25	Joliet 8	ST	518.0	15674.3	353647.65207	30.92	34.36	.12141E-03	0.68000
26	Will County 3	ST	251.0	15925.3	151144.82045	27.27	30.30	.12941E-03	0.69000
27	State Line 3	ST	187.0	16112.3	104424.87866	25.29	28.10	.12807E-03	0.69000
28	Crawford 8	ST	319.0	16431.3	162307.14739	23.04	25.60	.13087E-03	0.69000
29	Will County 1	ST	151.0	16582.3	70721.42311	21.21	23.57	.12616E-03	0.68000
30	Powerton 6	ST	700.0	17282.3	276549.72649	17.89	19.88	.12616E-03	6.58000
31	Waukegan 6	ST	100.0	17382.3	34229.98401	15.50	17.23	.11310E-03	6.58000
32	Crawford 7	ST	213.0	17595.3	68335.20161	14.53	16.14	.12996E-03	0.74000
33	Kincaid 2	ST	554.0	18149.3	151291.18879	12.37	13.74	.30281E-03	0.67000
34	New NG Pkr 1	UN	280.0	18429.3	69164.68926	11.19	11.65	.30833E-03	0.76000
35	New NG Pkr 2	UN	280.0	18709.3	61151.93282	9.89	10.30	.30833E-03	0.76700
36	New NG Pkr 3	UN	118.5	18827.8	23743.27651	9.07	9.45	.30833E-03	0.76800
37	New NG Pkr 4	UN	280.0	19107.8	51418.34720	8.32	8.66	.30833E-03	0.00060
38	New NG Pkr 5	UN	140.0	19247.8	23527.42279	7.61	7.93	.30833E-03	0.00060
39	New NG Pkr 6	UN	258.8	19506.6	39996.77617	7.00	7.29	.30833E-03	0.00060
40	New NG Pkr 7	UN	280.0	19786.6	38806.08959	6.28	6.54	.30833E-03	0.00060
41	Kincaid 1	ST	511.4	20298.0	57075.95645	5.05	5.62	.30281E-03	0.00060
42	New NG Pkr 8	UN	280.0	20578.0	29293.04887	4.74	4.94	.30833E-03	0.00060
43	New NG Pkr 9	UN	280.0	20858.0	26601.09916	4.30	4.48	.30833E-03	0.00060
44	New NG Pkr 10	UN	140.0	20998.0	12406.09495	4.01	4.18	.30833E-03	0.00060
45	New NG Pkr 11	UN	280.0	21278.0	23134.50291	3.74	3.90	.30833E-03	0.00060
46	New NG Pkr 12	UN	280.0	21558.0	21102.51499	3.41	3.56	.30833E-03	0.00060
47	New NG Pkr 13	UN	140.0	21698.0	9850.40132	3.19	3.32	.30833E-03	0.00060
48	New NG Pkr 14	UN	280.0	21978.0	18335.15481	2.97	3.09	.30833E-03	0.00060
49	New NG Pkr 15	UN	118.5	22096.5	7248.73484	2.77	2.89	.30833E-03	0.00060
50	New NG Pkr 16	UN	280.0	22376.5	15924.73301	2.58	2.68	.30833E-03	0.00060
51	New NG Pkr 17	UN	140.0	22516.5	7366.96423	2.38	2.48	.30833E-03	0.00060
52	New NG Pkr 18	UN	280.0	22796.5	13550.05992	2.19	2.28	.30833E-03	0.00060
53	New NG Pkr 19	UN	140.0	22936.5	6217.54782	2.01	2.10	.30833E-03	0.00060
54	New NG Pkr 20	UN	280.0	23216.5	11330.45456	1.83	1.91	.30833E-03	0.00060
55	New NG Pkr 21	UN	280.0	23496.5	9943.96764	1.61	1.68	.30833E-03	0.00060
56	New NG Pkr 22	UN	280.0	23776.5	8641.30361	1.40	1.46	.30833E-03	0.00060
57	New NG Pkr 23	UN	280.0	24056.5	7431.29947	1.20	1.25	.30833E-03	0.00060
58	Collins 1-3	ST	1638.0	25694.5	22852.36579	0.63	0.70	.33155E-03	0.00060
59	Collins 4-5	ST	1060.0	26754.5	6018.56549	0.26	0.29	.40399E-03	0.00060
60	Old Oil Pkr's	GT	426.0	27180.5	1277.49135	0.14	0.16	.59290E-03	0.00060
61	Old NG Pkr's	GT	602.0	27782.5	1169.36006	0.09	0.10	.67359E-03	0.24300

Total Expected Generation	30237244.41530
Total Energy Demand	30223908.12956
Final EUSE	1549.76440
Difference	14886.05014
Final LOLP	0.83371E-03
Total Prod Cost w/eca($)	0.22341E-09
Tot Prod Cost w/o eca($)	0.20072E-09

Table C.4.12 Results of ASE Calculation for Commonwealth Edison Summer 2010 - Integrated Gasification Combined Cycle Emission Constrained Dispatch - Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Average Emission calculation for file evDISPATCH.DAT.

Dispatch Order	Unit Name	Expected Generation (MWh)	-----Generation Emissions in Tons--- CO	NOx	SO2	TSP	VOC	CO2
1	La Salle 2	2152005.12000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	1986497.85600	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	1478476.80000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	2135577.60000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	2066171.32300	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	1587309.12000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	1196913.98253	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	1014463.23744	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	2259123.69311	0.00	0.00	0.00	0.00	0.00	0.00
12	CC 1	881536.24614	7.68	230.35	337.84	383.91	19.20	817726.24
13	CC 2	861547.78966	7.50	225.12	330.18	375.20	18.76	799134.65
14	CC 3	827442.00474	7.21	216.21	317.11	360.35	18.02	767547.52
15	Waukegan 7	586812.50802	94.17	1012.35	2177.72	294.29	14.71	626830.19
16	Waukegan 8	511642.32468	83.50	814.13	1378.75	260.94	13.05	555797.06
17	Will County 4	765993.79695	120.97	1512.07	2372.94	373.02	18.90	805178.21
18	HScoal	1163695.39418	186.19	2327.39	4422.04	581.85	29.09	1239335.59
19	Joliet 6	349696.69489	61.88	1951.23	1373.01	193.38	9.67	411904.24
20	Joliet 7	588053.66665	101.24	1518.59	2594.26	316.37	15.82	673874.22
21	State Line 4	298410.03038	49.32	1624.52	1017.25	154.13	7.71	328294.30
22	Powerton 5	555921.59016	93.39	2845.62	2013.83	291.86	14.59	621659.32
23	Will County 2	125165.93490	20.87	697.76	449.96	65.21	3.26	138900.39
24	Fisk 19	247844.91868	40.92	690.60	946.37	127.89	6.39	272401.39
25	Joliet 8	353647.65207	62.24	729.40	1594.95	194.51	9.73	414298.22
26	Will County 3	151144.82045	25.10	360.84	588.33	78.44	3.92	167085.06
27	State Line 3	104424.87866	17.74	104.25	382.60	55.45	2.77	118107.67
28	Crawford 8	162307.14739	27.63	483.55	682.14	86.35	4.32	183919.97
29	Will County 1	70721.42311	12.68	420.18	269.55	39.64	1.98	84431.83
30	Powerton 6	276549.72649	50.00	2078.13	1062.50	156.25	7.81	332813.77
31	Waukegan 6	34229.98401	7.40	165.09	154.92	23.12	1.16	49250.61
32	Crawford 7	68335.20161	12.96	146.97	307.71	40.49	2.02	86240.73
33	Kincaid 2	151291.18879	27.40	1156.02	5634.51	85.63	4.29	182393.63
34	New NG Pkr 1	69164.68926	43.37	46.52	0.24	5.13	3.15	46914.41
35	New NG Pkr 2	61151.93282	38.38	41.17	0.21	4.54	2.79	41515.74
36	New NG Pkr 3	23743.27651	14.91	16.00	0.08	1.76	1.08	16133.32
37	New NG Pkr 4	51418.34720	32.32	34.67	0.18	3.82	2.35	34968.85
38	New NG Pkr 5	23527.42279	14.80	15.88	0.08	1.75	1.08	16014.65
39	New NG Pkr 6	39996.77617	25.19	27.02	0.14	2.98	1.83	27248.80
40	New NG Pkr 7	38806.08959	24.46	26.24	0.13	2.89	1.78	26460.71
41	Kincaid 1	57075.95645	10.66	382.99	2191.39	33.30	1.67	70937.14
42	New NG Pkr 8	29293.04887	18.48	19.82	0.10	2.18	1.34	19991.48
43	New NG Pkr 9	26601.09916	16.80	18.02	0.09	1.98	1.22	18170.15
44	New NG Pkr 10	12406.09495	7.84	8.41	0.04	0.93	0.57	8481.49
45	New NG Pkr 11	23134.50291	14.63	15.70	0.08	1.73	1.06	15829.78
46	New NG Pkr 12	21102.51499	13.36	14.33	0.07	1.58	0.97	14451.95
47	New NG Pkr 13	9850.40132	6.24	6.70	0.03	0.74	0.45	6751.86
48	New NG Pkr 14	18335.15481	11.63	12.47	0.06	1.37	0.85	12578.56
49	New NG Pkr 15	7248.73484	4.60	4.94	0.03	0.54	0.33	4977.20
50	New NG Pkr 16	15924.73301	10.12	10.85	0.06	1.20	0.74	10943.87
51	New NG Pkr 17	7366.96423	4.68	5.02	0.03	0.55	0.34	5067.15
52	New NG Pkr 18	13550.05992	8.62	9.25	0.05	1.02	0.63	9328.06
53	New NG Pkr 19	6217.54782	3.96	4.25	0.02	0.47	0.29	4283.95
54	New NG Pkr 20	11330.45456	7.22	7.75	0.04	0.85	0.53	7813.54
55	New NG Pkr 21	9943.96764	6.34	6.81	0.03	0.75	0.46	6863.33
56	New NG Pkr 22	8641.30361	5.52	5.92	0.03	0.65	0.40	5969.37
57	New NG Pkr 23	7431.29947	4.75	5.10	0.03	0.56	0.35	5142.35
58	Collins 1-3	22852.36579	4.57	31.42	109.55	0.43	0.14	16996.45
59	Collins 4-5	6018.56549	1.29	11.29	30.97	1.05	0.16	6532.55
60	Old Oil Pkr's	1277.49135	1.26	5.03	0.01	0.14	0.08	1245.58
61	Old NG Pkr's	1169.36006	1.14	3.81	2.32	0.28	0.23	1543.91
Storage Units								
N/A	CAES A	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES B	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES C	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES D	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES E	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
	Totals	30477244.41528	1527.95	22164.37	33744.84	4624.68	257.88	10197453.11
	Average Emissions (lb/MWh)		0.10	1.45	2.21	0.30	0.02	669.13

Table C.4.13 Results of ISE Calculation for Commonwealth Edison Summer 2010 - Integrated Gasification Combined Cycle Emission Constrained Dispatch - Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Marginal Emission calculation between files evDISPATCH.DAT and .

Dispatch Order	Unit Name	Expected Generation(MWh)	CO	NOx	SO2	TSP	VOC	CO2
			-----Generation Emissions in Tons---					
1	La Salle 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	-54.57059	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	-934.09123	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	-4817.09594	0.00	0.00	0.00	0.00	0.00	0.00
12	CC 1	-1999.33425	-0.02	-0.52	-0.77	-0.87	-0.04	-1354.61
13	CC 2	-1220.73430	-0.01	-0.32	-0.47	-0.53	-0.03	-1132.37
14	CC 3	827442.00474	7.21	216.21	317.11	360.35	13.02	767547.62
15	Waukegan 7	-25986.52983	-4.17	-44.83	-96.44	-13.03	-0.65	-27758.68
16	Waukegan 8	-25358.29989	-4.30	-41.94	-96.79	-13.44	-0.67	-28633.02
17	Will County 4	-46237.48293	-7.30	-91.27	-173.42	-22.82	-1.14	-48602.76
18	HScoal	-84800.18475	-13.57	-169.60	-322.24	-42.40	-2.12	-90312.20
19	Joliet 6	-28670.35214	-5.07	-159.97	-112.57	-15.85	-0.79	-33770.52
20	Joliet 7	-51096.24508	-8.80	-131.95	-225.42	-27.49	-1.37	-58553.23
21	State Line 4	-26965.68674	-4.46	-146.80	-91.92	-13.93	-0.70	-29666.17
22	Powerton 5	-51606.34120	-8.67	-264.16	-186.94	-27.09	-1.35	-57708.79
23	Will County 2	-11734.68338	-1.96	-65.42	-42.19	-6.11	-0.31	-13022.33
24	Fisk 19	-23289.46141	-3.85	-64.89	-88.93	-12.02	-0.60	-25596.98
25	Joliet 8	-33121.80479	-5.83	-68.31	-149.38	-18.22	-0.91	-38802.19
26	Will County 3	-14037.89793	-2.33	-33.51	-54.64	-7.29	-0.36	-15518.48
27	State Line 3	-9637.03859	-1.64	-9.62	-35.31	-5.12	-0.26	-10899.78
28	Crawford 8	-14844.62025	-2.53	-44.23	-62.39	-7.90	-0.39	-16821.33
29	Will County 1	-6410.83205	-1.15	-38.09	-24.43	-3.59	-0.13	-7653.67
30	Powerton 6	-24527.78741	-4.43	-184.31	-94.24	-13.86	-0.69	-29517.97
31	Waukegan 6	-2971.18836	-0.64	-14.33	-13.45	-2.01	-0.10	-4274.99
32	Crawford 7	-5863.11364	-1.11	-12.61	-26.40	-3.47	-0.17	-7399.40
33	Kincaid 2	-12537.67387	-2.27	-95.80	-466.94	-7.10	-0.35	-15115.17
34	New NG Pkr 1	-5484.22165	-3.44	-3.69	-0.02	-0.41	-0.25	-3719.95
35	New NG Pkr 2	-4657.61249	-2.92	-3.14	-0.02	-0.35	-0.21	-3162.03
36	New NG Pkr 3	-1752.02625	-1.10	-1.18	-0.01	-0.13	-0.08	-1190.48
37	New NG Pkr 4	-3666.43868	-2.30	-2.47	-0.01	-0.27	-0.17	-2493.49
38	New NG Pkr 5	-1616.99303	-1.02	-1.09	-0.01	-0.12	-0.07	-1100.65
39	New NG Pkr 6	-2655.21309	-1.67	-1.79	-0.01	-0.20	-0.12	-1808.93
40	New NG Pkr 7	-2468.45959	-1.56	-1.67	-0.01	-0.18	-0.11	-1683.17
41	Kincaid 1	26909.27609	5.02	180.57	1033.16	15.70	0.79	33444.33
42	New NG Pkr 8	-7661.94293	-4.83	-5.19	-0.03	-0.57	-0.35	-5229.01
43	New NG Pkr 9	-6679.60946	-4.22	-4.52	-0.02	-0.50	-0.31	-4562.57
44	New NG Pkr 10	-3043.96765	-1.92	-2.06	-0.01	-0.23	-0.14	-2081.02
45	New NG Pkr 11	-5602.27222	-3.54	-3.80	-0.02	-0.42	-0.26	-3833.35
46	New NG Pkr 12	-5100.75584	-3.23	-3.46	-0.02	-0.38	-0.23	-3493.23
47	New NG Pkr 13	-2405.94940	-1.52	-1.64	-0.01	-0.18	-0.11	-1649.13
48	New NG Pkr 14	-4578.89538	-2.90	-3.11	-0.02	-0.34	-0.21	-3141.28
49	New NG Pkr 15	-1861.57749	-1.18	-1.27	-0.01	-0.14	-0.09	-1278.21
50	New NG Pkr 16	-4241.64972	-2.69	-2.89	-0.01	-0.32	-0.20	-2914.97
51	New NG Pkr 17	-585.25925	-0.37	-0.40	0.00	-0.04	-0.03	-402.55
52	New NG Pkr 18	-1107.22588	-0.70	-0.76	0.00	-0.08	-0.05	-762.23
53	New NG Pkr 19	-520.33989	-0.33	-0.36	0.00	-0.04	-0.02	-358.52
54	New NG Pkr 20	-966.11167	-0.62	-0.66	0.00	-0.07	-0.04	-666.24
55	New NG Pkr 21	-862.54204	-0.55	-0.59	0.00	-0.07	-0.04	-595.33
56	New NG Pkr 22	-755.35238	-0.48	-0.52	0.00	-0.06	-0.04	-521.79
57	New NG Pkr 23	-648.29475	-0.41	-0.44	0.00	-0.05	-0.03	-448.61
58	Collins 1-3	-1843.88768	-0.37	-2.54	-8.84	-0.03	-0.01	-1371.39
59	Collins 4-5	-374.80865	-0.08	-0.70	-1.93	-0.07	-0.01	-406.82
60	Old Oil Pkr's	-59.78199	-0.06	-0.24	0.00	-0.01	0.00	-58.34
61	Old NG Pkr's	-40.65233	-0.04	-0.13	-0.08	-0.01	-0.01	-53.67
Storage Units								
N/A	CAES A	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES B	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES C	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES D	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES E	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	Totals	273386.38890	-115.95	-1336.03	-1026.08	106.65	2.40	189390.33
	Average Marginal Emissions (lb/MWh)		-0.85	-9.77	-7.51	0.78	0.02	1385.51
	Actual Emissions Responsibility (tons)		13.71	198.82	302.70	41.48	2.31	91473.00
	Average Actual Emissions (lb/MWh)		0.10	1.45	2.21	0.30	0.02	669.18

Table C.4.14 Results of Dispatch Calculation for Commonwealth Edison Summer 2010 - Combustion Turbine Emission Constrained Dispatch - Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Dispatch Order	Unit Name	Tech-nology	CAP	CAP SUM	Expected Generation(MWh)	Adjusted Capacity	Energy Factor(%)		
1	La Salle 2	NB	1048.0	1048.0	2152005.12000	93.00	100.00	.37090E-04	0.00000
2	La Salle 1	NB	967.4	2015.4	1986497.85600	93.00	100.00	.38980E-04	0.00000
3	Zion 1	NP	720.0	2735.4	1478476.80000	93.00	100.00	.39310E-04	0.00000
4	Zion 2	NP	1040.0	3775.4	2135577.60000	93.00	100.00	.39930E-04	0.00000
5	Byron 1	NP	1120.0	4895.4	2299852.80000	93.00	100.00	.41470E-04	0.00000
6	Byron 2	NP	1120.0	6015.4	2299852.80000	93.00	100.00	.42130E-04	0.00000
7	Braidwood 1	NP	1006.2	7021.6	2066171.32800	93.00	100.00	.42580E-04	0.00000
8	Dresden 3	NB	773.0	7794.6	1587309.12000	93.00	100.00	.38680E-04	0.00000
9	Quad Cities 2	NB	577.0	8371.6	1196918.98253	93.95	101.02	.40650E-04	0.00000
10	Quad Cities 1	NB	487.4	8859.0	1014463.23744	94.27	101.36	.40700E-04	0.00000
11	Braidwood 2	NP	1090.0	9949.0	2259123.69311	93.87	100.93	.43520E-04	0.00000
12	CC 1	CC	420.0	10369.0	881536.24614	95.06	99.02	.10970E-03	0.00000
13	CC 2	CC	420.0	10789.0	861547.78966	92.90	96.77	.10970E-03	0.82000
14	Waukegan 7	ST	328.0	11117.0	612844.33380	84.62	94.02	.10970E-03	0.82000
15	Waukegan 8	ST	297.0	11414.0	538977.59963	82.19	94.02	.11611E-03	0.72000
16	Will County 4	ST	470.8	11884.8	816120.45548	78.51	91.32	.11548E-03	0.71000
17	HScoal	ST	750.0	12634.8	1262504.30456	76.24	87.23	.13063E-03	0.74000
18	Joliet 6	ST	269.5	12904.3	385262.20720	64.74	79.41	.13087E-03	0.05800
19	Joliet 7	ST	499.0	13403.3	654607.63613	59.41	71.94	.11893E-03	0.08300
20	State Line 4	ST	279.7	13683.0	335253.50007	54.29	66.01	.12239E-03	0.00060
21	Powerton 5	ST	592.3	14275.3	630683.00728	48.22	60.32	.12795E-03	0.75000
22	Will County 2	ST	148.0	14423.3	142971.01585	43.75	53.58	.12730E-03	0.66000
23	Fisk 19	ST	316.0	14739.3	284349.27349	40.75	48.61	.12842E-03	0.75000
24	Joliet 8	ST	518.0	15257.3	408673.85920	35.73	45.28	.13024E-03	0.76000
25	Will County 3	ST	251.0	15508.3	175700.98160	31.70	39.70	.12239E-03	0.79000
26	State Line 3	ST	187.0	15695.3	121804.07680	29.50	35.23	.13031E-03	0.68000
27	Crawford 8	ST	319.0	16014.3	190086.87277	26.99	32.78	.12889E-03	0.69000
28	Will County 1	ST	151.0	16165.3	83117.54047	24.93	29.99	.13181E-03	0.69000
29	Powerton 6	ST	700.0	16865.3	327183.94817	21.17	27.70	.12698E-03	0.69000
30	Waukegan 6	ST	100.0	16965.3	40712.71016	18.44	23.52	.12698E-03	0.68000
31	Crawford 7	ST	213.0	17178.3	81450.92984	17.32	20.49	.11391E-03	6.58000
32	New NG Pkr 1	UN	280.0	17458.3	103565.15806	16.75	19.24	.13087E-03	6.58000
33	Kincaid 2	ST	554.0	18012.3	160544.43137	13.12	17.45	.30833E-03	0.74000
34	New NG Pkr 2	UN	280.0	18292.3	73443.12069	11.88	14.58	.31071E-03	0.67000
35	New NG Pkr 3	UN	118.5	18410.8	28501.10333	10.89	12.37	.30833E-03	0.76000
36	New NG Pkr 4	UN	280.0	18690.8	61629.07701	9.97	11.35	.30833E-03	0.76700
37	New NG Pkr 5	UN	140.0	18830.8	28131.60759	9.10	10.38	.30833E-03	0.76800
38	New NG Pkr 6	UN	258.8	19089.6	47667.16312	8.34	9.48	.30833E-03	0.00060
39	New NG Pkr 7	UN	280.0	19369.6	45991.67216	7.44	8.69	.30833E-03	0.00060
40	New NG Pkr 8	UN	280.0	19649.6	40982.39759	6.63	7.75	.30833E-03	0.00060
41	New NG Pkr 9	UN	280.0	19929.6	36682.21501	5.93	6.91	.30833E-03	0.00060
42	New NG Pkr 10	UN	140.0	20069.6	16942.53087	5.48	6.18	.30833E-03	0.00060
43	CT 1	CT	417.0	20486.6	45537.32139	4.95	5.71	.30833E-03	0.00060
44	New NG Pkr 11	UN	280.0	20766.6	27098.63442	4.38	5.15	.30833E-03	0.00060
45	New NG Pkr 12	UN	280.0	21046.6	24673.97465	3.99	4.57	.30833E-03	0.00060
46	New NG Pkr 13	UN	140.0	21186.6	11522.28974	3.73	4.16	.30833E-03	0.00060
47	New NG Pkr 14	UN	280.0	21466.6	21496.63913	3.48	3.88	.30833E-03	0.00060
48	New NG Pkr 15	UN	118.5	21585.1	8528.08792	3.26	3.62	.30833E-03	0.00060
49	New NG Pkr 16	UN	280.0	21865.1	18832.18405	3.05	3.40	.30833E-03	0.00060
50	New NG Pkr 17	UN	140.0	22005.1	8769.60965	2.84	3.17	.30833E-03	0.00060
51	New NG Pkr 18	UN	280.0	22285.1	16262.23446	2.63	2.96	.30833E-03	0.00060
52	New NG Pkr 19	UN	140.0	22425.1	7530.43891	2.44	2.74	.30833E-03	0.00060
53	New NG Pkr 20	UN	280.0	22705.1	13866.08892	2.24	2.54	.30833E-03	0.00060
54	New NG Pkr 21	UN	280.0	22985.1	12353.69149	2.00	2.34	.30833E-03	0.00060
55	New NG Pkr 22	UN	280.0	23265.1	10911.69637	1.76	2.08	.30833E-03	0.00060
56	New NG Pkr 23	UN	280.0	23545.1	9547.23392	1.54	1.84	.30833E-03	0.00060
57	Kincaid 1	ST	511.4	24056.5	13278.40543	1.18	1.61	.30833E-03	0.00060
58	Collins 1-3	ST	1638.0	25694.5	22852.36579	0.63	1.31	.31071E-03	0.00060
59	Collins 4-5	ST	1060.0	26754.5	6018.56549	0.26	0.70	.33247E-03	0.00060
60	Old Oil Pkr's	GT	426.0	27180.5	1277.49135	0.14	0.29	.40491E-03	0.00060
61	Old NG Pkr's	GT	602.0	27782.5	1169.36006	0.09	0.16	.59319E-03	0.00060
							0.10	.67359E-03	0.24300

Total Expected Generation	30237244.41530
Total Energy Demand	30223908.12956
Final EUSE	1549.76440
Difference	14886.05014
Final LOLP	0.83371E-03
Total Prod Cost w/eta($)	0.23060E+09
Tot Prod Cost w/o eta($)	0.21097E+09

Table C.4.15 Results of ASE Calculation for Commonwealth Edison Summer 2010 - Combustion Turbine Emission Constrained Dispatch - Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Average Emission calculation for file evDISPATCH.DAT.

Dispatch Order	Unit Name	Expected Generation (MWh)	CO	NOx	SO2	TSP	VOC	CO2
			-----Generation Emissions in Tons---					
1	La Salle 2	2152005.12000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	1986497.85600	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	1478476.80000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	2135577.60000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	2066171.32800	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	1537309.12000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	1196918.98253	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	1014463.23744	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	2259123.69311	0.00	0.00	0.00	0.00	0.00	0.00
12	CC 1	881536.24614	7.68	230.35	337.84	383.91	19.20	827726.24
13	CC 2	861547.78966	7.50	225.12	330.18	375.20	18.76	799184.65
14	Waukegan 7	612844.33380	98.35	1057.25	2274.33	307.34	15.37	654637.25
15	Waukegan 8	538977.59963	87.96	857.62	1979.13	274.88	13.74	565491.37
16	Will County 4	816120.45548	128.88	1611.02	3060.94	402.76	20.14	857869.10
17	HScoal	1262504.30456	202.00	2525.01	4797.52	631.25	31.56	1344567.08
18	Joliet 6	385262.20720	68.18	2149.67	1512.66	213.05	10.65	453796.50
19	Joliet 7	654607.63613	112.70	1690.46	2887.87	352.18	17.61	750141.07
20	State Line 4	335253.50007	55.41	1825.09	1142.85	173.16	8.66	368827.46
21	Powerton 5	630683.00728	105.95	3228.31	2284.65	331.11	16.56	705261.27
22	Will County 2	142971.01585	23.84	797.02	513.97	74.49	3.72	158659.23
23	Fisk 19	284349.27349	46.95	792.31	1085.76	146.72	7.34	312522.60
24	Joliet 8	408673.85920	71.93	842.89	1843.12	224.77	11.24	478761.43
25	Will County 3	175700.98160	29.18	419.47	683.92	91.19	4.56	194232.16
26	State Line 3	121804.07680	20.70	121.59	446.28	64.68	3.23	137764.06
27	Crawford 8	190086.87277	32.36	566.31	798.90	101.13	5.06	215398.84
28	Will County 1	83117.54047	14.91	493.83	316.79	46.59	2.33	99231.12
29	Powerton 6	327183.94817	59.15	2458.62	1257.04	184.86	9.24	393749.52
30	Waukegan 6	40712.71016	8.80	196.36	184.26	27.50	1.38	58578.06
31	Crawford 7	81450.92984	15.44	175.18	366.77	48.26	2.41	102793.11
32	New NG Pkr 1	103565.15806	64.94	69.66	0.35	7.67	4.72	70248.25
33	Kincaid 2	160544.43137	29.08	1226.72	5379.12	90.87	4.54	193549.16
34	New NG Pkr 2	73443.12069	46.09	49.44	0.25	5.45	3.35	49860.17
35	New NG Pkr 3	28501.10333	17.90	19.20	0.10	2.12	1.30	19366.21
36	New NG Pkr 4	61629.07701	38.74	41.56	0.21	4.58	2.82	41913.01
37	New NG Pkr 5	28131.60759	17.70	18.99	0.10	2.09	1.29	19148.62
38	New NG Pkr 6	47667.16312	30.02	32.20	0.16	3.55	2.18	32474.45
39	New NG Pkr 7	45991.67216	28.99	31.10	0.16	3.43	2.11	31360.34
40	New NG Pkr 8	40982.39759	25.85	27.73	0.14	3.06	1.88	27969.05
41	New NG Pkr 9	36682.21501	23.16	24.85	0.13	2.74	1.68	25056.15
42	New NG Pkr 10	16942.53087	10.71	11.49	0.06	1.27	0.78	11582.85
43	CT 1	45537.32139	28.80	30.90	0.16	3.40	2.09	31158.91
44	New NG Pkr 11	27098.63442	17.14	18.39	0.09	2.03	1.25	18542.24
45	New NG Pkr 12	24673.97465	15.62	16.76	0.09	1.85	1.14	16897.85
46	New NG Pkr 13	11522.28974	7.30	7.83	0.04	0.86	0.53	7897.84
47	New NG Pkr 14	21496.63913	13.63	14.62	0.07	1.61	0.99	14747.45
48	New NG Pkr 15	8528.08792	5.41	5.81	0.03	0.64	0.39	5855.64
49	New NG Pkr 16	18832.18405	11.96	12.83	0.07	1.41	0.87	12941.95
50	New NG Pkr 17	8769.60965	5.58	5.98	0.03	0.66	0.41	6031.91
51	New NG Pkr 18	16262.23446	10.35	11.10	0.06	1.22	0.75	11195.17
52	New NG Pkr 19	7530.43891	4.80	5.14	0.03	0.57	0.35	5188.55
53	New NG Pkr 20	13866.08892	8.84	9.48	0.05	1.04	0.64	9562.12
54	New NG Pkr 21	12353.69149	7.88	8.45	0.04	0.93	0.57	8526.52
55	New NG Pkr 22	10911.69637	6.97	7.47	0.04	0.82	0.51	7537.75
56	New NG Pkr 23	9547.23392	6.11	6.55	0.03	0.72	0.44	6606.54
57	Kincaid 1	13278.40543	2.48	89.10	509.82	7.75	0.39	16503.13
58	Collins 1-3	22852.36579	4.57	31.42	109.55	0.43	0.14	16996.45
59	Collins 4-5	6018.56549	1.29	11.29	30.97	1.05	0.16	6532.55
60	Old Oil Pkr's	1277.49135	1.26	5.03	0.01	0.14	0.08	1246.58
61	Old NG Pkr's	1169.36006	1.14	3.81	2.32	0.28	0.23	2543.91
Storage Units								
N/A	CAES A	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES B	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES C	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES D	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES E	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
	Totals	30477244.41532	1744.98	24175.04	34739.30	4615.48	265.19	10274353.45
	Average Emissions (lb/MWh)		0.11	1.59	2.28	0.30	0.02	674.23

Table C.4.16 Results of ISE Calculation for Commonwealth Edison Summer 2010 - Combustion Turbine Emission Constrained Dispatch - Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Marginal Emission calculation between files evDISPATCH.DAT and .

Dispatch Order	Unit Name	Expected Generation(MWh)	CO	NOx	SO2	TSP	VOC	CO2
1	La Salle 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	-54.57059	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	-934.09123	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	-4817.09594	0.00	0.00	0.00	0.00	0.00	0.00
12	CC 1	-1999.33425	-0.02	-0.52	-0.77	-0.87	-0.04	-1354.61
13	CC 2	-1220.73430	-0.01	-0.32	-0.47	-0.53	-0.03	-1132.37
14	Waukegan 7	45.29595	0.01	0.08	0.17	0.02	0.00	43.38
15	Waukegan 8	976.97506	0.16	1.55	3.59	0.50	0.02	1061.29
16	Will County 4	3889.17560	0.61	7.68	14.59	1.92	0.10	4088.13
17	HScoal	14008.72563	2.24	28.02	53.23	7.00	0.35	14919.29
18	Joliet 6	6895.16017	1.22	38.47	27.07	3.81	0.19	8121.74
19	Joliet 7	15457.72440	2.66	39.92	68.19	8.32	0.42	17713.62
20	State Line 4	9877.78295	1.63	53.77	33.67	5.10	0.26	10866.99
21	Powerton 5	23155.07592	3.89	118.53	83.88	12.16	0.61	25893.16
22	Will County 2	6070.39757	1.01	33.84	21.82	3.16	0.16	6736.50
23	Fisk 19	13214.89340	2.18	36.82	50.46	6.82	0.34	14524.23
24	Joliet 8	21904.40234	3.86	45.18	98.79	12.05	0.60	25661.01
25	Will County 3	10518.26322	1.75	25.11	40.94	5.46	0.27	11527.62
26	State Line 3	7742.15955	1.32	7.73	28.37	4.11	0.21	8756.61
27	Crawford 8	12935.10513	2.20	38.54	54.36	6.88	0.34	14657.54
28	Will County 1	5985.28531	1.07	35.56	22.81	3.35	0.17	7145.62
29	Powerton 6	26106.43427	4.72	196.18	100.30	14.75	0.74	31417.79
30	Waukegan 6	3511.53779	0.76	16.94	15.89	2.37	0.12	5052.45
31	Crawford 7	7252.61459	1.38	15.60	32.66	4.30	0.21	9152.98
32	New NG Pkr 1	28916.24715	18.13	19.45	0.10	2.14	1.32	19613.89
33	Kincaid 2	-3284.43129	-0.59	-25.10	-122.32	-1.86	-0.09	-3959.64
34	New NG Pkr 2	7633.57538	4.79	5.14	0.03	0.57	0.35	5182.40
35	New NG Pkr 3	3005.80057	1.89	2.03	0.01	0.22	0.14	2042.41
36	New NG Pkr 4	6544.29113	4.11	4.41	0.02	0.49	0.30	4450.67
37	New NG Pkr 5	2987.19177	1.88	2.02	0.01	0.22	0.14	2033.32
38	New NG Pkr 6	5015.17386	3.16	3.39	0.02	0.37	0.23	3416.71
39	New NG Pkr 7	4717.12298	2.97	3.19	0.02	0.35	0.22	3216.46
40	New NG Pkr 8	4027.40579	2.54	2.73	0.01	0.30	0.18	2748.56
41	New NG Pkr 9	3401.50639	2.15	2.30	0.01	0.25	0.16	2323.43
42	New NG Pkr 10	1492.46827	0.94	1.01	0.01	0.11	0.07	1020.33
43	CT 1	45537.32139	28.80	30.90	0.16	3.40	2.09	31158.91
44	New NG Pkr 11	-1638.14071	-1.04	-1.11	-0.01	-0.12	-0.08	-1120.90
45	New NG Pkr 12	-1529.29618	-0.97	-1.04	-0.01	-0.11	-0.07	-1047.33
46	New NG Pkr 13	-734.06098	-0.47	-0.50	0.00	-0.05	-0.03	-503.15
47	New NG Pkr 14	-1417.41106	-0.90	-0.96	0.00	-0.11	-0.07	-972.39
48	New NG Pkr 15	-582.22441	-0.37	-0.40	0.00	-0.04	-0.03	-399.77
49	New NG Pkr 16	-1334.19868	-0.85	-0.91	0.00	-0.10	-0.06	-916.89
50	New NG Pkr 17	817.38617	0.52	0.56	0.00	0.06	0.04	562.21
51	New NG Pkr 18	1604.94866	1.02	1.10	0.01	0.12	0.07	1104.87
52	New NG Pkr 19	792.55120	0.50	0.54	0.00	0.06	0.04	546.08
53	New NG Pkr 20	1569.52269	1.00	1.07	0.01	0.12	0.07	1082.35
54	New NG Pkr 21	1547.18181	0.99	1.06	0.01	0.12	0.07	1067.86
55	New NG Pkr 22	1515.04038	0.97	1.04	0.01	0.11	0.07	1046.58
56	New NG Pkr 23	1467.63970	0.94	1.01	0.01	0.11	0.07	1015.58
57	Kincaid 1	-16888.27493	-3.15	-113.32	-648.41	-9.85	-0.49	-20989.68
58	Collins 1-3	-1843.88768	-0.37	-2.54	-8.84	-0.03	-0.01	-1371.39
59	Collins 4-5	-374.80865	-0.08	-0.70	-1.93	-0.07	-0.01	-406.82
60	Old Oil Pkr's	-59.78199	-0.06	-0.24	0.00	-0.01	0.00	-58.34
61	Old NG Pkr's	-40.65233	-0.04	-0.13	-0.08	-0.01	-0.01	-53.67
Storage Units								
N/A	CAES A	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES B	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES C	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES D	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES E	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	Totals	273386.38894	101.07	674.65	-31.62	97.45	9.70	266290.67
	Average Marginal Emissions (lb/MWh)		0.74	4.94	-0.23	0.71	0.07	1948.09
	Actual Emissions Responsibility (tons)		15.65	216.85	311.62	41.40	2.38	92152.81
	Average Actual Emissions (lb/MWh)		0.11	1.59	2.28	0.30	0.02	674.23

Table C.4.17 Results of Dispatch Calculation for Commonwealth Edison Summer 2010 - Integrated Gasification Combined Cycle Economic Dispatch - Base Case Scenario with Additional Capacity Added but no EV load

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Dispatch Order	Unit Name	Tech-nology	CAP	CAP SUM	Expected Generation(MWh)	Adjusted Capacity	Energy Factor(%)
1	La Salle 2	NB	1048.0	1048.0	2152005.12000	93.00	100.00
2	La Salle 1	NB	967.4	2015.4	1986497.85600	93.00	100.00
3	Zion 1	NP	720.0	2735.4	1478476.80000	93.00	100.00
4	Zion 2	NP	1040.0	3775.4	2135577.60000	93.00	100.00
5	Byron 1	NP	1120.0	4895.4	2299852.80000	93.00	100.00
6	Byron 2	NP	1120.0	6015.4	2299852.80000	93.00	100.00
7	Braidwood 1	NP	1006.2	7021.6	2066171.32800	93.00	100.00
8	Dresden 3	NB	773.0	7794.6	1587309.12000	93.00	100.00
9	Quad Cities 2	NB	577.0	8371.6	1196973.55312	93.95	101.02
10	Quad Cities 1	NB	487.4	8859.0	1015397.32867	94.35	101.45
11	Braidwood 2	NP	1090.0	9949.0	2263940.78905	94.07	101.15
12	Waukegan 7	ST	328.0	10277.0	648302.46339	89.52	99.46
13	CC 1	CC	420.0	10697.0	869060.16624	93.71	97.62
14	CC 2	CC	420.0	11117.0	841740.50758	90.77	94.55
15	CC 3	ST	417.0	11534.0	799595.24092	86.84	90.46
16	Waukegan 8	ST	297.0	11831.0	508992.00643	77.62	86.24
17	Joliet 7	ST	499.0	12330.0	802365.28612	72.82	80.92
18	Will County 4	ST	470.8	12800.8	691638.10881	66.53	73.93
19	Joliet 8	ST	518.0	13318.8	682072.97320	59.64	66.26
20	Joliet 6	ST	269.5	13588.3	322925.92402	54.27	60.30
21	HScoal	ST	750.0	14338.3	827897.39768	49.99	52.08
22	Fisk 19	ST	316.0	14654.3	276008.50653	39.56	43.95
23	State Line 4	ST	279.7	14934.0	222163.29061	35.97	39.97
24	Will County 3	ST	251.0	15185.0	182627.85144	32.95	36.61
25	Powerton 5	ST	592.3	15777.3	370415.85451	28.32	31.47
26	Will County 2	ST	148.0	15925.3	81720.60346	25.01	27.79
27	Crawford 8	ST	319.0	16244.3	160998.68284	22.86	25.40
28	State Line 3	ST	187.0	16431.3	85969.84382	20.82	23.13
29	Kincaid 2	ST	554.0	16985.3	218919.02992	17.90	19.89
30	Will County 1	ST	151.0	17136.3	52242.73384	15.67	17.41
31	Powerton 6	ST	700.0	17836.3	201303.59788	13.02	14.47
32	Kincaid 1	ST	511.4	18347.7	114740.46941	10.16	11.29
33	Waukegan 6	ST	100.0	18447.7	19919.33572	9.02	10.02
34	Crawford 7	ST	213.0	18660.7	39663.40932	8.43	9.37
35	New NG Pkr 1	UN	280.0	18940.7	50223.13345	8.12	8.46
36	New NG Pkr 2	UN	280.0	19220.7	44590.14363	7.21	7.51
37	New NG Pkr 3	UN	118.5	19339.2	17401.87338	6.65	6.93
38	New NG Pkr 4	UN	280.0	19619.2	37959.46684	6.14	6.40
39	New NG Pkr 5	UN	140.0	19759.2	17526.86930	5.67	5.91
40	New NG Pkr 6	UN	258.8	20018.0	30095.43327	5.27	5.49
41	New NG Pkr 7	UN	280.0	20298.0	29622.31308	4.79	4.99
42	New NG Pkr 8	UN	280.0	20578.0	26971.81112	4.36	4.54
43	New NG Pkr 9	UN	280.0	20858.0	24635.89210	3.98	4.15
44	New NG Pkr 10	UN	140.0	20998.0	11528.94088	3.73	3.89
45	New NG Pkr 11	UN	280.0	21278.0	21546.29934	3.49	3.63
46	New NG Pkr 12	UN	280.0	21558.0	19673.36424	3.18	3.31
47	New NG Pkr 13	UN	140.0	21698.0	9176.11316	2.97	3.09
48	New NG Pkr 14	UN	280.0	21978.0	17038.74746	2.76	2.87
49	New NG Pkr 15	UN	118.5	22096.5	6713.28379	2.57	2.67
50	New NG Pkr 16	UN	280.0	22376.5	14676.15315	2.37	2.47
51	New NG Pkr 17	UN	140.0	22516.5	6747.14418	2.18	2.27
52	New NG Pkr 18	UN	280.0	22796.5	12314.72451	1.99	2.07
53	New NG Pkr 19	UN	140.0	22936.5	5601.92259	1.81	1.89
54	New NG Pkr 20	UN	280.0	23216.5	10107.55750	1.63	1.70
55	New NG Pkr 21	UN	280.0	23496.5	8741.75658	1.41	1.47
56	New NG Pkr 22	UN	280.0	23776.5	7474.49029	1.21	1.26
57	New NG Pkr 23	UN	280.0	24056.5	6315.82503	1.02	1.06
58	Collins 1-3	ST	1638.0	25694.5	18353.08283	0.51	0.56
59	Collins 4-5	ST	1060.0	26754.5	4419.14323	0.19	0.21
60	Old Oil Pkr's	GT	426.0	27180.5	887.26914	0.09	0.11
61	Old NG Pkr's	GT	602.0	27782.5	782.22245	0.06	0.07

Total Expected Generation	29964463.36004
Total Energy Demand	29946973.16792
Final EUSE	943.50664
Difference	18433.69877
Final LOLP	0.54727E-03
Final numEUSE	944.17420
Final numLOLP	0.57955E-03

Table C.4.18 Results of ASE Calculation for Commonwealth Edison Summer 2010 - Integrated Gasification Combined Cycle Economic Dispatch - Base Case Scenario with Additional Capacity Added but no EV load

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Average Emission calculation for file baseDISPATCH.DAT.

Dispatch Order	Unit Name	Expected Generation(MWh)	CO	NOx	SO2	TSP	VOC	CO2
			-----Generation Emissions in Tons---					
1	La Salle 2	2152005.12000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	1986497.85600	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	1478476.80000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	2135577.60000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	2299852.80000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	2066171.32800	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	1587309.12000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	1196973.55312	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	1015397.32867	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	2263940.78905	0.00	0.00	0.00	0.00	0.00	0.00
12	Waukegan 7	648302.46839	104.04	1118.43	2405.92	325.12	16.26	692513.46
13	CC 1	869060.16624	7.57	227.09	333.06	378.48	18.92	806153.25
14	CC 2	841740.50758	7.33	219.95	322.59	366.58	18.33	780811.12
15	CC 3	799595.24092	6.96	208.93	306.44	348.22	17.41	741716.54
16	Waukegan 8	508992.00643	83.07	809.91	1869.02	259.59	12.98	552918.02
17	Joliet 7	802365.28612	138.14	2072.03	3539.71	431.67	21.58	919462.48
18	Will County 4	691638.10881	109.22	1365.29	2594.06	341.32	17.07	727018.86
19	Joliet 8	682072.97320	120.04	1406.78	3076.15	375.14	18.76	799048.49
20	Joliet 6	322925.92402	57.14	1801.85	1267.90	178.58	8.93	380371.22
21	HScoal	827897.39768	132.46	1555.79	3146.01	413.95	20.70	881710.73
22	Fisk 19	276008.50653	45.57	769.07	1053.91	142.42	7.12	303355.43
23	State Line 4	222153.29061	36.72	1209.44	757.33	114.75	5.74	244411.83
24	Will County 3	182627.85144	30.33	436.01	710.88	94.78	4.74	201889.61
25	Powerton 5	370415.85451	62.23	1896.07	1341.83	194.47	9.72	414217.53
26	Will County 2	81720.60346	13.62	455.57	293.78	42.58	2.13	90687.81
27	Crawford 8	160998.68284	27.41	479.65	676.65	85.65	4.28	182437.27
28	State Line 3	85969.84382	14.61	85.82	314.98	45.65	2.28	97234.47
29	Kincaid 2	218919.02992	39.65	1672.76	8153.16	123.91	6.20	263924.40
30	Will County 1	52242.73384	9.37	310.39	199.12	29.28	1.46	62370.77
31	Powerton 6	201303.59788	36.40	1512.70	773.41	113.74	5.69	242258.81
32	Kincaid 1	114740.46941	21.42	769.94	4405.38	66.95	3.35	142605.77
33	Waukegan 6	19919.33572	4.31	96.07	90.15	13.46	0.67	28660.24
34	Crawford 7	39663.40932	7.52	85.31	178.60	23.50	1.18	50056.21
35	New NG Pkr 1	50223.13345	31.77	34.08	0.17	3.75	2.31	34365.18
36	New NG Pkr 2	44590.14363	28.20	30.25	0.15	3.33	2.05	30510.81
37	New NG Pkr 3	17401.87338	11.01	11.81	0.06	1.30	0.80	11907.23
38	New NG Pkr 4	37959.46684	24.01	25.76	0.13	2.84	1.75	25973.77
39	New NG Pkr 5	17526.86930	11.09	11.89	0.06	1.31	0.81	11992.76
40	New NG Pkr 6	30095.43327	19.04	20.42	0.20	2.25	1.38	20592.80
41	New NG Pkr 7	29622.31308	18.74	20.10	0.10	2.21	1.36	20269.07
42	New NG Pkr 8	26971.81112	17.06	18.30	0.09	2.02	1.24	18455.45
43	New NG Pkr 9	24635.89210	15.58	16.72	0.08	1.84	1.13	16857.11
44	New NG Pkr 10	11528.94088	7.29	7.82	0.04	0.86	0.53	7888.68
45	New NG Pkr 11	21546.29934	13.63	14.62	0.07	1.61	0.99	14743.06
46	New NG Pkr 12	19673.36424	12.44	13.35	0.07	1.47	0.90	13461.50
47	New NG Pkr 13	9176.11316	5.80	6.23	0.03	0.69	0.42	6278.76
48	New NG Pkr 14	17038.74746	10.78	11.56	0.06	1.27	0.78	11658.76
49	New NG Pkr 15	6713.28379	4.25	4.55	0.02	0.50	0.31	4593.56
50	New NG Pkr 16	14676.15315	9.28	9.96	0.05	1.10	0.68	10042.16
51	New NG Pkr 17	6747.14418	4.27	4.58	0.02	0.50	0.31	4616.73
52	New NG Pkr 18	12314.72451	7.79	8.36	0.04	0.92	0.57	8426.35
53	New NG Pkr 19	5601.92259	3.54	3.80	0.02	0.42	0.26	3833.12
54	New NG Pkr 20	10107.55750	6.39	6.86	0.03	0.76	0.46	6916.10
55	New NG Pkr 21	8741.75658	5.53	5.93	0.03	0.65	0.40	5981.55
56	New NG Pkr 22	7474.49029	4.73	5.07	0.03	0.56	0.34	5114.42
57	New NG Pkr 23	6315.82503	3.99	4.29	0.02	0.47	0.29	4321.60
58	Collins 1-3	18353.08283	3.67	25.24	87.98	0.34	0.11	13650.11
59	Collins 4-5	4419.14323	0.95	8.29	22.74	0.77	0.12	4796.54
60	Old Oil Pkr's	887.26914	0.87	3.49	0.00	0.09	0.06	865.80
61	Old NG Pkr's	782.22245	0.77	2.55	1.55	0.18	0.15	1032.77
Storage Units								
N/A	CAES A	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES B	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES C	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
N/A	CAES D	48000.00000	10.56	11.33	0.05	1.25	0.77	11424.00
N/A	CAES E	48000.00000	10.56	11.33	0.06	1.25	0.77	11424.00
	Totals	30204463.36005	1450.41	21057.32	37924.10	4550.06	249.86	9982100.03
	Average Emissions (lb/MWh)		0.10	1.39	2.51	0.30	0.02	660.97

Table C.4.19 Results of MSE Calculation for Commonwealth Edison Summer 2010 - Integrated Gasification Combined Cycle Economic Dispatch - Unconstrained High EV Scenario

Utility	Date	Case #
ComEd	Apr18'94	sum2010

Marginal Emission calculation between files evDISPATCH.DAT and baseDISPATCH.DAT.

Dispatch Order	Unit Name	Expected Generation(MWh)	-----Generation Emissions in Tons--- CO	NOx	SO2	TSP	VOC	CO2
1	La Salle 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
2	La Salle 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
3	Zion 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
4	Zion 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
5	Byron 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
6	Byron 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
7	Braidwood 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
8	Dresden 3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
9	Quad Cities 2	-54.57059	0.00	0.00	0.00	0.00	0.00	0.00
10	Quad Cities 1	-934.09123	0.00	0.00	0.00	0.00	0.00	0.00
11	Braidwood 2	-4817.09594	0.00	0.00	0.00	0.00	0.00	0.00
12	Waukegan 7	-1504.06893	-0.24	-2.59	-5.58	-0.75	-0.04	-1606.64
13	CC 1	-1488.06532	-0.01	-0.39	-0.57	-0.65	-0.03	-1380.35
14	CC 2	-182.63836	0.00	-0.05	-0.07	-0.08	0.00	-159.42
15	CC 3	1814.93804	0.02	0.47	0.70	0.79	0.04	1683.56
16	Waukegan 8	2650.31825	0.43	4.22	9.73	1.35	0.07	2879.04
17	Joliet 7	7462.86635	1.28	19.27	32.92	4.02	0.20	8552.00
18	Will County 4	10529.31833	1.66	20.78	39.49	5.20	0.26	11067.95
19	Joliet 8	15261.35429	2.69	31.48	68.83	8.39	0.42	17878.68
20	Joliet 6	9190.51020	1.63	51.28	36.08	5.08	0.25	10625.41
21	HScoal	31033.20255	4.97	62.07	117.93	15.52	0.78	33050.36
22	Fisk 19	13176.92869	2.18	36.72	50.31	6.80	0.34	14482.50
23	State Line 4	11823.53783	1.95	64.37	40.31	6.11	0.31	13007.61
24	Will County 3	10626.22336	1.76	25.37	41.36	5.52	0.28	11746.97
25	Powerton 5	24640.36633	4.14	126.13	89.26	12.94	0.65	27554.09
26	Will County 2	5994.39502	1.00	33.42	21.55	3.12	0.16	6652.16
27	Crawford 8	12598.65267	2.14	37.53	52.95	6.70	0.34	14276.29
28	State Line 3	7164.84652	1.22	7.15	26.25	3.80	0.19	8103.66
29	Kincaid 2	19993.02507	3.62	152.77	744.60	11.32	0.57	24103.19
30	Will County 1	5132.14517	0.92	30.49	19.56	2.88	0.14	6127.09
31	Powerton 6	21449.43238	3.88	161.18	82.41	12.12	0.61	25813.32
32	Kincaid 1	13225.15933	2.47	88.74	507.77	7.72	0.39	16436.96
33	Waukegan 6	2347.02815	0.51	11.32	10.62	1.59	0.08	3376.94
34	Crawford 7	4700.18824	0.89	10.11	21.16	2.78	0.14	5931.76
35	New NG Pkr 1	5947.88780	3.76	4.04	0.02	0.44	0.27	4069.84
36	New NG Pkr 2	5194.93963	3.29	3.52	0.02	0.39	0.24	3554.64
37	New NG Pkr 3	1983.03592	1.25	1.35	0.01	0.15	0.09	1356.89
38	New NG Pkr 4	4186.09808	2.65	2.84	0.01	0.31	0.19	2864.34
39	New NG Pkr 5	1852.13027	1.17	1.26	0.01	0.14	0.09	1267.32
40	New NG Pkr 6	3027.42274	1.91	2.05	0.01	0.23	0.14	2071.51
41	New NG Pkr 7	2765.71298	1.75	1.88	0.01	0.21	0.13	1892.44
42	New NG Pkr 8	2321.23775	1.47	1.57	0.01	0.17	0.11	1588.31
43	New NG Pkr 9	1965.20706	1.24	1.33	0.01	0.15	0.09	1344.69
44	New NG Pkr 10	877.15407	0.55	0.60	0.00	0.07	0.04	600.19
45	New NG Pkr 11	1588.20357	1.00	1.08	0.01	0.12	0.07	1086.73
46	New NG Pkr 12	1429.15075	0.90	0.97	0.00	0.11	0.07	977.90
47	New NG Pkr 13	674.28816	0.43	0.46	0.00	0.05	0.03	461.38
48	New NG Pkr 14	1296.40735	0.82	0.88	0.00	0.10	0.06	887.07
49	New NG Pkr 15	535.45105	0.34	0.36	0.00	0.04	0.02	366.38
50	New NG Pkr 16	1248.57986	0.79	0.85	0.00	0.09	0.06	854.34
51	New NG Pkr 17	619.82005	0.39	0.42	0.00	0.05	0.03	424.11
52	New NG Pkr 18	1235.33541	0.78	0.84	0.00	0.09	0.06	845.28
53	New NG Pkr 19	615.62523	0.39	0.42	0.00	0.05	0.03	421.24
54	New NG Pkr 20	1222.89706	0.77	0.83	0.00	0.09	0.06	836.77
55	New NG Pkr 21	1202.21106	0.76	0.82	0.00	0.09	0.06	822.61
56	New NG Pkr 22	1166.81332	0.74	0.79	0.00	0.09	0.05	798.39
57	New NG Pkr 23	1115.47444	0.71	0.76	0.00	0.08	0.05	763.26
58	Collins 1-3	4499.28296	0.90	6.19	21.57	0.08	0.03	3346.34
59	Collins 4-5	1599.42226	0.34	3.00	8.23	0.28	0.04	1736.01
60	Old Oil Pkr's	390.22221	0.38	1.54	0.00	0.04	0.03	380.78
61	Old NG Pkr's	387.13761	0.38	1.26	0.77	0.09	0.08	511.14
Storage Units								
N/A	CAES A	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES B	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES C	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES D	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	CAES E	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	Totals	272781.05525	68.98	1013.72	2038.29	126.04	8.31	296523.02
	Average Marginal Emissions (lb/MWh)		0.51	7.43	14.94	0.92	0.06	2174.07
	Actual Emissions Responsibility (tons)		13.60	197.54	357.68	41.85	2.31	91996.95
	Average Actual Emissions (lb/MWh)		0.10	1.45	2.62	0.31	0.02	674.51

C.5 Summary of Computational Results

This appendix section describes the electric utility simulation results. Results for the cases that assumed unconstrained charging are described in Section C.5.1 below. In the unconstrained charging cases, we assume that the vehicles are plugged in for charging immediately upon arrival at their final destination for the day. Section C.5.2 explains the cases in which the time of charging was altered to examine the effects of the charging time on capacity expansion needs, dispatching of units, and emissions. Section C.5.3 describes the marginal systems emissions results.

The process of obtaining these results is rather involved and required several interrelated analyses. The details of the procedures are outlined in Appendix C.4 through the example of one utility. The base case results are shown for this one illustrative utility with base case defined as the computation of generation and emissions from a utility's different generating units without any infusion of EVs. We will not dwell on the base case results in this chapter, as our interest focuses on the change in emissions precipitated by the charging of EVs.

Recall that the required resource additions without the EVs have been obtained from the IRP submissions of utilities. These plans list committed and planned units through the year 2000 and in some cases through 2010. In the case where the plans did not proceed through the year 2010, we continued adding capacity of the same technology called for by the respective IRP plan in order to maintain the specified EUSE in 2010. In addition to such planned resources, the example in Section C.4 show that, where necessary, we have added generating units to meet the additional demand of EV charging while maintaining the same level of system reliability. No capacity additions for additional EV load were required in the year 2000 in any of the regions.

The following explains the nomenclature used in this appendix section:

Total System Emissions (TSE) are computed (in tons) simply as the total effluent that is produced in a particular scenario. In a base case scenario, this would be the total emissions for the season without EVs. In a scenario including EVs, the total emissions are associated with all the energy, including the energy for charging EVs.

Average System Emissions (ASE) are the average emissions of pollutants per MWh of energy produced. The system demand, and therefore the emissions, change from hour to hour. The total tonnage of emissions over a period of study, usually a season, is divided by the energy produced during that period and expressed as the ASE in lb/MWh.

Incremental System Emissions (ISE) are described as follows. The base case simulation for a particular year assumed no EV charging. A subsequent computation of emissions accounting for the total number of EVs present at some future year, subtracted from the base case emissions, gave us the total resulting **tonnage of emissions** from the EVs. Note that with a large penetration of EVs in some future year, new generating capacity exists that did not exist in the base case. The new generators added to meet the demand of EVs is also dispatched to meet the native load of the system. Consequently, the change in system emissions that result from the penetration of EVs is not only from the charging of the EVs, but is also from **the redispatching of the existing and the added generating units to meet the native load.** Therefore, ISE represent the change in the total system emissions arising from the planning of the utility system to accommodate a certain number of EVs in the future. The units of ISE are in tons. It will be shown later that ISE can be positive or negative.

Marginal System Emissions (MSE) are obtained as follows. The utility system is simulated with and without the EV charging load. In **both** simulations the generation capacity necessary to maintain reliability with EVs is present. The difference between emission in these two cases arises from the generators that are the sources to feed the energy to the batteries. In other words, the difference between emissions in these two cases is the actual change in emissions that one can observe with EV charging, and without EVs at a certain future date. The assumption is that the extra generating plant to meet the EV loads is committed and built and dispatched whether EVs are charged or not. The tonnage of emissions is divided by the charging energy to express MSE in lb/ MWh. This figure is comparable to the familiar gm/mile used as a metric for conventional vehicles.

Unconstrained charging of EVs implies that the vehicles are plugged in for charging as soon as they arrive at their stations (homes or garages). Constrained charging refers to cases when the charging is deliberately delayed to precipitate some economic benefits such as reserve capacity requirement. The delay can be due to direct load control, or policy initiatives such as time of day pricing. The characteristics of these cases, referred to as **policy cases of constrained charging**, are described later in Section C.5.2.

The purpose of the above nomenclature arises from two questions: "How will EVs affect utility emissions?" and "What is the proper allocation of emissions due to the charging of EVs?" The second allocation question is very different from the former policy question. The policy question is answered by modeling a system and determining the incremental change in emissions with and without EVs (hence the ISE calculation). Answering the second allocation question is more complex and addresses determining responsibility for the creation of emissions. For this purpose, using the marginal calculation (MSE) to represent EV emissions may be more appropriate for a customer class purchasing electricity on a marginal basis. However, if a customer class purchases electricity based on average costs, the ASE calculation is more appropriate.

To clarify further, the TSE measure of emissions does not necessarily indicate the state of cleanliness of a system. TSE is not only influenced by the technology of generating units in a system, but is also dependent on the size of the system. ASE is a measure of the system state of cleanliness as it indicates the emissions per unit of energy produced. ISE is a measure of the change in TSE by certain policy initiatives, such as the penetration of EVs. Finally, MSE is a measure of increase in emissions arising from the energy and its source to charge the EVs.

C.5.1 Results of Unconstrained Charging

In the following examples, the emissions resulting from EV charging are shown for the utilities studied. In the tables, we indicate ISE as well as ASE emissions and the vehicle charging energy.

C.5.1.1 Chicago Metropolitan Area

It is not clear if Commonwealth Edison (CE) will employ an emission constrained dispatch of its system or if it will resort to economic dispatch by installing flue gas scrubbers. Consequently, we computed the results for both modes of system dispatch.

Tables C.5.1 through C.5.5 show the results obtained for the years 2000 and 2010. Table C.5.1 indicates the TSE, ISE, and ASE of different pollutants for the four seasons under economic dispatch in the year 2000. As indicated earlier, no capacity addition was required for the year 2000. In the year 2000, total annual SO_2 emissions will be under the permitted annual cap. Therefore, it was necessary to simulate only the economic dispatch procedure.

Although in the year 2010 CE has to resort to emission constrained dispatch to comply with the CAAA, our first simulation is that of economic dispatch. The motivation here is to examine what emissions result if CE undertakes economic dispatch and purchases the required SO_2 allowances. This means that CE will not undertake any mitigative measures, such as cleaning coal or installing scrubbers at the affected Kincaid units. Although this may not be true, such an assumption yields the maximum SO_2 emissions that could result in this utility.

The results shown in Table C.5.2 assumed[1] that a combined cycle generating unit would be added to meet the demand of EVs. As planned by CE, this generating unit would be of Integrated Gasification (coal) Combined Cycle (IGCC) technology. Note that the ISE of SO_2, CO, and NO_x are negative in all seasons.[2] Table C.5.3 indicates the results obtained for the assumption that a CT is added to meet the EV load. In this case, all the ISEs are positive.

Results of emission constrained dispatch are shown in Table C.5.4 which reveals a drastic change.[3] The SO_2 emission after adding a CC unit is positive during some seasons and negative in others. Evidently, the total annual SO2 emission is the same as the base case emission constrained dispatch (in Section 3.3.7) as required by the CAAA. Similarly, Table C.5.5 for the constrained dispatch case, with a CT unit addition instead of a CC unit, shows that ISE is lower than under economic dispatch (compare Tables C.5.3 and C.5.5).

An important observation is that all ISE seasonal SO_2 emissions under emission constrained dispatch are higher than under economic dispatch when IGCC unit is added. This can be seen by comparing Tables C.5.2 and C.5.4. For example, the emissions during the summer for the high penetration case are -2685 tons for economic dispatch. The corresponding rate for the constrained dispatch is -1026 tons. This situation arises because under emission constrained dispatch, cleaner machines are dispatched earlier in the merit order. As a consequence, units on the margin that supply EV charging energy under emission constrained dispatch are dirtier than those under economic dispatch. In our example shown in Table C.2.1, the unit on the margin under economic dispatch has an incremental emission rate of 1 lb/MWh. Under emission constrained dispatch (depending on the ceiling on emissions) either the 5 MW or the 20 MW machine will be on the margin. Both these units have a marginal emission rate higher than 1 lb/MWh.

The situation for CT addition can be seen by comparing Tables C.5.3 and C.5.5. The goal of economic dispatch being the production of energy from the lowest cost resources, most of the charging energy comes from existing units (the cost of production from CT is higher than existing units). Therefore, for

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[1] The base case results reported in this table are also for economic dispatch.

[2] Reasons for negative incremental emissions will be apparent from Section 3.3.7. This situation arises from the fact that the IGCC unit added is cleaner and is dispatched to meet native system load in addition to the EV load. Hence, negative ISE indicates a decrease in total system emissions.

[3] The base case results reported in this table are also for constrained dispatch. For constrained dispatch, note that the total of seasonal SO_2 ISE should add to zero (since the annual CAAA cap is unchanged). This is not the case in our tables. The error arises from round off and other errors in computation. This error, as a percentage of total annual SO_2 emission, is very small.

economic dispatch, ISE for CT additions are higher than for IGCC additions (compare Tables C.5.2 and C.5.3).

For these reasons, Tables C.5.1 through C.5.5 show a wide range of variation of all pollutants. Additionally, there are several uncertainties associated with the future. For example, will the system be under economic or emission constrained dispatch? What technology of generation will be added to meet the EV charging load? What is the variability in the penetration of EVs? Could this capacity come from nonutility suppliers who are either within or outside the Chicago area? What will be the price of SO_2 allowances traded in the market? How many allowances is CE likely to purchase or sell by over complying with the CAAA? These are unanswerable questions.

Because of these uncertainties, it is not possible to put a fine point on the emissions resulting from EV charging. One has to accept a band of variability in emissions. An example of the variability of emissions can be demonstrated by an examination of SO_2 emissions for the summer of 2010. The ISEs can vary from a low of -2685 tons to a high of +2071 tons depending on the technology of the added generation, the dispatch procedure used, and the number of vehicles. On top of these possible variations, uncertainties associated with other outcomes discussed earlier could influence the results even further.

C.5.1.2 Houston Metropolitan Area

The Houston Light and Power Company (HLP) need not resort to a constrained dispatch in order to comply with the CAAA. As a result, only the economic dispatch procedure had to be considered. Table C.5.6 indicates the results obtained for the year 2000.

Table C.5.7, and C.5.8 indicate the ISEs for the year 2010. The tables show the results for the addition of a CC unit and the addition of a CT unit respectively. The inset table shows that a very small capacity addition was required in the low EV penetration scenario.

For the year 2010, ISEs for SO_2 ,CO, and NO_x are negative both for the high EV penetration, CC unit addition scenario. The reason for obtaining negative numbers when a CC unit is added has been previously explained in connection with the Chicago results.

The ISE of pollutants is relatively small in comparison with the TSE, even for the high EV penetration scenario.

C.5.1.3 Washington, D.C. Metropolitan Area

This region is served by two utilities: Potomac Electric Power Company (PEPCO), and Virginia Electric Power Company (VEPCO). The charging load of the total number of vehicles provided by ANL (see Appendix B) was divided between the two utilities as follows: the household vehicles were distributed on the basis of electricity sales to the residential sector in the air basin by the two utilities, and the fleet vehicles were distributed based on the sum of electricity sales to the commercial and industrial sectors in the air basin.

For the utilities serving this region, computations were conducted only for the year 2010.

Potomac Electric Power Company. Tables C.5.9 and C.5.10 indicate the results for the options of installing CC and CT units to meet the demand of EVs. The results for the two capacity options are almost identical arising from a very little capacity addition that was required to maintain reliability. Therefore, the energy contribution from these units was also very small. Consequently, the generation from the existing units in the two scenarios was nearly identical.

Virginia Electric Power Company. The data made available for this utility indicate that the cost of oil per Btu is slightly less than the cost of natural gas. The effect of this situation on the results obtained is discussed later. Tables C.5.11 and C.5.12 show the emissions corresponding to the two technologies of capacity addition options for this utility. There is a slight increase in SO_2 and NO_x emissions for the case of CC unit addition. The reason for this is the same as for the case in Chicago–with the addition of CT units more charging energy comes from oil-fired generation, which has higher rates of emissions for these effluents.

C.5.1.4 Los Angeles Metropolitan Area

This region is served primarily by two utilities–Southern California Edison (SCE) and Los Angeles Department of Water and Power (LADWP). The EV population provided by ANL (see Appendix B) was divided between the two utilities as follows: the household vehicles were distributed on the basis of electricity sales to the residential sector in the air basin by the two utilities, and the fleet vehicles were distributed based on the sum of electricity sales to the commercial and industrial sectors in the air basin.

Southern California Edison Company. Table C.5.13 shows the SCE results for the year 2000. The planned capacity of SCE is sufficient to accommodate the penetration of EVs in the year 2000 and maintain an adequate level of system reliability.

For the year 2010, additional capacity was required. Tables C.5.14 and C.5.15 indicate the ISEs and ASEs with the addition of a CC unit and the addition of a CT unit. The dispatch of the utilities in California is not influenced by the CAAA as their annual SO_2 emissions are below the sum of the allowances granted by the EPA. Consequently, the results in these tables model only the economic dispatch procedure. Appendix C.7, Tables C.7.2 through C.7.3 list the origin (in or out-basin) of the ISEs and total system emissions (TSE) for the high and low EV penetrations under unconstrained charging scenarios.

An examination of energy outputs from different generating units in the results of dispatch simulation revealed the following. For the high EV penetration CC unit scenario, a majority of the ISEs come from the capacity added due to the EV load. Some of these emissions displace existing in-basin generation. In the low penetration CC unit scenario, emissions of ISEs come from existing in and out-basin generation and the capacity added to meet the EV demand. In the CT unit scenarios, a majority of the emissions come from existing in and out-basin generation as very little energy is produced by the added CT unit.

Because the generating units are relatively clean compared to the other regions, EV charging and the subsequent addition of additional capacity did not result in any discernible change in the ISEs. Consequently, the magnitude of ISE for most pollutants in Tables C.5.14 and C.5.15 is small in comparison with TSE.

To clarify this further, Table C.7.1 of Appendix C.7 for the summer season of 2010 shows the changes in energy output from different generating units of the SCE system that arise from charging EVs with the addition of a CC unit (# 37) in the high EV penetration scenario. It can be seen that the added CC unit supplies 1,104,934 MWh into the system as opposed to the charging energy of 795,351 MWh (the total of changes in energy production at the end of the table). The tally of total emissions shows an increase of only 3.56 tons of SO_2. It is also important to note that this unit plays a prominent role in determining which units contribute to the ISE. In the CT addition scenario, the added unit makes a negligible contribution to ISE.

Los Angeles Department of Water and Power. Tables C.5.16, C.5.17, and C.5.18 show the computational results for LADWP scenarios. As with SCE, this utility does not have to resort to emission constrained dispatch.

Table C.5.16 shows the results for the year 2000 with no required additional installation of capacity. For the year 2010, additional capacity installation was required. Tables C.5.16 and C.5.17 indicate the options of adding CC or CT units for the year 2010.

For the addition of either type of technology, the ISEs of SO_2 in 2010 are very small–even negligible. The ISE of NO_x and CO are slightly negative for the case of a CC unit addition because this technology is somewhat cleaner than that of the existing units in the system. The sources of ISE follow the same pattern as in SCE. A majority of the ISEs come from the added CC unit in the CC scenarios and from existing in-basin generation in the CT scenario.

Tables C.7.6 to C.7.9 of Section C.7 show the ISE and TSE from plants within and outside the air basin.

C.5.2 Controlled Charging Strategies

Unconstrained charging of EVs could increase system peak demand. Such a circumstance would lead to higher capital investments to augment the generation, transmission and distribution facilities to maintain the same present level of supply reliability. With this concern in mind, off-peak charging may be implemented, either through pricing mechanisms or through several direct load control options.

Our intent in this section is to examine whether off-peak charging is beneficial under all circumstances. We do so by comparing the effects of different off-peak charging scenarios for the different regions in this study.

A question arises as to the purpose of off-peak charging. Is our goal to reduce the peak load (and hence the future capital investment), or is it to reduce ISEs? It will be shown that these two purposes could conflict with each other in some regions.

C.5.2.1 Effect of Off-peak Charging

Off-peak charging generally implies peak load reduction. Figures C.5.1 and C.5.2 (also shown in Section C.4) show a typical summer and winter day's demand profile of CE of Chicago. Also, the figure shows the addition of an EV unconstrained charging profile to the load. (The computation of an EV charging profile is discussed in Section C.3.)

The following observations result from the figures under discussion. The peak system load without EVs occurs at 18:00 hours during the winter season and at 16:00 hours during the summer season. The peak of the EV charging load may not occur at the same times as the peak demand during the summer months as shown in Figure C.5.1. However, it is evident from the figures that the additional EV demand increases the system peak in the unconstrained charging scenario. The increase in system peak demand is greater if the native load peak and the charging peak are coincident than otherwise.

In the case of SCE in Figure C.5.3, the system peak and the charging peaks are not coincident; the system peak occurs at 15:00 hours and the charging peak is at 18:00 hours. The combined system peak that occurs at 16:00 hour is slightly higher than the system peak without the penetration of EVs.

The shifting of the system peak from 15:00 hours to 16:00 hours arises from the fact that, in this time interval, the rate of system load reduction in the post peak period (MWh/min) is less than the rate of increase of EV charging load.

These figures show that the charging load and the system load peaks may not be coincident even under unconstrained charging. Therefore, it is possible that the system peak load does not necessarily increase by unconstrained charging in some regions, particularly in certain seasons. Consequently, an analysis of off-peak charging for peak reduction should be preceded by an analysis of the temporal pattern of demands to determine if constrained charging is necessary and beneficial in all seasons.

Another important matter regarding off-peak charging is its effect on resource expansion. The goal of a resource expansion *plan* is to determine the required resource to meet the system annual peak load at a preestablished level of reliability.[4] The required reserve is greatly influenced by the peak demand season. Once the required resources have been determined and installed, the critical period of *operation* is the peak load season. For example, in a utility where the peak season is the summer, that season is the critical one. It is during that season that load control measures are instituted. In the off-peak seasons (fall, spring, and winter in our example), because the system load drops and the planned installed capacity is dictated mostly by the peak season, there is ample reserve capacity. Hence, there is no incentive for the utility to undertake the expenses and complications of instituting load control in the non-peak seasons that will inconvenience the customers. Therefore, in the operating record of utilities, load control is implemented only during a handful of days during the peak season.

In light of the above discussion, for the off-peak charging of EVs, we determined the resource addition based on a reliability index to supply the annual demand profile in accordance with North American utility planning practice. The reliability index is greatly influenced by the peak season loads because of its nonlinear nature.[5] Consequently, although all the hourly loads during the year are used for reliability computation, the reliability index is greatly influenced by the peak season. In the simulation of utility operations, we assume that off-peak charging is instituted every day during the peak load season. During other seasons, we assume that unconstrained charging will be permitted.

The above discussion indicates that off-peak charging during the peak season reduces the peak load and greatly influences the reserve capacity. However, will off-peak charging reduce emissions? This is not necessarily the case. We focus on this situation in the following discussions.

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[4] The criterion used may vary from utility to utility. Some use loss of load probability and others expected unserved energy as reliability indices. Some utilities use a combination of these as the index of reliability. Even the method of computing these seemingly identical indices may vary from utility to utility.

[5] As an example, for a given generation portfolio, if the load on the system increases by 20%, the reliability index deteriorates by more than 20%.

C.5.2.2 Effect of Off-peak Charging on Emissions

Figures C.5.4 and C.5.5 portray the marginal SO_2 emissions for different load levels.[6] In these illustrative figures, random outages of machines are not considered. The load in only 1 hour is considered. In order to compute the emissions during a day or season, one has to take account for all the hourly loads. Nevertheless, these figures can be used to make some general observations regarding emissions.

Consider the effect of unconstrained charging of EVs in Chicago during peak hours. The system load that corresponds to the peak period is between 15,000 and 20,000 MW. The SO_2 emissions associated with this strategy of charging seen in Figure C.5.4 are high. The high rate of emission in this region of load is predicated by two "dirty" units that are dispatched at these load levels. If we resort to off-peak charging (corresponding to system loads between 10,000 and 15,000 MW), the incremental emission will be lower than that under on-peak charging. Therefore, in this instance, off-peak charging will not only result in reducing the system peak but also in reducing emissions.

Consider Figure C.5.5, the situation in PEPCO. In contrast with the situation in Chicago, if the unconstrained charging of EVs happens when PEPCO's system load is between 4,000 and 5,000 MW, the range of loads during the peak period, the incremental emissions are between zero and 5 lb/MWh. If the off-peak charging happens corresponding to system loads between 2,500 and 3,500 MW, the incremental emissions could be as high as 25 lb/MWh. Under these circumstances, peak load reduction can be achieved by off-peak charging only at the cost of increased emissions. The trade off between these two and the optimization of the charging process to maximize benefits is a matter for serious consideration.

In the following discussion, we show the results of some off-peak charging scenarios. We have not attempted to optimize the strategies but rather we have only examined some ad hoc strategies for off-peak charging.

C.5.2.3 Off-peak Charging and Required Reserve

Some studies (conducted by other researchers) assume that the reserve capacity is a fixed percentage of the annual peak demand. This is an approximation that may be acceptable for certain types of studies, but it does not represent the actual utility planning philosophy. As discussed earlier, the planning of resources in North American utilities entails the use of a reliability index to determine system adequacy.

If the approximation of fixed percent reserve is made, because off-peak charging of EVs does not increase the peak load, the conclusion is that no additional capacity to charge the EVs would be required. This conclusion is incorrect, however, because loads other than those of the peak hour also contribute to the computation of the reliability index. Therefore, an increase in the off-peak loads by off-peak charging will also require some additional capacity. The required capacity for off-peak charging is, of course, less than what is required for on-peak charging because of the nonlinear nature of the index. But the point is that **the required additional capacity for off peak charging is not zero as the simpler approximation indicates.**

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[6] These figures can be obtained from a table of generators arranged in their order of merit with corresponding emission coefficients.

In our simulation of off-peak charging, the required capacity was determined iteratively so that the reliability index with charging, off-peak or unconstrained, is the same as in the base case. The needed capacity obtained in this manner for each case is indicated in the following tables (lower right-hand corner of C.5.19 through C.5.25) that portray the results.

C.5.2.4 Computational Procedure

Off-peak charging for the high EV penetration case for the summer of 2010 in all the four regions was simulated. Additionally, for SCE and LADWP, off-peak charging with low EV penetration in the summer of 2010 was also examined. The interest in the low penetration case arises from the fact that it is closer to the number of EVs under the ZEV sales mandate[7] legislated in California.

In actual operating practice, strategies for off-peak charging have to be chosen to optimally reduce the reserve capacity and emissions. Such a choice of strategy varies from utility to utility. We selected some ad hoc strategies to represent the spectrum of possible strategies, which are shown in Table C.5.26. This table indicates the times of day during which the vehicles are connected for charging. The number of vehicles connected to the system in each hour for charging were uniformly distributed during these periods (see Section C.3).

To further illustrate the strategies, a description of the off-peak cases examined for Chicago follows.

Case 0: Indicates the unconstrained charging scenario.

Case 1: Postpones charging of household vehicles until 5:00 p.m. Household vehicles arriving prior to 5:00 p.m. are disallowed from charging through direct load control.

Case 2: Fleet vehicles arriving between 4 and 5:00 p.m. are disallowed from charging. Then, fleet vehicles are connected for charging from 5:00 p.m. to 12:00 a.m. The number of vehicles connected during this time period is uniformly distributed at 5-minute computational intervals. Household vehicle charging is as in Case 1.

Case 3: All the fleet vehicles are withheld from charging until 10:00 p.m. The fleet vehicles are then connected to the system for charging from 10:00 p.m. to 12 a.m., uniformly distributed in the 5-minute intervals of computation. Household vehicle charging is as in Case 1.

The simulation procedure is identical to the unconstrained case except that the demand profile was modified. The demand profile for different cases of charging was synthesized using the procedure outlined in Section C.3. As an example of this procedure, Figure C.5.6 shows the charging demand for a typical day in the summer of 2010 in Chicago for the cases described above. The addition of these charging demand profiles to that of the system results in a new system temporal load profile. In Figure C.5.7, some hours of a peak day's profile are chosen to indicate the effect on the system peak. Compared to the unconstrained charging case, the system peak load is decreased in all these cases. Although this portrayal shows the profiles

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[7] The mandate requires that a certain percent of new vehicles sold be ZEVs. It stipulates the percentages for each year in the period 1998–2003. For example, the percentage of ZEVs are 2% in 1998 and 10% in 2003.

of a single day, recall that there are variations in the load pattern day to day, and that the computation of emissions is made for the whole season.

C.5.2.5 Results of Off-peak Charging Scenarios

Off-peak charging studies were conducted only for the high EV penetration. Only for Los Angeles, low EV penetration was also considered. The results are shown in Tables C.5.20 to C.5.28. An inset in these tables indicates the capacity added to maintain the same level of reliability as in the base case. We will now discuss the results obtained for different regions.

- *Chicago Metropolitan Area*

Tables C.5.19 and C.5.20 show the ISEs obtained for the three off-peak charging cases under economic and emission constrained dispatch. Table C.5.19 assumes the addition of an IGCC unit, and Table C.5.21 assumes the addition of a CT unit. Several aspects are worthy of note.

For the addition of an IGCC unit in Table C.5.19 the ISEs for SO_2, CO, and NO_x are negative in some cases and positive in others. The negative numbers arise from the fact that the added CC unit capacity is used to supply some system load in addition to the charging load, as in the unconstrained case.

Under emission-constrained dispatch, the annual TSE for SO_2 remains the same in all cases. Although the table shows the emissions for the summer season, the ISE can be positive in some seasons and negative in others, as under unconstrained charging.

Table C.5.19 shows ISE and TSE only for the summer season. As an example, for Case 1 under emission constrained dispatch, the SO_2 ISE is -607 tons. Since the annual SO_2 emission is fixed, the ISE in other seasons is such that the net ISE for the year is zero (within limits of computational errors). Additionally, we note in Table C.5.19 that although the peak demand is reduced for all these cases of off-peak charging, ISE of SO_2 and some other pollutants have increased when compared to those of the unconstrained charging. This is because we require a smaller capacity increment of IGCC technology in the off-peak charging cases (see inset of capacity additions). Thus, less of the relatively cleaner IGCC technology is available to meet the system demand.

As in the case of unconstrained charging, ISEs for off-peak charging are higher with the CT unit addition as well. In addition, ISE is higher than the results with the addition of an IGCC unit (compare Tables C.5.19 to C.5.20). The ISEs for CT unit addition are not negative because the CT unit, having a higher cost of generation relative to the other generating units, does not supply any significant system load.

The variations in the ISEs between the cases and seasons arise from several complex factors of generating unit marginal emissions, and the size and type of capacity additions as explained in connection with Figures C.5.4. The conclusion of this discussion is to indicate that **there is no *apriori* assurance that constrained charging results in reduced emissions.** Similarly, there is no assurance that emission constrained dispatch necessarily reduces emissions during the season of worst air quality. While constrained charging may reduce the additional capacity requirement in general, it might actually increase the emissions in a season when compared to the case of unconstrained charging.

- *Houston Metropolitan Area*

Table C.5.21 shows TSE and ISE in the Houston Light and Power Company system for unconstrained and off-peak charging in the summer season of 2010. Because the added capacity is almost zero, there is no difference between the emissions obtained for CC and CT unit additions. In contrast with the situation in Chicago, the ISEs decrease from Case 1 to Case 3. The reason for this has been explained in relation to Figure C.5.4. For HLP, when EV charging is moved off-peak, more energy comes from relatively cleaner machines. Consequently, delayed charging not only results in reduced need for additional generating resources, but also in reduced emissions.

- *Washington, D.C. Metropolitan Area*

Potomac Electric Power Company. Table C.5.22 provides the results for the year 2010 summer season with unconstrained and constrained EV charging scenarios. Because the capacity added is very small, there is no discernable difference in the emissions of most pollutants between the CC and CT unit addition scenarios. The results of computation showed differences only in the fourth decimal place. The emissions increase progressively by delayed off-peak charging.

Virginia Electric Power Company. As was indicated earlier, this system was simulated under economic dispatch with mitigative measures proposed by the utility to comply with Title 4 of the CAAA. Economic dispatch was simulated for all controlled charging strategies as well. Table C.5.23 shows that the emissions of SO_2, CO, and NO_x increase with delayed charging. We conclude, therefore, that for both utilities in the Washington, D.C., area, increased emissions result from delayed charging.

- *Los Angeles Metropolitan Area*

High EV Penetration

Southern California Edison Company. Table C.5.24 shows that ISE of most pollutants are small, and are about the same, in the two scenarios of CC and CT addition studied. There is a small decrease in the ISE of NO_x and CO with delayed charging. As discussed in Section C.3, when the charging energy is moved off-peak, more ISEs come from existing in and out-basin generation than from the CC unit added to maintain reliability (in both low and high penetration scenarios). There is no predominant pattern in the sources of ISEs in the CT addition scenario.

Los Angeles Department of Water and Power. Table C.5.25 indicates that the emissions of pollutants are similar to those of SCE. The emissions are not very much affected by delayed charging. The only exceptions are those of the NO_x and CO; they decrease with delayed charging for CC unit addition, and increase with the delay for CT unit addition. This is the opposite of the situation in SCE in which these emissions decrease with delayed charging. As SCE and the LADWP serve customers in the same air quality district, these results substantiate that one cannot formulate universal conclusions on the effect of delayed charging on emissions even within the same region. Also, in-basin ISEs increase as the EV charging energy is moved further off-peak in the CC policy scenarios (Appendix C.7). The same pattern exists for the CT scenarios.

Low EV Penetration

Tables C.5.24 and C.5.25 also show the ISEs in SCE and LADWP for the low EV penetration scenario. As in the high EV penetration case, the emissions of NO_x decrease with delayed charging in the SCE system, although NO_x ISEs increase from the system of the LADWP.

C.5.3 Marginal System Emissions

As the previous section discusses, the ISE can be negative under certain circumstances. If the unit added to meet the charging demand of the EVs is cleaner, and has a lower incremental cost of generation than several existing units, ISE can be negative.

A negative ISE indicates that the penetration of EVs hastens the addition of new cleaner generation technologies.[8] (However, negative value for TSE does not indicate that if one abstains from charging EVs, emissions will increase!)

In some policy-related analysis, one may wish to know the actual emissions that can be attributed to the charging of the EVs. For instance, one may wish to know the differences between the resulting emissions when vehicles are charged off-peak versus when charging is unconstrained. Similarly, one may wish to compute the emissions that result from increased or decreased driving patterns, or to compute emissions per mile driven. For such computations, TSE or ISE may be inappropriate. As discussed previously in this section C.5, the appropriate emissions to use are the MSE or ASE. The figures are computed by assuming that the added generating unit is a *fait accompli*, and by tracking the generating units that supply the charging energy.

Driven by the above need, we have computed the MSEs for the six utilities under study in the summer season of 2010. Computations include both the unconstrained and constrained charging scenario. In the tables portraying the results of computation, we also indicate ASE for purposes of comparison.

The procedures for the calculation of MSE and ASE were discussed earlier in Section C.5. MSE is the difference between two TSEs obtained by including and excluding EVs. The additional generation to meet the demand of EVs is included as a resource in the simulations to obtain TSEs with and without the EV demand. Base load plants do not contribute to MSE. Such plants are fully loaded in both simulations that include and exclude EVs. Consequently, the difference between the TSEs of the two simulations cannot contain any energy component from base load units. In contrast to this, the computation of ASE includes the total emission from all plants in the system. ASE is the ratio of the total emission to the total energy generated. Hence, the calculation of ASE does include emission and energy contributions from base load generators.

C.5.3.1 Marginal Emissions Under Unconstrained Charging

- *Chicago Metropolitan Area*

Tables C.5.27 to C.5.32 show the results obtained for Chicago. Some important observations are as follows.

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[8] In the absence of the EVs, the natural demand growth in the system would call for the addition of cleaner units eventually. The penetration of EVs accelerates the demand growth and the addition of cleaner units.

Tables C.5.27 and C.5.28 show the MSE for the addition of a IGCC under economic and constrained dispatch. The SO_2 emission under constrained dispatch is lower. Since the annual SO_2 emission cap is the same with or without the EVs, under constrained dispatch, cleaner units have to supply the EV charging energy in order to meet the annual emission cap. We observe the same trend in Tables C.5.29 and C.5.30 for the two dispatch scenarios for the addition of a CT unit.

An important observation is that the MSE is generally higher than the ASE. This difference between ASE and MSE is smaller in case of emission constrained dispatch. The reason for this is that a large component of nuclear energy dilutes the emissions from coal-fired generators in the calculation of ASE. In the MSE calculation, all of the marginal energy comes from coal and gas fired generation.

MSEs for the policy cases (Tables C.5.31 and C.5.32) demonstrate mixed results. Under economic dispatch, emissions rates decrease as charging energy is moved further off-peak (Case 1 to Case 3). This decrease occurs because cleaner machines supply more energy as the charging moves off-peak. However, this trend of reducing emissions by delayed charging is not very pronounced under emission constrained dispatch. This arises from the fact that the annual SO_2 emissions are fixed for all delayed charging cases. Note as well that under certain circumstances (Cases 2 and 3 for IGCC addition), the MSE under emission constrained dispatch can be lower than ASE.

- *Houston Metropolitan Area*

Examining the MSE results for HLP with unconstrained charging again reveals that the MSEs of SO_2 and NO_x are much larger than the ASEs (Tables C.5.33 and C.5.34). The trends in the policy cases are mixed when the EV charging is moved off-peak (see Table C.5.35). The SO_2 emissions decrease, the NO_x, CO, and CO_2 emissions increase, and the TSP and VOC emissions are unaffected. As stated earlier, the CC and CT scenario results are identical because practically no capacity addition was required for the off-peak charging cases.

- *Washington, D.C. Metropolitan Area*

Potomac Electric Power Company. The PEPCO results in Tables C.5.36 and C.5.37 reverse the trends observed from the previous utilities. The MSEs are smaller than the ASEs for SO_2, CO, and NOx. The same trend is observed (Table C.5.38) for off-peak cases as well. Furthermore, MSEs increase as the EV charging energy is pushed further off-peak. But the change is very small.

Virginia Electric Power Company. VEPCO's service area borders PEPCO, but unlike PEPCO, the MSEs are much larger than the ASEs for SO_2, CO, and NO_x for the addition of a CC or CT unit (see Tables C.5.39 and C.5.40). However VEPCO's off-peak charging cases (Table C.5.41) do follow the same pattern as PEPCO's; the emission rates increase as charging occurs further off-peak. Again, these changes are very small.

- *Los Angeles Metropolitan Area*

Southern California Edison. Tables C.5.42 and C.5.43 show the MSE of pollutants in comparison with the ASE for the summer of 2010 for the scenarios of CC and CT unit addition. Note that the MSE is of the same order of magnitude as ASE, and is smaller for some pollutants. This indicates the overall "cleanliness" of the generating units in the system.

The following are some exceptions. The MSE rate for SO_2 is much lower than ASE, reflecting the fact that SCE's cycling and peaking capacity is gas-fired and that it has some coal fired capacity in its base load generation. The MSE of carbon-related emissions are higher than ASE.

Table C.5.44 shows the effect of constrained charging on the MSE of pollutants. Delayed charging has no effect on MSE of SO_2. But CO emissions show a decrease with delayed charging. No particular pattern is apparent for the MSE of other pollutants.

Los Angeles Department of Water and Power. Tables C.5.45 and C.5.46 indicate the MSE in the unconstrained charging case for the scenarios of CC and CT addition. We note in both scenarios that while the MSE of SO_2 and NOx are much lower than ASE, the carbon related MSE is higher than ASE.

Table C.5.47 shows the MSE for different cases of constrained charging. As in the case of SCE, CO emissions decrease with delayed charging. However, note that the MSE of the two utilities serving the same region could be quite different. For example, the MSE for two important pollutants, CO and NO_x, is almost twice as high in LADWP than in SCE (compare Tables C.5.44 and C.5.47).

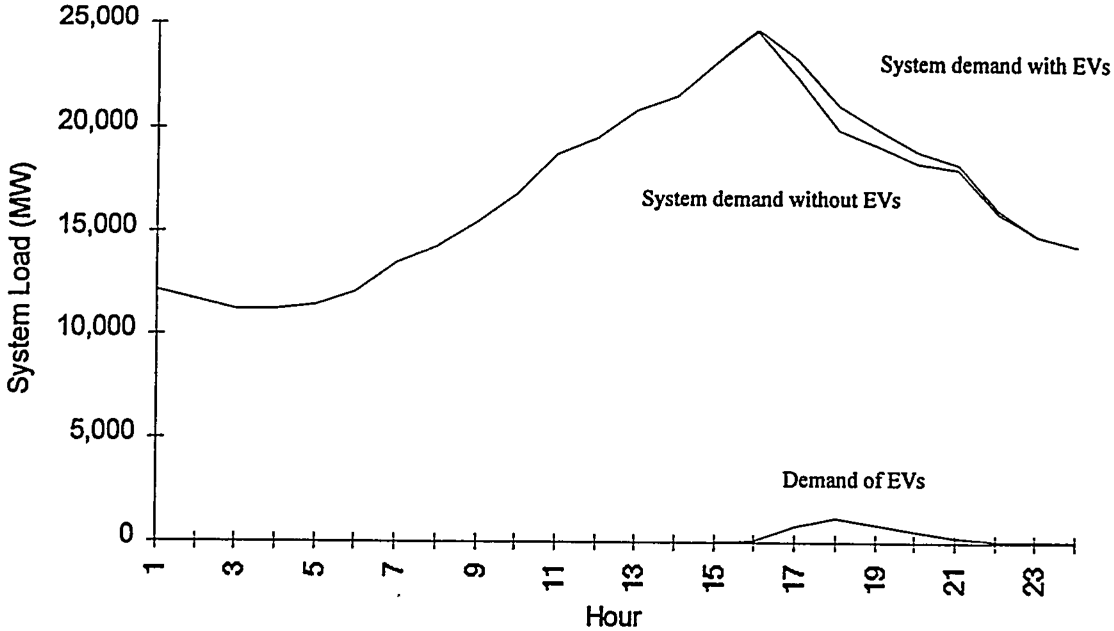

Figure C.5.1 Chicago Summer 2010 Peak Day Temporal Profile With/Without EV Unconstrained Charging

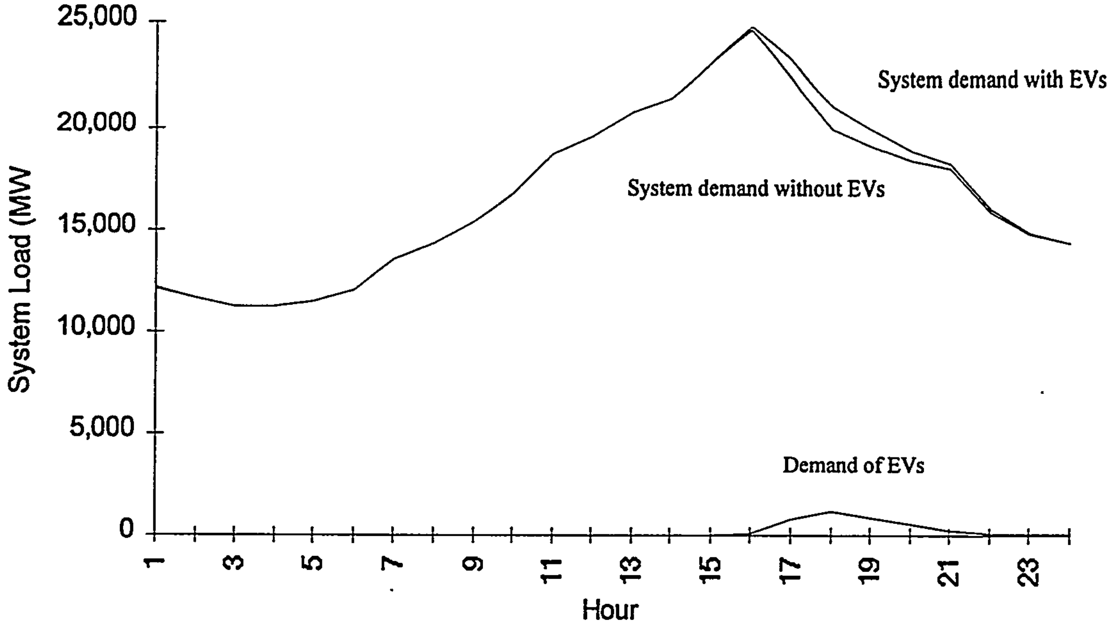

Figure C.5.2 Chicago Winter 2010 Peak Day Temporal Profile With/Without EV Unconstrained Charging

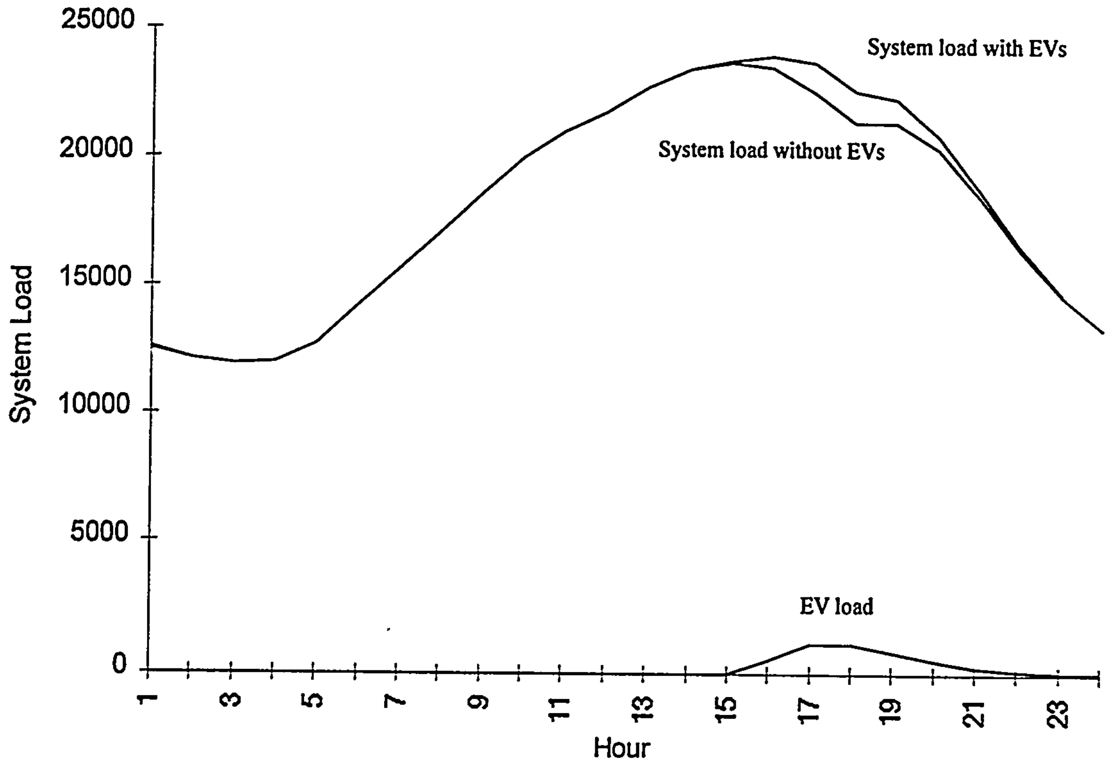

**Figure C.5.3 SCE Temporal Demand: 2010-Peak Day-
Low EV Penetration Scenario**

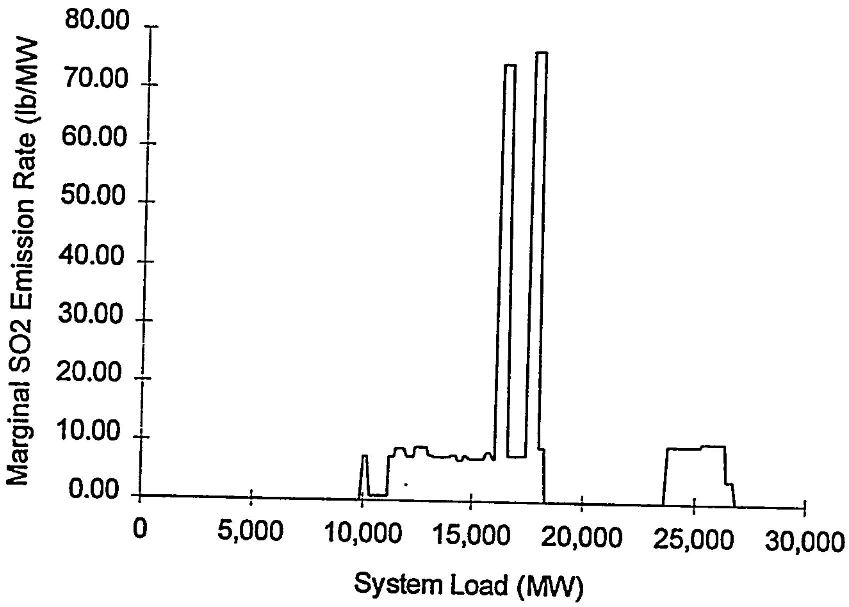

Figure C.5.4 System Marginal SO2 Emission Rate for CE (2010)

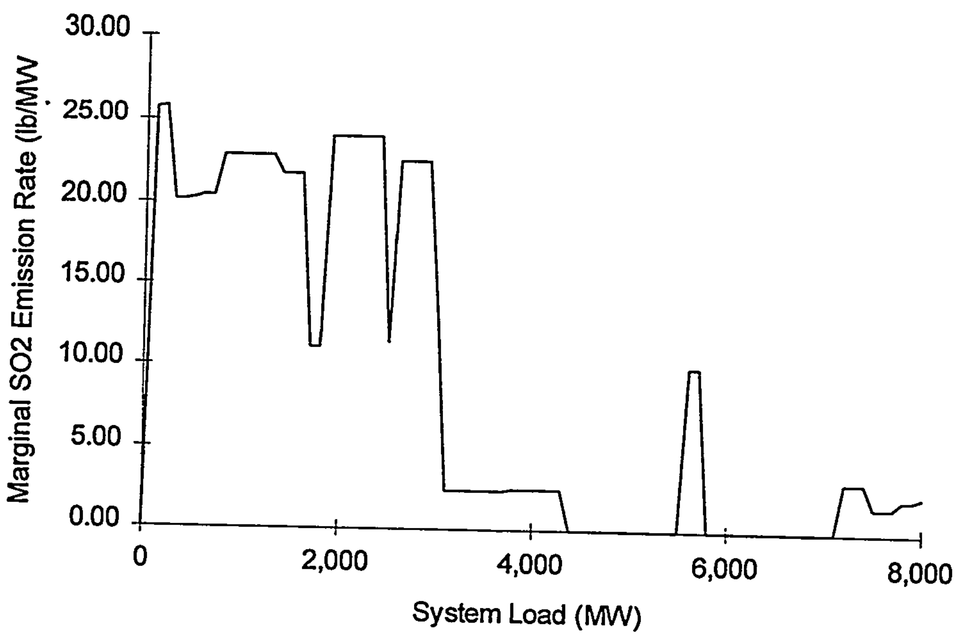

Figure C.5.5 System Marginal SO2 Emission Rate for PEPCO (2010)

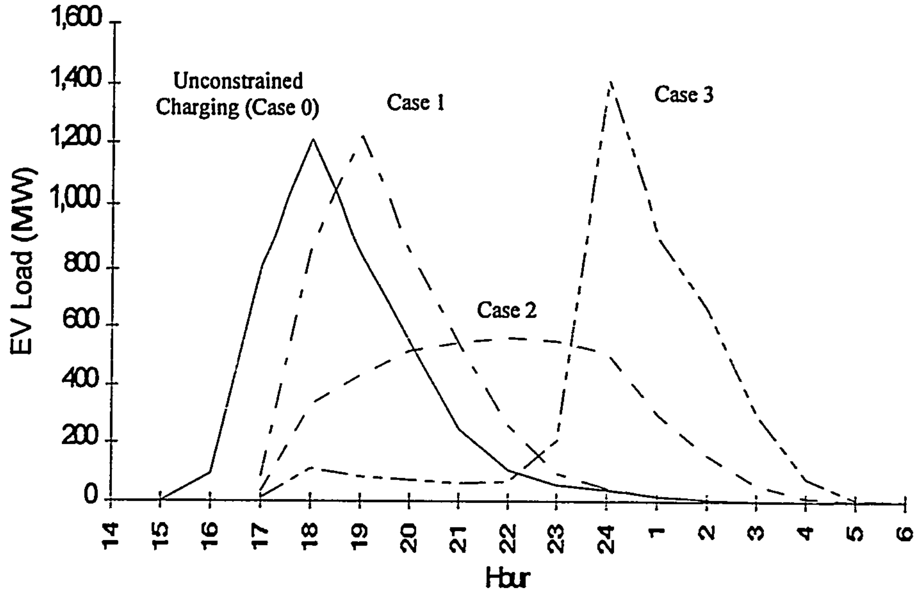

Figure C.5.6 EV Charging Demand on CE's System for Off-peak Charging Scenarios, Summer of 2010

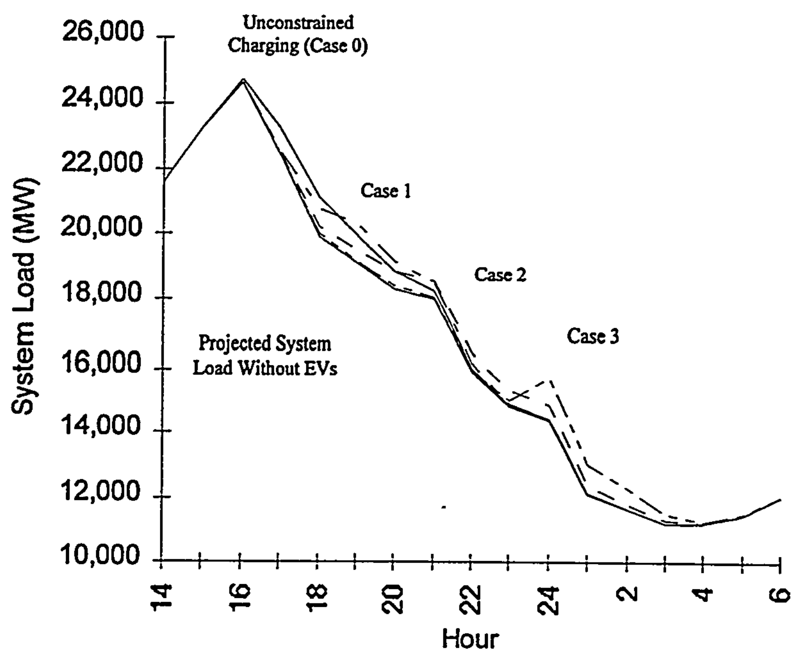

Figure C.5.7 Effect of Delayed EV Charging on System Demand of CE, Summer of 2010

Table C.5.1 Commonwealth Edison Co. Of Chicago - Year 2000

Scenario: Year 2000 - Economic Dispatch - Unconstrained EV Charging

	SO2				CO				NOx			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	32,343	20,863	25,229	34,177	1,035	695	826	1,013	18,864	12,407	13,975	18,448
EV Scenario ISE (tons)	140	81	132	125	4	2	4	3	74	48	68	62
Base Case ASE (lb/MWh)	2.58	1.92	1.94	3.09	0.08	0.06	0.06	0.09	1.51	1.14	1.07	1.67
EV Scenario ASE (lb/MWh)	2.59	1.93	1.95	3.1	0.08	0.06	0.06	0.09	1.51	1.15	1.07	1.67

	TSP				VOC				CO2			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	2,914	2,129	2,211	2,844	153	107	119	149	6,301,159	4,546,000	4,849,163	6,151,895
EV Scenario ISE (tons)	9	7	9	8	1	0	1	0	19,989	15,727	20,249	17,310
Base Case ASE (lb/MWh)	0.23	0.2	0.17	0.26	0.01	0.01	0.01	0.01	502.98	418.75	372.41	555.6
EV Scenario ASE (lb/MWh)	0.23	0.2	0.17	0.26	0.01	0.01	0.01	0.01	504.2	419.87	373.67	556.75

Notes:

(1) The TSE is the total tons of emissions during a simulation period (a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation.

(2) The seasons are defined as follows:
Winter Season (1/1/00 - 3/31/00 : 2184 h)
Spring Season (4/1/00 - 6/30/00 : 2184 h)
Summer Season (7/1/00 - 9/31/00 : 2208 h)
Fall Season (10/1/00 - 12/31/00 : 2208 h)

(3) The EV charging energy for each season is:

Charging Energy (MWh)			
Winter	Spring	Summer	Fall
18,566	16,816	20,415	16,420

Table C.5.2 Commonwealth Edison Co. Of Chicago - Year 2010 ISE

Scenario: Year 2010 - Integrated Gasification Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	60,516	23,801	42,648	57,890	2,308	824	1,616	1,990	33,863	13,748	23,534	30,109
Low EV Scenario ISE	-741	-647	-685	-859	-37	-18	-24	-40	-391	-331	-373	-412
High EV Scenario ISE	-3,095	-2,435	-2,685	-3,422	-149	-69	-97	-152	-1,622	-1,258	-1,463	-1,641

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	5,589	2,871	4,586	5,098	330	148	255	294	12,533,168	6,166,492	10,106,727	11,337,722
Low EV Scenario ISE	32	15	24	28	0	1	1	0	49,954	29,137	45,959	39,387
High EV Scenario ISE	115	59	90	105	0	2	3	-1	174,877	118,863	171,896	151,267

Notes:

(1) The TSE is the total tons of emissions during a simulation period (a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 h)
Spring Season (4/1/10 - 6/30/10 : 2184 h)
Summer Season (7/1/10 - 9/31/10 : 2208 h)
Fall Season (10/1/10 - 12/31/10 : 2208 h)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	68,500	58,165	71,928	57,461
High EV	250,339	228,574	273,386	226,319

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	105
High EV	417

Table C.5.3 Commonwealth Edison Co. Of Chicago - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	60,516	23,801	42,648	57,890	2,305	824	1,615	1,987	33,859	13,748	23,533	30,107
Low EV Scenario ISE	413	315	539	404	28	8	20	19	203	170	267	191
High EV Scenario ISE	1,424	1,316	2,071	1,551	104	33	78	77	708	699	1,020	732

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	5,588	2,871	4,586	5,097	330	148	255	293	12,529,145	6,166,399	10,105,947	11,334,939
Low EV Scenario ISE	22	27	32	22	3	1	2	2	63,708	57,245	77,029	57,249
High EV Scenario ISE	75	107	122	84	9	5	9	8	229,391	229,223	291,989	222,489

Notes:

(1) The TSE is the total tons of emissions during a simulation period (a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 h)
Spring Season (4/1/10 - 6/30/10 : 2184 h)
Summer Season (7/1/10 - 9/31/10 : 2208 h)
Fall Season (10/1/10 - 12/31/10 : 2208 h)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	68,500	58,165	71,928	57,461
High EV	250,339	228,574	273,386	226,319

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	105
High EV	417

Table C.5.4 Commonwealth Edison Co. Of Chicago - Year 2010 ISE

Scenario: Year 2010 - Integrated Gasification Combined Cycle - Emission-Constrained Dispatch - Unconstrained EV Charging

	SO_2 (tons)				CO (tons)				NO_x (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	44,305	19,246	34,771	44,102	2,434	827	1,644	2,073	32,376	14,002	23,500	28,941
Low EV Scenario ISE	714	-458	-252	247	-54	-20	-29	-53	-169	-322	-339	-246
High EV Scenario ISE	2,125	-1,742	-1,026	394	-211	-76	-116	-198	-825	-1,236	-1,336	-1,073

	TSP (tons)				VOC (tons)				CO_2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	5,423	2,836	4,518	4,979	335	147	255	297	12,337,873	6,108,705	10,003,063	11,197,518
Low EV Scenario ISE	51	16	28	42	3	0	1	-1	70,268	30,008	50,485	54,579
High EV Scenario ISE	182	63	107	153	-2	2	2	-2	247,610	121,774	189,390	203,162

Notes:

(1) The TSE is the total tons of emissions during a simulation period (a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 h)
Spring Season (4/1/10 - 6/30/10 : 2184 h)
Summer Season (7/1/10 - 9/31/10 : 2208 h)
Fall Season (10/1/10 - 12/31/10 : 2208 h)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	68,543	58,165	71,925	57,380
High EV	250,486	228,574	273,386	226,088

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	105
High EV	417

Table C.5.5 Commonwealth Edison Co. Of Chicago - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Emission Constrained Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	44,305	19,246	34,771	44,102	2,434	827	1,644	2,073	32,376	14,002	23,500	28,841
Low EV Scenario ISE	250	229	-253	-250	30	9	29	26	167	166	146	85
High EV Scenario ISE	-121	298	-32	-725	124	43	101	105	399	556	675	323

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	5,423	2,836	4,518	4,979	335	147	255	297	12,337,873	6,108,705	10,008,063	11,197,518
Low EV Scenario ISE	19	26	23	13	3	1	3	2	61,197	56,808	66,795	47,878
High EV Scenario ISE	54	96	97	54	10	6	10	9	225,524	218,154	266,291	190,044

Notes:

(1) The TSE is the total tons of emissions during a simulation period (a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 h)
Spring Season (4/1/10 - 6/30/10 : 2184 h)
Summer Season (7/1/10 - 9/31/10 : 2208 h)
Fall Season (10/1/10 - 12/31/10 : 2208 h)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	68,543	58,165	71,928	57,380
High EV	250,486	228,574	273,386	226,088

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	105
High EV	417

Table C.5.6 Houston Light and Power of Houston - Year 2000

Scenario: Year 2000 - Economic Dispatch - Unconstrained EV Charging

	SO2				CO				NOx			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	4,403	6,722	7,324	664	8,072	8,156	10,212	847	24,378	25,901	30,430	2,251
EV Scenario ISE (tons)	4	5	11	3	2	4	3	3	12	12	15	12
Base Case ASE (lb/MWh)	0.54	0.75	0.71	0.80	0.99	0.91	0.99	1.02	2.99	2.89	2.95	2.71
EV Scenario ASE (lb/MWh)	0.54	0.75	0.71	0.80	0.99	0.91	0.99	1.02	2.99	2.89	2.96	2.71

	TSP				VOC				CO2			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	489	538	619	58	489	538	619	58	9,778,660	11,003,916	12,701,210	1,055,946
EV Scenario ISE (tons)	0	0	0	0	0	0	0	0	4,892	5,149	7,169	4,909
Base Case ASE (lb/MWh)	0.06	0.06	0.06	0.07	0.06	0.06	0.06	0.07	1199.35	1227.78	1231.29	1271.33
EV Scenario ASE (lb/MWh)	0.06	0.06	0.06	0.07	0.06	0.06	0.06	0.07	1199.43	1227.85	1231.43	1271.36

Notes:
(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation.

(2) The seasons are defined as follows:
Winter Season (1/1/00 - 3/31/00 : 2184 hr)
Spring Season (4/1/00 - 6/30/00 : 2184 hr)
Summer Season (7/1/00 - 9/31/00 : 2208 hr)
Fall Season (10/1/00 - 12/31/00 : 2208 hr)

(3) The EV charging energy for each season is:

Charging Energy (MWh)			
Winter	Spring	Summer	Fall
7,081	7,415	9,299	7,346

Table C.5.7 Houston Light and Power - Year 2010 ISE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	10,853	10,123	14,847	8,473	7,331	7,754	10,231	8,867	23,134	26,170	31,690	22,659
Low EV Scenario ISE	85	67	102	61	7	10	9	4	41	39	72	42
High EV Scenario ISE	-222	-61	-126	-119	-83	-99	-61	-89	-212	-271	-139	-218

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	666	754	749	690	571	646	624	591	11,782,315	12,992,013	15,617,649	12,010,747
Low EV Scenario ISE	2	2	2	2	2	2	2	2	37,347	36,838	48,310	36,607
High EV Scenario ISE	14	15	16	15	7	9	8	8	31,081	51,303	68,462	38,500

Notes:
(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	53,746	55,185	71,665	54,407
High EV	183,823	189,586	239,944	185,946

(4) Capacity added to maintain the same reliability as in the base case:

	Capacity (MW)
Low EV	16
High EV	171

Table C.5.8 Houston Light and Power - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	10,853	10,123	14,847	8,473	7,331	7,754	10,231	8,867	23,134	26,170	31,690	22,659
Low EV Scenario ISE	125	91	130	86	17	26	16	14	68	79	95	73
High EV Scenario ISE	213	198	169	146	32	71	30	26	81	179	116	124

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	666	754	749	690	571	646	624	591	11,782,315	12,992,013	15,617,649	12,010,747
Low EV Scenario ISE	2	1	2	2	2	1	2	1	48,200	45,849	58,454	46,943
High EV Scenario ISE	12	8	14	10	8	6	10	7	149,689	150,151	178,546	150,732

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	53,746	55,185	71,665	54,407
High EV	183,823	189,586	239,944	185,946

(4) Capacity added to maintain the same reliability as in the base case:

	Capacity (MW)
Low EV	16
High EV	171

Table C.5.9 Potomac Electric Power Co. - Year 2010 ISE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	23,178	24,723	29,045	24,309	1,350	1,321	1,584	1,350	15,302	15,857	18,747	15,727
Low EV Scenario ISE	1	5	3	1	1	2	2	1	2	8	5	3
High EV Scenario ISE	1	13	6	4	4	5	4	4	4	20	13	8

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	1,890	1,918	2,218	1,917	225	213	264	218	7,156,056	7,119,644	8,554,076	7,208,863
Low EV Scenario ISE	1	2	2	1	1	1	1	0	7,830	8,901	10,311	7,888
High EV Scenario ISE	3	5	5	3	1	1	2	1	21,994	25,162	28,298	22,479

Notes:
(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	16,999	16,765	21,435	16,481
High EV	47,919	48,215	60,089	47,312

(4) Capacity added to maintain sam reliability as in the base case:

	Capacity (MW)
Low EV	22
High EV	72

Table C.5.10 Potomac Electric Power Co. - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	23,178	24,723	29,045	24,309	1,350	1,321	1,584	1,350	15,302	15,857	18,747	15,727
Low EV Scenario ISE	1	5	3	1	2	2	3	2	2	8	7	3
High EV Scenario ISE	1	12	6	4	4	5	8	4	5	20	17	9

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	1,890	1,918	2,218	1,917	225	213	264	218	7,156,056	7,119,644	8,554,076	7,208,863
Low EV Scenario ISE	1	2	2	1	1	1	1	0	7,877	8,983	11,306	7,932
High EV Scenario ISE	3	5	5	3	1	1	2	1	22,147	25,430	31,548	22,629

Notes:
(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	16,999	16,765	21,435	16,481
High EV	47,919	48,215	60,089	47,312

(4) Capacity added to maintain sam reliability as in the base case:

	Capacity (MW)
Low EV	22
High EV	72

Table C.5.11 Virginia Power - Year 2010 ISE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	23,395	14,128	34,046	22,540	3,484	3,061	3,979	3,254	28,497	23,899	35,078	26,880
Low EV Scenario ISE	41	16	121	43	4	3	5	4	44	22	44	44
High EV Scenario ISE	143	59	417	153	13	10	18	13	156	82	154	159

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	2,738	2,355	3,537	2,531	622	589	737	603	17,995,569	14,957,363	20,926,728	17,377,721
Low EV Scenario ISE	5	1	7	5	1	0	1	1	21,317	23,575	21,098	20,952
High EV Scenario ISE	16	3	24	17	2	1	4	2	75,371	85,601	73,568	75,825

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	23,055	22,853	28,966	22,357
High EV	82,145	83,044	102,377	81,305

(4) Capacity added to maintain the same reliability as in the base case:

	Capacity (MW)
Low EV	16
High EV	59

Table C.5.12 Virginia Power - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	23,395	14,128	34,046	22,540	3,484	3,061	3,979	3,254	28,497	23,899	35,078	26,880
Low EV Scenario ISE	72	21	144	67	4	3	6	4	51	23	51	50
High EV Scenario ISE	257	77	505	246	13	10	20	13	181	86	178	180

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	2,738	2,355	3,537	2,531	622	589	737	603	17,995,569	14,957,363	20,926,728	17,377,721
Low EV Scenario ISE	6	1	8	6	1	0	1	1	23,585	24,002	24,075	22,898
High EV Scenario ISE	21	4	29	21	2	1	4	2	83,891	87,208	84,756	83,138

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	23,055	22,853	28,966	22,357
High EV	82,145	83,044	102,377	81,305

(4) Capacity added to maintain the same reliability as in the base case:

	Capacity (MW)
Low EV	16
High EV	59

Table C.5.13 Southern California Edison - Year 2000

Scenario: Year 2000 - Economic Dispatch - Unconstrained EV Charging

	SO2				CO				NOx			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	9,182	7,080	9,308	9,286	3,022	2,714	3,334	2,926	18,597	15,104	20,145	18,571
EV Scenario ISE (tons)	0	0	0	0	4	4	5	4	14	16	18	17
Base Case ASE (lb/MWh)	0.79	0.60	0.67	0.73	0.26	0.23	0.24	0.23	1.60	1.28	1.45	1.46
EV Scenario ASE (lb/MWh)	0.79	0.60	0.67	0.73	0.26	0.23	0.24	0.23	1.60	1.28	1.45	1.46

	PM10				ROG				C			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	930	826	973	1,018	349	354	417	382	3,027,065	2,740,064	3,403,667	3,041,719
EV Scenario ISE (tons)	0	0	1	0	0	0	0	0	3,102	342	4,175	3,421
Base Case ASE (lb/MWh)	0.08	0.07	0.07	0.08	0.03	0.03	0.03	0.03	260.44	232.21	244.99	239.13
EV Scenario ASE (lb/MWh)	0.08	0.07	0.07	0.08	0.03	0.03	0.03	0.03	260.50	232.30	245.07	239.21

Notes:
(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation.

(2) The seasons are defined as follows:
Winter Season (1/1/00 - 3/31/00 : 2184 hr)
Spring Season (4/1/00 - 6/30/00 : 2184 hr)
Summer Season (7/1/00 - 9/31/00 : 2208 hr)
Fall Season (10/1/00 - 12/31/00 : 2208 hr)

(3) The EV charging energy for each season is:

Charging Energy (MWh)			
Winter	Spring	Summer	Fall
18726	20499	25142	20439

Table C.5.14 Southern California Edison - Year 2010 ISE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	9,112	6,018	7,919	7,886	2,992	2,360	2,918	2,544	16,184	11,210	14,727	13,992
Low EV Scenario ISE	1	1	2	1	22	24	37	25	28	26	72	39
High EV Scenario ISE	0	3	4	3	30	49	68	50	-30	16	68	35

	PM10 (tons)				ROG (tons)				C (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	1,360	1,062	1,250	1,145	544	472	556	509	3,542,689	2,805,672	3,408,947	3,086,112
Low EV Scenario ISE	11	14	13	12	6	8	8	7	30,205	34,116	44,597	33,987
High EV Scenario ISE	33	32	40	31	21	19	24	19	65,407	78,178	99,447	77,202

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	247,039	270,604	333,000	262,569
High EV	592,080	647,091	795,352	628,530

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	162
High EV	620

Table C.5.15 Southern California Edison - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	9,112	6,018	7,919	7,886	2,992	2,360	2,918	2,544	16,184	11,210	14,727	13,992
Low EV Scenario ISE	1	1	2	1	37	31	50	34	93	69	147	85
High EV Scenario ISE	3	3	8	3	98	78	127	82	317	178	358	214

	PM10 (tons)				ROG (tons)				C (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	1,360	1,062	1,250	1,145	544	472	556	509	3,542,689	2,805,672	3,408,947	3,086,112
Low EV Scenario ISE	11	11	12	11	6	7	7	5	40,684	37,111	49,820	37,295
High EV Scenario ISE	21	26	32	22	12	16	16	13	96,992	89,735	129,273	90,037

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	247,039	270,604	333,000	262,569
High EV	592,080	647,091	795,352	628,530

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	162
High EV	620

Table C.5.16 Los Angeles Dept. Of Water and Power - Year 2000

Scenario: Year 2000 - Economic Dispatch - Unconstrained EV Charging

	SO2				CO				NOx			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	5,539	5,509	6,102	5,787	585	605	718	569	7,170	7,960	8,543	7,779
EV Scenario ISE (tons)	0	0	0	0	1	1	3	1	3	2	5	2
Base Case ASE (lb/MWh)	1.80	1.73	1.70	1.83	0.19	0.19	0.20	0.18	2.33	2.50	2.38	2.46
EV Scenario ASE (lb/MWh)	1.80	1.73	1.70	1.82	0.19	0.19	0.20	0.18	2.33	2.49	2.37	2.46

	PM10				ROG				C			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE (tons)	462	478	538	506	92	96	108	95	956,819	992,035	1,110,094	959,312
EV Scenario ISE (tons)	0	0	0	0	0	0	0	0	1,187	1,275	1,703	1,257
Base Case ASE (lb/MWh)	0.15	0.15	0.15	0.16	0.03	0.03	0.03	0.03	310.95	311.55	309.26	303.36
EV Scenario ASE (lb/MWh)	0.15	0.15	0.15	0.16	0.03	0.03	0.03	0.03	310.90	311.49	309.22	303.30

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation.

(2) The seasons are defined as follows:
Winter Season (1/1/00 - 3/31/00 : 2184 hr)
Spring Season (4/1/00 - 6/30/00 : 2184 hr)
Summer Season (7/1/00 - 9/31/00 : 2208 hr)
Fall Season (10/1/00 - 12/31/00 : 2208 hr)

(3) The EV charging energy for each season is:

Charging Energy (MWh)			
Winter	Spring	Summer	Fall
8,695	9,565	11,932	9,474

Table C.5.17 Los Angeles Dept. Of Water and Power - Year 2010 ISE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	5,484	5,507	6,122	5,787	748	744	1,006	705	7,478	8,261	9,099	8,050
Low EV Scenario ISE	1	1	1	1	-4	4	-1	7	-102	-29	-37	-21
High EV Scenario ISE	1	1	2	1	-14	-4	-12	1	-153	-76	-97	-57

	PM10 (tons)				ROG (tons)				C (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	499	521	587	556	107	112	126	111	1,089,906	1,137,177	1,284,066	1,104,818
Low EV Scenario ISE	11	11	10	10	7	7	7	6	7,897	21,750	15,701	22,327
High EV Scenario ISE	19	16	21	16	12	11	13	9	21,055	28,657	34,691	28,603

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	110,200	120,220	148,820	116,530
High EV	238,998	267,065	330,261	259,016

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	210
High EV	496

Table C.5.18 Los Angeles Dept. Of Water and Power - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	5,484	5,507	6,122	5,787	748	744	1,006	705	7,478	8,261	9,099	8,050
Low EV Scenario ISE	1	1	1	1	36	33	51	32	123	76	146	73
High EV Scenario ISE	1	1	2	1	81	76	107	75	263	171	309	166

	PM10 (tons)				ROG (tons)				C (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	499	521	587	556	107	112	126	111	1,089,906	1,137,177	1,284,066	1,104,818
Low EV Scenario ISE	2	4	3	3	1	2	1	2	19,272	18,484	26,570	17,808
High EV Scenario ISE	5	8	8	8	1	4	3	4	41,794	41,406	58,854	39,983

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	110,200	120,220	148,820	116,530
High EV	238,998	267,065	330,261	259,016

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	210
High EV	496

Table C.5.19 Commonwealth Edison Co. Of Chicago - Year 2010 Summer Off-Peak Charging ISE

Scenario: Year 2010 - Integrated Gasification Combined Cycle (High EV Scenario) - Summer Charging Policy Scenarios

Economic Dispatch	SO2 (tons)				CO (tons)				NOx (tons)			
	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case TSE	42647.80	N/A	N/A	N/A	1615.19	N/A	N/A	N/A	23,533	N/A	N/A	N/A
High EV Scenario ISE	-2685.40	-1008.99	915.61	1409.48	-95.80	-45.03	25.34	48.35	-1,462	-577	501	831
Emission Constrained Dispatch												
Base Case TSE	34770.92	N/A	N/A	N/A	1643.91	N/A	N/A	N/A	23,500	N/A	N/A	N/A
High EV Scenario ISE	-1026.08	-606.93	961.07	1455.90	-115.96	-50.33	23.71	46.61	-1,336	-586	532	915

Economic Dispatch	TSP (tons)				VOC (tons)				CO2 (tons)			
	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case TSE	4586.35	N/A	N/A	N/A	255.07	N/A	N/A	N/A	10,105,947	N/A	N/A	N/A
High EV Scenario ISE	89.75	111.00	134.59	143.71	3.10	4.77	6.99	7.57	172,676	225,345	289,469	310,704
Emission Constrained Dispatch												
Base Case TSE	4518.03	N/A	N/A	N/A	255.49	N/A	N/A	N/A	10,008,063	N/A	N/A	N/A
High EV Scenario ISE	106.65	114.52	136.99	147.06	2.39	4.62	6.94	7.48	189,390	228,856	292,497	314,709

Notes:

(1) The TSE is the total tons of emissions during a simulation period (a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
273,386

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	274
Case 2	78
Case 3	0.1

Table C.5.20 Commonwealth Edison Co. Of Chicago - Year 2010 Summer Off-Peak Charging ISE

Scenario Year 2010 - Combustion Turbine (High EV Scenario) - Summer Charging Policy Scenarios

Economic Dispatch	SO2 (tons) Unconstrained	SO2 Case 1	SO2 Case 2	SO2 Case 3	CO (tons) Unconstrained	CO Case 1	CO Case 2	CO Case 3	NOx (tons) Unconstrained	NOx Case 1	NOx Case 2	NOx Case 3
Base Case TSE	42647.80	N/A	N/A	N/A	1615.19	N/A	N/A	N/A	23,533	N/A	N/A	N/A
High EV Scenario ISE	2070.63	2176.83	1848.90	1410.69	77.66	71.05	58.89	48.39	1,020	1,081	987	832
Emission Constrained Dispatch												
Base Case TSE	34770.92	N/A	N/A	N/A	1643.91	N/A	N/A	N/A	23,500	N/A	N/A	N/A
High EV Scenario ISE	-31.62	45.90	-41.12	-215.36	101.07	94.60	79.67	66.44	675	741	717	630

Economic Dispatch	TSP (tons) Unconstrained	TSP Case 1	TSP Case 2	TSP Case 3	VOC (tons) Unconstrained	VOC Case 1	VOC Case 2	VOC Case 3	CO2 (tons) Unconstrained	CO2 Case 1	CO2 Case 2	CO2 Case 3
Base Case TSE	4586.35	N/A	N/A	N/A	255.07	N/A	N/A	N/A	10,105,947	N/A	N/A	N/A
High EV Scenario ISE	122.11	132.08	140.87	143.72	8.78	8.59	8.09	7.57	291,989	304,675	312,660	310,734
Emission Constrained Dispatch												
Base Case TSE	4518.03	N/A	N/A	N/A	255.49	N/A	N/A	N/A	10,008,063	N/A	N/A	N/A
High EV Scenario ISE	97.45	107.60	119.38	124.95	9.70	9.50	8.90	8.24	266,291	279,327	290,277	290,809

Notes:

(1) The TSE is the total tons of emissions during a simulation period (a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
273,386

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	274
Case 2	78
Case 3	0.1

Table C.5.21 Houston Light and Power Company- Year 2010 Summer Off-Peak Charging ISE

Scenario: Year 2010 - High EV Scenario - Combined Cycle and Combustion Turbine - Summer Charging Policy Scenarios

	SO2 (tons)				CO (tons)				NOx (tons)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case TSE	14,847	N/A	N/A	N/A	10,231	N/A	N/A	N/A	31,690	N/A	N/A	N/A
High EV Scenario ISE	-126	541	531	507	-61	82	89	106	-139	401	400	397
Combustion Turbine												
Base Case TSE	14,847	N/A	N/A	N/A	10,231	N/A	N/A	N/A	31,690	N/A	N/A	N/A
High EV Scenario ISE	169	541	531	507	30	82	89	106	116	401	400	397

	TSP (tons)				VOC (tons)				CO2 (tons)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case TSE	749	N/A	N/A	N/A	624	N/A	N/A	N/A	15,617,649	N/A	N/A	N/A
High EV Scenario ISE	16	4	4	4	8	5	5	5	68,462	205,936	206,706	207,945
Combustion Turbine												
Base Case TSE	749	N/A	N/A	N/A	624	N/A	N/A	N/A	15,617,649	N/A	N/A	N/A
High EV Scenario ISE	14	4	4	4	10	5	5	5	178,546	205,999	206,771	208,010

Notes:
(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
Summer
239,944

(3) Capacity added to maintain the same reliability as in the base case:

	Capacity (MW)
Case 1	0.1
Case 2	0.1
Case 3	0.1

Table C.5.22 Potomac Electric Power Co. - Year 2010 Summer Off-Peak Charging ISE

Scenario: Year 2010 - High EV Penetration - Combined Cycle and Combustion Turbine - Summer Off-peak Charging Scenarios

	SO2 (tons)				CO (tons)				NOx (tons)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case TSE	29,045	N/A	N/A	N/A	1,584	N/A	N/A	N/A	18,747	N/A	N/A	N/A
High EV Scenario ISE	7	12	14	17	4	6	7	7	13	20	22	25
Combustion Turbine												
Base Case TSE	29,045	N/A	N/A	N/A	1,584	N/A	N/A	N/A	18,747	N/A	N/A	N/A
High EV Scenario ISE	6	12	14	17	8	8	8	8	17	22	23	26

	TSP (tons)				VOC (tons)				CO2 (tons)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case TSE	2,218	N/A	N/A	N/A	264	N/A	N/A	N/A	8,554,076	N/A	N/A	N/A
High EV Scenario ISE	5	5	6	6	2	2	2	2	28,298	30,851	31,550	32,433
Combustion Turbine												
Base Case TSE	2,218	N/A	N/A	N/A	264	N/A	N/A	N/A	8,554,076	N/A	N/A	N/A
High EV Scenario ISE	5	5	6	6	2	2	2	2	31,548	32,170	32,465	32,783

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
Summer
60,089

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	29
Case 2	20
Case 3	8

Table C.5.23 Virginia Power - Year 2010 Summer Off-peak Charging ISE

Scenario: Year 2010 - High EV Penetration - Combined Cycle and Combustion Turbine - Summer Off-peak Charging Scenarios

	SO2 (tons)				CO (tons)				NOx (tons)			
	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Combined Cycle												
Base Case TSE	34,046	N/A	N/A	N/A	3,979	N/A	N/A	N/A	35,078	N/A	N/A	N/A
High EV Scenario ISE	417	426	443	455	18	14	14	15	154	139	145	149
Combustion Turbine												
Base Case TSE	34,046	N/A	N/A	N/A	3,979	N/A	N/A	N/A	35,078	N/A	N/A	N/A
High EV Scenario ISE	505	10	10	10	20	0	0	0	178	3	3	3

	TSP (tons)				VOC (tons)				CO2 (tons)			
	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Combined Cycle												
Base Case TSE	3,537	N/A	N/A	N/A	737	N/A	N/A	N/A	20,926,728	N/A	N/A	N/A
High EV Scenario ISE	24	25	25	26	4	3	3	3	73,568	74,775	76,327	77,401
Combustion Turbine												
Base Case TSE	3,537	N/A	N/A	N/A	737	N/A	N/A	N/A	20,926,728	N/A	N/A	N/A
High EV Scenario ISE	29	29	29	29	4	3	3	3	84,756	85,042	85,449	85,734

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
Summer
102,377

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	55
Case 2	49
Case 3	45

Table C.5.24 Southern California Edison - Year 2010 Summer Off-peak Charging ISE

Scenario: Year 2010 - Combined Cycle and Combustion Turbine - Summer Off-peak Charging Scenarios

	SO2 (tons)				CO (tons)				NOx (tons)			
	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Combined Cycle												
Base Case TSE	9,368	N/A	N/A	N/A	3,451	N/A	N/A	N/A	17,421	N/A	N/A	N/A
Low EV Scenario ISE	13	2	2	2	37	40	38	30	72	87	72	30
High EV Scenario ISE	4	4	4	4	68	80	84	80	68	135	147	115
Combustion Turbine												
Base Case TSE	9,368	N/A	N/A	N/A	3,451	N/A	N/A	N/A	17,421	N/A	N/A	N/A
Low EV Scenario ISE	2	2	2	2	50	47	43	33	147	118	93	47
High EV Scenario ISE	8	4	4	4	127	119	111	95	358	310	262	171

	PM10 (tons)				ROG (tons)				C (tons)			
	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Combined Cycle												
Base Case TSE	1,479	N/A	N/A	N/A	657	N/A	N/A	N/A	4,032,584	N/A	N/A	N/A
Low EV Scenario ISE	13	15	15	17	8	7	8	10	44,597	47,772	47,178	44,652
High EV Scenario ISE	40	36	36	40	24	20	24	24	99,447	104,982	110,001	111,842
Combustion Turbine												
Base Case TSE	1,479	N/A	N/A	N/A	657	N/A	N/A	N/A	4,032,584	N/A	N/A	N/A
Low EV Scenario ISE	12	13	15	17	7	8	8	10	49,820	51,760	50,188	46,815
High EV Scenario ISE	32	32	36	40	16	20	20	24	129,273	127,304	124,481	119,235

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The EV charging energy is:

	Charging Energy (MWh)
Low EV	333,000
High EV	795,352

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)	
	Low EV	High EV
Case 1	64	354
Case 2	48	226
Case 3	34	112

Table C.5.25 Los Angeles Dept. Of Water and Power - Year 2010 Summer Off-peak ChargingISE

Scenario: Year 2010 - Combined Cycle and Combustion Turbine - Summer Off-peak Charging Scenarios

	SO2 (tons)				CO (tons)				NOx (tons)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case TSE	6,122	N/A	N/A	N/A	1,006	N/A	N/A	N/A	9,099	N/A	N/A	N/A
Low EV Scenario ISE	1	1	1	1	-1	28	26	19	-37	48	113	139
High EV Scenario ISE	2	2	2	2	-12	41	54	51	-97	53	182	272
Combustion Turbine												
Base Case TSE	6,122	N/A	N/A	N/A	1,006	N/A	N/A	N/A	9,099	N/A	N/A	N/A
Low EV Scenario ISE	1	1	1	1	51	43	32	20	146	160	155	144
High EV Scenario ISE	2	2	2	2	107	99	81	59	309	339	343	337

	PM10 (tons)				ROG (tons)				C (tons)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case TSE	587	N/A	N/A	N/A	126	N/A	N/A	N/A	1,284,066	N/A	N/A	N/A
Low EV Scenario ISE	10	7	4	3	7	4	2	1	15,701	19,952	23,302	24,374
High EV Scenario ISE	21	17	12	8	13	10	7	3	34,691	42,117	48,568	52,576
Combustion Turbine												
Base Case TSE	587	N/A	N/A	N/A	126	N/A	N/A	N/A	1,284,066	N/A	N/A	N/A
Low EV Scenario ISE	3	3	3	3	1	1	1	1	26,570	26,104	25,435	24,643
High EV Scenario ISE	8	7	7	7	3	3	2	3	58,854	58,126	56,920	55,811

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The EV charging energy is:

	Charging Energy (MWh)
	Summer
Low EV	148,820
High EV	330,261

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)	
	Low EV	High EV
Case 1	65	231
Case 2	24	95
Case 3	3	35

Table C.5.26 Policy Cases of EV Charging: Hours During Which Vehicles Are Connected for Charging

Utility	System Peak	Policy Case	Household Vehicles		Fleet Vehicles	
			Start	Stop	Start	Stop
CE	4 PM	Unconstrained	3 PM	12 AM	4 PM	6 PM
		Case 1	5 PM	12 AM	5 PM	7 PM
		Case 2	5 PM	12 AM	5 PM	12 AM
		Case 3	5 PM	12 AM	10 PM	12 AM
HLP	5 PM	Unconstrained	3 PM	12 AM	4 PM	6 PM
		Case 1	6 PM	12 AM	8 PM	10 PM
		Case 2	6 PM	12 AM	7 PM	12 AM
		Case 3	6 PM	12 AM	10 PM	12 AM
PEPCO	5 PM	Unconstrained	3 PM	12 AM	4 PM	6 PM
		Case 1	6 PM	12 AM	8 PM	10 PM
		Case 2	6 PM	12 AM	7 PM	12 AM
		Case 3	6 PM	12 AM	10 PM	12 AM
VEPCO	4 PM	Unconstrained	3 PM	12 AM	4 PM	6 PM
		Case 1	5 PM	12 AM	6 PM	8 PM
		Case 2	5 PM	12 AM	6 PM	12 AM
		Case 3	5 PM	12 AM	10 PM	12 AM
LADWP	4 PM	Unconstrained	3 PM	12 AM	4 PM	6 PM
		Case 1	5 PM	12 AM	6 PM	8 PM
		Case 2	5 PM	12 AM	6 PM	12 AM
		Case 3	5 PM	12 AM	10 PM	12 AM
SCE	3 PM	Unconstrained	3 PM	12 AM	4 PM	6 PM
		Case 1	4 PM	12 AM	6 PM	9 PM
		Case 2	4 PM	12 AM	5 PM	12 AM
		Case 3	4 PM	12 AM	10 AM	12 PM

Table C.5.27 Commonwealth Edison Co. Of Chicago - Year 2010 MSE

Scenario Year 2010 - Integrated Gasification Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	4.17	1.87	2.82	4.47	0.16	0.06	0.11	0.15	2.33	1.08	1.58	2.32
Low EV Scenario MSE	[illegible]	[illegible]	15.21	[illegible]	[illegible]	[illegible]	0.52	[illegible]			7.49	[illegible]
High EV Scenario MSE	[illegible]	[illegible]	14.94	[illegible]		[illegible]	0.51		[illegible]	[illegible]	7.43	[illegible]
Low EV Scenario ASE	4.11	1.82	2.77	4.39	0.16	0.06	0.11	0.15	2.3	1.05	1.53	2.29
High EV Scenario ASE	3.92	1.66	2.62	4.17	0.15	0.06	0.1	0.14	2.2	0.97	1.45	2.18

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.39	0.23	0.3	0.39	0.02	0.01	0.02	0.02	864	485	669	875
Low EV Scenario MSE	[illegible]	[illegible]	0.91	[illegible]	[illegible]	[illegible]	0.06		[illegible]	[illegible]	2,163	[illegible]
High EV Scenario MSE	[illegible]	[illegible]	0.92	[illegible]	[illegible]	[illegible]	0.06		[illegible]	[illegible]	2,174	[illegible]
Low EV Scenario ASE	0.39	0.23	0.3	0.39	0.02	0.01	0.02	0.02	865	486	671	876
High EV Scenario ASE	0.39	0.23	0.31	0.4	0.02	0.01	0.02	0.02	869	489	675	879

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 - 2160 h)
Spring Season (4/1/10 - 6/30/10 : 2184 h)
Summer Season (7/1/10 - 9/31/10 . 2208 h)
Fall Season (10/1/10 - 12/31/10 2208 h)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	68,500	58,165	71,928	57,461
High EV	250,339	228,574	273,386	226,319

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	105
High EV	417

Table C.5.28 Commonwealth Edison Co. Of Chicago - Year 2010 MSE

Scenario Year 2010 - Integrated Gasification Combined Cycle - Emission Constrained Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	3.05	1.51	2.30	3.40	[illegible]	[illegible]	0.11	0.16	[illegible]	1.10	[illegible]	[illegible]
Low EV Scenario MSE	[illegible]	[illegible]	-13.37	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	2.80	[illegible]
High EV Scenario MSE	[illegible]		5.22	[illegible]		[illegible]	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]
Low EV Scenario ASE	3.10	1.47	2.26	3.41	0.16	0.06	0.11	0.16	2.21	[illegible]	1.53	[illegible]
High EV Scenario ASE	[illegible]	[illegible]	2.21	3.40	0.15	0.06	0.10	[illegible]	2.16	[illegible]	1.45	[illegible]

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.37	0.22	0.30	0.38	0.02	0.01	0.02	0.02	850	480	663	864
Low EV Scenario MSE	[illegible]	[illegible]	0.53	[illegible]	[illegible]	[illegible]	0.07	[illegible]	[illegible]	[illegible]	1,755	[illegible]
High EV Scenario MSE	[illegible]	[illegible]	0.82	[illegible]	[illegible]	[illegible]	0.06	[illegible]	[illegible]	[illegible]	2,066	[illegible]
Low EV Scenario ASE	0.38	0.22	0.30	0.39	0.02	0.01	0.02	0.02	853	481	664	866
High EV Scenario ASE	0.38	0.23	0.30	0.39	0.02	0.01	0.02	0.02	860	485	669	872

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load.
The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 h)
Spring Season (4/1/10 - 6/30/10 : 2184 h)
Summer Season (7/1/10 - 9/31/10 : 2208 h)
Fall Season (10/1/10 - 12/31/10 : 2208 h)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	68,543	58,165	71,928	57,380
High EV	250,486	228,574	273,386	226,088

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	105
High EV	417

Table C.5.29 Commonwealth Edison Co. Of Chicago - Year 2010 MSE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	4.17	1.87	2.82	4.47	0.16	0.06	0.11	0.15	2.33	1.08	1.56	2.32
Low EV Scenario MSE	[illegible]	[illegible]	15.34	[illegible]	[illegible]	[illegible]	0.53	[illegible]	[illegible]	[illegible]	7.51	[illegible]
High EV Scenario MSE	[illegible]	[illegible]	15.49	[illegible]	[illegible]	[illegible]	0.54	[illegible]	[illegible]	[illegible]	7.54	[illegible]
Low EV Scenario ASE	4.19	1.89	2.85	4.49	0.16	0.07	0.11	0.15	2.34	1.09	1.57	2.33
High EV Scenario ASE	4.23	1.95	2.93	4.55	0.16	0.07	0.11	0.16	2.36	1.13	1.61	2.36

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.39	0.23	0.30	0.39	0.02	0.01	0.02	0.02	864	485	669	875
Low EV Scenario MSE	[illegible]	[illegible]	0.90	[illegible]	[illegible]	[illegible]	0.06	[illegible]	[illegible]	[illegible]	2,157	[illegible]
High EV Scenario MSE	[illegible]	[illegible]	0.89	[illegible]	[illegible]	[illegible]	0.06	[illegible]	[illegible]	[illegible]	2,150	[illegible]
Low EV Scenario ASE	0.39	0.23	0.31	0.39	0.02	0.01	0.02	0.02	866	488	673	877
High EV Scenario ASE	0.39	0.23	0.31	0.40	0.02	0.01	0.02	0.02	872	498	682	884

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 h)
Spring Season (4/1/10 - 6/30/10 : 2184 h)
Summer Season (7/1/10 - 9/31/10 : 2208 h)
Fall Season (10/1/10 - 12/31/10 : 2208 h)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	68,500	58,165	71,928	57,461
High EV	250,339	228,574	273,386	226,319

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	105
High EV	417

Table C.5.30 Commonwealth Edison Co. Of Chicago - Year 2010 MSE

Scenario: Year 2010 - Combustion Turbine - Emission Constrained Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	3.05	1.51	2.30	3.40	0.17	0.06	0.11	0.16	2.23	1.10	1.56	2.23
Low EV Scenario MSE	[illegible]	[illegible]	-8.75	[illegible]	[illegible]	[illegible]	0.80	[illegible]	[illegible]	[illegible]	3.82	
High EV Scenario MSE	[illegible]	[illegible]	1.67	[illegible]	[illegible]	[illegible]	0.70	[illegible]	[illegible]	[illegible]	5.26	[illegible]
Low EV Scenario ASE	3.06	1.53	2.28	3.38	0.17	0.07	0.11	0.16	2.24	1.11	1.56	2.23
High EV Scenario ASE	3.02	1.52	2.28	3.32	0.17	0.07	0.11	0.17	2.24	1.13	1.59	2.23

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.37	0.22	0.30	0.38	0.02	0.01	0.02	0.02	850	480	663	864
Low EV Scenario MSE	[illegible]	[illegible]	0.61	[illegible]	[illegible]	[illegible]	0.07	[illegible]	[illegible]	[illegible]	1,843	[illegible]
High EV Scenario MSE	[illegible]	[illegible]	0.73	[illegible]	[illegible]	[illegible]	0.07	[illegible]	[illegible]	[illegible]	1,985	[illegible]
Low EV Scenario ASE	0.37	0.22	0.30	0.38	0.02	0.01	0.02	0.02	853	483	666	866
High EV Scenario ASE	0.37	0.23	0.30	0.38	0.02	0.01	0.02	0.02	857	493	674	871

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 h)
Spring Season (4/1/10 - 6/30/10 : 2184 h)
Summer Season (7/1/10 - 9/31/10 : 2208 h)
Fall Season (10/1/10 - 12/31/10 : 2208 h)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	68,543	58,165	71,928	57,380
High EV	250,486	228,574	273,386	226,088

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	105
High EV	417

Table C.5.31 Commonwealth Edison Co. Of Chicago - Year 2010 Summer Off-Peak Charging MSE

Scenario: Year 2010 - Integrated Gasification Combined Cycle - High EV Penetration - Summer Off-Peak Charging Scenarios

Economic Dispatch	SO2 (lb/MWh) Unconstrained	SO2 Case 1	SO2 Case 2	SO2 Case 3	CO (lb/MWh) Unconstrained	CO Case 1	CO Case 2	CO Case 3	NOx (lb/MWh) Unconstrained	NOx Case 1	NOx Case 2	NOx Case 3
Base Case ASE	2.82	N/A	N/A	N/A	0.11	N/A	N/A	N/A	1.56	N/A	N/A	N/A
High EV Scenario MSE	14.94	15.75	13.2	9.99	0.51	0.48	0.41	0.34	7.43	7.88	7.05	5.89
High EV Scenario ASE	2.62	2.73	2.96	2.89	0.1	0.1	0.11	0.11	1.45	1.51	1.58	1.6
Emission Constrained Dispatch												
Base Case ASE	2.3	N/A	N/A	N/A	0.11	N/A	N/A	N/A	1.56	N/A	N/A	N/A
High EV Scenario MSE	5.22	11.2	9.87	8.25	0.61	0.52	0.44	0.35	6.06	7.37	6.9	6.16
High EV Scenario ASE	2.21	2.24	2.86	2.38	0.1	0.1	0.11	0.11	1.45	1.5	1.6	1.6

Economic Dispatch	TSP (lb/MWh) Unconstrained	TSP Case 1	TSP Case 2	TSP Case 3	VOC (lb/MWh) Unconstrained	VOC Case 1	VOC Case 2	VOC Case 3	CO2 (lb/MWh) Unconstrained	CO2 Case 1	CO2 Case 2	CO2 Case 3
Base Case ASE	0.3	N/A	N/A	N/A	0.02	N/A	N/A	N/A	669	N/A	N/A	N/A
High EV Scenario MSE	0.92	0.99	1.02	1.02	0.06	0.06	0.06	0.05	2,174	2,260	2,255	2,201
High EV Scenario ASE	0.31	0.31	0.31	0.31	0.02	0.02	0.02	0.02	675	678	682	683
Emission Constrained Dispatch												
Base Case ASE	0.3	N/A	N/A	N/A	0.02	N/A	N/A	N/A	663	N/A	N/A	N/A
High EV Scenario MSE	0.82	0.96	1	1.01	0.06	0.06	0.06	0.05	2,066	2,233	2,240	2,200
High EV Scenario ASE	0.3	0.3	0.31	0.31	0.02	0.02	0.02	0.02	672	672	676	677

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The EV charging energy is

Charging Energy (MWh)
273,386

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	274
Case 2	78
Case 3	0.1

Table C.5.32 Commonwealth Edison Co. Of Chicago - Year 2010 Summer Off-Peak Charging MSE

Scenario: Year 2010 - Combustion Turbine - High EV Penetration - Summer Off-Peak Charging Scenarios

Economic Dispatch	SO2 (lb/MWh) Unconstrained	Case 1	Case 2	Case 3	CO (lb/MWh) Unconstrained	Case 1	Case 2	Case 3	NOx (lb/MWh) Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	2.82	N/A	N/A	N/A	0.11	N/A	N/A	N/A	1.56	N/A	N/A	N/A
High EV Scenario MSE	15.49	16.2	13.39	9.99	0.54	0.5	0.42	0.34	7.54	7.99	7.13	5.89
High EV Scenario ASE	2.93	2.94	2.92	2.89	0.11	0.11	0.11	0.11	1.61	1.62	1.61	1.6
Emission Constrained Dispatch												
Base Case ASE	2.3	N/A	N/A	N/A	0.11	N/A	N/A	N/A	1.56	N/A	N/A	N/A
High EV Scenario MSE	1.67	1.74	9.46	-1.13	0.7	0.66	0.45	0.47	5.25	5.68	6.86	4.53
High EV Scenario ASE	2.28	2.31	2.28	2.27	0.11	0.12	0.11	0.11	1.59	1.61	1.59	1.58

Economic Dispatch	TSP (lb/MWh) Unconstrained	Case 1	Case 2	Case 3	VOC (lb/MWh) Unconstrained	Case 1	Case 2	Case 3	CO2 (lb/MWh) Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	0.3	N/A	N/A	N/A	0.02	N/A	N/A	N/A	663	N/A	N/A	N/A
High EV Scenario MSE	0.89	0.81	1.02	1.02	0.06	0.07	0.06	0.05	2,150	2,076	2,255	2,202
High EV Scenario ASE	0.31	0.31	0.31	0.31	0.02	0.02	0.02	0.02	682	683	684	683
Emission Constrained Dispatch												
Base Case ASE	0.3	N/A	N/A	N/A	0.02	N/A	N/A	N/A	663	N/A	N/A	N/A
High EV Scenario MSE	0.73	0.81	0.99	0.89	0.07	0.07	0.06	0.06	1,985	2,076	2,232	2,066
High EV Scenario ASE	0.3	0.31	0.3	0.3	0.02	0.02	0.02	0.02	674	680	676	676

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
273,386

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	274
Case 2	78
Case 3	0.1

Table C.5.33 Houston Light and Power - Year 2010 MSE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	1.14	0.94	1.19	0.86	0.77	0.72	0.82	0.90	2.43	2.43	2.54	2.30
Low EV Scenario MSE			4.53				0.56				3.36	
High EV Scenario MSE			4.41				0.56				3.34	
Low EV Scenario ASE	1.14	0.95	1.19	0.86	0.77	0.72	0.81	0.90	2.43	2.42	2.53	2.29
High EV Scenario ASE	1.10	0.93	1.17	0.84	0.75	0.71	0.80	0.88	2.39	2.38	2.50	2.25

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.07	0.07	0.06	0.07	0.06	0.06	0.05	0.06	1,237.61	1,206.36	1,251.76	1,219.13
Low EV Scenario MSE			0.03				0.04				1,683.95	
High EV Scenario MSE			0.03				0.04				1,675.00	
Low EV Scenario ASE	0.07	0.07	0.06	0.07	0.06	0.06	0.05	0.06	1,238.04	1,206.69	1,252.04	1,219.48
High EV Scenario ASE	0.07	0.07	0.06	0.07	0.06	0.06	0.05	0.06	1,229.01	1,200.55	1,245.28	1,211.61

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	53,746	55,185	71,665	54,407
High EV	183,823	189,586	239,944	185,946

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	16
High EV	171

Table C.5.34 Houston Light and Power - Year 2010 MSE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	1.14	0.94	1.19	0.86	0.77	0.72	0.82	0.90	2.43	2.43	2.54	2.30
Low EV Scenario MSE			4.51				0.56				3.35	
High EV Scenario MSE			4.20				0.56				3.23	
Low EV Scenario ASE	1.15	0.95	1.19	0.86	0.77	0.72	0.82	0.90	2.43	2.43	2.54	2.30
High EV Scenario ASE	1.15	0.95	1.19	0.86	0.76	0.72	0.81	0.89	2.42	2.42	2.52	2.29

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.07	0.07	0.06	0.07	0.06	0.06	0.05	0.06	1,237.61	1,206.36	1,251.76	1,219.13
Low EV Scenario MSE			0.03				0.04				1,681.50	
High EV Scenario MSE			0.04				0.04				1,650.43	
Low EV Scenario ASE	0.07	0.07	0.06	0.07	0.06	0.06	0.05	0.06	1,239.18	1,207.52	1,252.85	1,220.53
High EV Scenario ASE	0.07	0.07	0.06	0.07	0.06	0.06	0.05	0.06	1,241.31	1,209.66	1,254.02	1,222.91

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	53,746	55,185	71,665	54,407
High EV	183,823	189,586	239,944	185,946

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	16
High EV	171

Table C.5.35 Houston Light and Power - Year 2010 Summer Off-Peak Charging MSE

Scenario: Year 2010 - Combined Cycle and Combustion Turbine(high EV scenario) - Summer Charging Policy Scenarios

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	1.19	N/A	N/A	N/A	0.82	N/A	N/A	N/A	2.54	N/A	N/A	N/A
High EV Scenario MSE	4.41	4.51	4.43	4.24	0.56	0.68	0.74	0.88	3.34	3.34	3.34	3.31
High EV Scenario ASE	1.17	1.22	1.22	1.22	0.80	0.81	0.82	0.82	2.50	2.54	2.54	2.54
Combustion Turbine												
Base Case ASE	1.19	N/A	N/A	N/A	0.82	N/A	N/A	N/A	2.54	N/A	N/A	N/A
High EV Scenario MSE	4.20	4.51	4.43	4.24	0.56	0.68	0.74	0.88	3.23	3.34	3.34	3.31
High EV Scenario ASE	1.19	1.22	1.22	1.22	0.81	0.81	0.82	0.82	2.52	2.54	2.54	2.54

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	0.06	N/A	N/A	N/A	0.05	N/A	N/A	N/A	1251.76	N/A	N/A	N/A
High EV Scenario MSE	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	1675.00	1717.16	1723.59	1733.91
High EV Scenario ASE	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	1254.28	1256.27	1256.35	1256.46
Combustion Turbine												
Base Case ASE	0.06	N/A	N/A	N/A	0.05	N/A	N/A	N/A	1251.76	N/A	N/A	N/A
High EV Scenario MSE	0.04	0.03	0.03	0.03	0.04	0.04	0.04	0.04	1650.43	1717.16	1723.59	1733.91
High EV Scenario ASE	0.06	0.06	0.06	0.06	0.05	0.05	0.05	0.05	1254.02	1256.27	1256.35	1256.46

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
Summer
239,944

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	0.1
Case 2	0.1
Case 3	0.1

Table C.5.36 Potomac Electric Power Co. - Year 2010 MSE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	5.15	5.80	5.50	5.58	0.30	0.31	0.30	0.31	3.40	3.72	3.55	3.61
Low EV Scenario MSE			0.57				0.28				0.80	
High EV Scenario MSE			0.55				0.28				0.77	
Low EV Scenario ASE	5.14	5.79	5.49	5.57	0.30	0.31	0.30	0.31	3.39	3.72	3.54	3.61
High EV Scenario ASE	5.12	5.77	5.47	5.55	0.30	0.31	0.30	0.31	3.38	3.71	3.53	3.59

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.42	0.45	0.42	0.44	0.05	0.05	0.05	0.05	1590.03	1670.24	1619.81	1654.76
Low EV Scenario MSE			0.19				0.07				1099.61	
High EV Scenario MSE			0.18				0.07				1094.46	
Low EV Scenario ASE	0.42	0.45	0.41	0.44	0.05	0.05	0.05	0.05	1588.77	1669.05	1618.47	1653.45
High EV Scenario ASE	0.41	0.45	0.41	0.44	0.05	0.05	0.05	0.05	1586.47	1666.72	1615.97	1650.95

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	16,999	16,765	21,435	16,461
High EV	47,919	48,215	60,089	47,312

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	22
High EV	72

Table C.5.37 Potomac Electric Power Co. - Year 2010 MSE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	5.15	5.80	5.50	5.58	0.30	0.31	0.30	0.31	3.40	3.72	3.55	3.61
Low EV Scenario MSE			0.57				0.28				0.80	
High EV Scenario MSE			0.55				0.29				0.77	
Low EV Scenario ASE	5.14	5.79	5.49	5.57	0.30	0.10	0.30	0.31	3.39	3.72	3.54	3.61
High EV Scenario ASE	5.12	5.77	5.47	5.55	0.30	0.31	0.30	0.31	3.38	3.71	3.53	3.60

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.42	0.45	0.42	0.44	0.05	0.05	0.05	0.05	1590.03	1670.24	1619.81	1654.76
Low EV Scenario MSE			0.19				0.07				1101.92	
High EV Scenario MSE			0.18				0.07				1102.14	
Low EV Scenario ASE	0.42	0.45	0.41	0.44	0.05	0.05	0.05	0.05	1588.78	1669.07	1618.66	1653.46
High EV Scenario ASE	0.42	0.45	0.41	0.44	0.05	0.05	0.05	0.05	1586.50	1666.78	1616.58	1650.99

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	16,999	16,765	21,435	16,461
High EV	47,919	48,215	60,089	47,312

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	22
High EV	72

Table C.5.38 Potomac Electric Power Co. - Year 2010 Summer Off-Peak Charging MSE

Scenario: Year 2010 - High EV Penetration - Combined Cycle and Combustion Turbine - Summer Off-peak Charging Scenarios

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Combined Cycle												
Base Case ASE	5.50	N/A	N/A	N/A	0.30	N/A	N/A	N/A	3.55	N/A	N/A	N/A
High EV Scenario MSE	0.55	0.56	0.59	0.61	0.28	0.27	0.26	0.26	0.77	0.80	0.84	0.88
High EV Scenario ASE	5.47	5.48	5.48	5.48	0.30	0.30	0.30	0.30	3.53	3.53	3.53	3.53
Combustion Turbine												
Base Case ASE	5.50	N/A	N/A	N/A	0.30	N/A	N/A	N/A	3.55	N/A	N/A	N/A
High EV Scenario MSE	0.55	0.56	0.59	0.61	0.29	0.27	0.26	0.26	0.77	0.80	0.84	0.88
High EV Scenario ASE	5.47	5.48	5.48	5.48	0.30	0.30	0.30	0.30	3.53	3.53	3.53	3.53

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Combined Cycle												
Base Case ASE	0.42	N/A	N/A	N/A	0.05	N/A	N/A	N/A	1619.81	N/A	N/A	N/A
High EV Scenario MSE	0.18	0.19	0.20	0.20	0.07	0.07	0.07	0.06	1094.46	1089.54	1093.81	1096.33
High EV Scenario ASE	0.41	0.41	0.41	0.41	0.05	0.05	0.05	0.05	1615.97	1616.43	1616.56	1616.73
Combustion Turbine												
Base Case ASE	0.42	N/A	N/A	N/A	0.05	N/A	N/A	N/A	1619.81	N/A	N/A	N/A
High EV Scenario MSE	0.18	0.19	0.20	0.20	0.07	0.07	0.07	0.06	1102.14	1092.13	1095.47	1096.89
High EV Scenario ASE	0.41	0.41	0.41	0.41	0.05	0.05	0.05	0.05	1616.58	1616.68	1616.73	1616.80

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
Summer
60,532

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	29
Case 2	20
Case 3	8

Table C.5.39 Virginia Power - Year 2010 MSE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	1.88	1.20	2.31	1.87	0.28	0.26	0.27	0.27	2.29	2.03	2.38	2.23
Low EV Scenario MSE			10.10				0.42				3.64	
High EV Scenario MSE			10.01				0.42				3.61	
Low EV Scenario ASE	1.89	1.20	2.32	1.88	0.28	0.26	0.27	0.27	2.29	2.03	2.38	2.23
High EV Scenario ASE	1.89	1.20	2.33	1.88	0.28	0.26	0.27	0.27	2.29	2.03	2.38	2.24

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.22	0.20	0.24	0.21	0.05	0.05	0.05	0.05	1446.11	1270.48	1419.87	1441.70
Low EV Scenario MSE			0.57				0.08				1708.34	
High EV Scenario MSE			0.57				0.08				1700.70	
Low EV Scenario ASE	0.22	0.20	0.24	0.21	0.05	0.05	0.05	0.05	1446.48	1271.24	1419.91	1442.09
High EV Scenario ASE	0.22	0.20	0.24	0.21	0.05	0.05	0.05	0.05	1447.37	1273.21	1419.93	1443.10

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	23,055	22,853	28,966	22,357
High EV	82,145	83,044	102,377	81,305

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	16
High EV	59

Table C.5.40 Virginia Power - Year 2010 MSE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	1.88	1.20	2.31	1.87	0.28	0.26	0.27	0.27	2.29	2.03	2.38	2.23
Low EV Scenario MSE			10.11				0.42				3.65	
High EV Scenario MSE			10.03				0.42				3.62	
Low EV Scenario ASE	1.89	1.20	2.32	1.88	0.28	0.26	0.27	0.27	2.29	2.03	2.38	2.23
High EV Scenario ASE	1.90	1.20	2.34	1.89	0.28	0.26	0.27	0.27	2.29	2.03	2.38	2.24

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.22	0.20	0.24	0.21	0.05	0.05	0.05	0.05	1446.11	1270.48	1419.87	1441.70
Low EV Scenario MSE			0.57				0.08				1709.45	
High EV Scenario MSE			0.57				0.08				1704.92	
Low EV Scenario ASE	0.22	0.20	0.24	0.21	0.05	0.05	0.05	0.05	1446.66	1271.27	1420.11	1442.25
High EV Scenario ASE	0.22	0.20	0.24	0.21	0.05	0.05	0.05	0.05	1448.04	1273.35	1420.68	1443.69

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	23,055	22,853	28,966	22,357
High EV	82,145	83,044	102,377	81,305

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	16
High EV	59

Table C.5.41 Virginia Power - Year 2010 Summer Off-Peak Charging MSE

Scenario: Year 2010 - High EV Penetration - Combined Cycle and Combustion Turbine - Summer Off-peak Charging Scenarios

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	2.31	N/A	N/A	N/A	0.27	N/A	N/A	N/A	2.38	N/A	N/A	N/A
High EV Scenario MSE	10.01	10.08	10.21	10.31	0.42	0.41	0.41	0.40	3.61	3.62	3.64	3.66
High EV Scenario ASE	2.33	2.33	2.34	2.34	0.27	0.27	0.27	0.27	2.38	2.38	2.38	2.38
Combustion Turbine												
Base Case ASE	2.31	N/A	N/A	N/A	0.27	N/A	N/A	N/A	2.38	N/A	N/A	N/A
High EV Scenario MSE	10.03	10.10	10.09	10.32	0.42	0.41	0.40	0.40	3.62	3.62	3.58	3.67
High EV Scenario ASE	2.34	2.34	2.34	2.34	0.27	0.27	0.27	0.27	2.38	2.38	2.38	2.38

	TSP (lb/MWh)				VOC (lb/MWh)				CO2 (lb/MWh)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	0.24	N/A	N/A	N/A	0.05	N/A	N/A	N/A	1419.87	N/A	N/A	N/A
High EV Scenario MSE	0.57	0.57	0.58	0.58	0.08	0.08	0.08	0.08	1700.70	1701.84	1705.41	1709.94
High EV Scenario ASE	0.24	0.24	0.24	0.24	0.05	0.05	0.05	0.05	1419.93	1420.01	1420.12	1420.19
Combustion Turbine												
Base Case ASE	0.24	N/A	N/A	N/A	0.05	N/A	N/A	N/A	1419.87	N/A	N/A	N/A
High EV Scenario MSE	0.57	0.57	0.57	0.58	0.08	0.08	0.08	0.08	1704.92	1705.71	1700.96	1710.99
High EV Scenario ASE	0.24	0.24	0.24	0.24	0.05	0.05	0.05	0.05	1420.68	1420.70	1420.73	1420.74

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The EV charging energy is:

Charging Energy (MWh)
Summer
102,377

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Case 1	55
Case 2	49
Case 3	45

Table C.5.42 Southern California Edison - Year 2010 MSE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.67	0.51	0.57	0.62	0.22	0.20	0.21	0.20	1.19	0.95	1.06	1.10
Low EV Scenario MSE			0.01				0.30				0.86	
High EV Scenario MSE			0.01				0.29				0.81	
Low EV Scenario ASE	0.66	0.51	0.56	0.61	0.22	0.20	0.21	0.20	1.19	0.95	1.05	1.10
High EV Scenario ASE	0.66	0.50	0.55	0.61	0.22	0.20	0.21	0.20	1.17	0.93	1.04	1.08

	PM10 (lb/MWh)				ROG (lb/MWh)				C (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.10	0.09	0.09	0.09	0.04	0.04	0.04	0.04	260.49	237.77	245.37	242.62
Low EV Scenario MSE			0.07				0.04				297.09	
High EV Scenario MSE			0.07				0.04				293.94	
Low EV Scenario ASE	0.10	0.09	0.09	0.09	0.04	0.04	0.04	0.04	260.35	237.91	245.59	242.76
High EV Scenario ASE	0.10	0.09	0.09	0.09	0.04	0.04	0.04	0.04	259.65	237.86	245.48	242.68

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	247,039	270,604	333,000	262,569
High EV	592,080	647,091	795,352	628,530

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	162
High EV	620

Table C.5.43 Southern California Edison - Year 2010 MSE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.67	0.51	0.57	0.62	0.22	0.20	0.21	0.20	1.19	0.95	1.06	1.10
Low EV Scenario MSE			0.01				0.71				1.52	
High EV Scenario MSE			0.01				0.63				1.34	
Low EV Scenario ASE	0.66	0.51	0.56	0.61	0.22	0.20	0.21	0.20	1.19	0.95	1.06	1.10
High EV Scenario ASE	0.66	0.50	0.55	0.61	0.22	0.20	0.21	0.21	1.19	0.94	1.06	1.09

	PM10 (lb/MWh)				ROG (lb/MWh)				C (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.10	0.09	0.09	0.09	0.04	0.04	0.04	0.04	260.49	237.77	245.37	242.62
Low EV Scenario MSE			0.05				0.03				321.73	
High EV Scenario MSE			0.06				0.03				311.09	
Low EV Scenario ASE	0.10	0.09	0.09	0.09	0.04	0.04	0.04	0.04	261.11	238.12	245.90	242.98
High EV Scenario ASE	0.10	0.09	0.09	0.09	0.04	0.04	0.04	0.04	261.92	238.67	247.25	243.51

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	247,039	270,604	333,000	262,569
High EV	592,080	647,091	795,352	628,530

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	162
High EV	620

Table C.5.44 Southern California Edison - Year 2010 Summer Off-Peak Charging MSE

Scenario: Year 2010 - Combined Cycle and Combustion Turbine - Summer Charging Policy Scenarios

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	0.57	N/A	N/A	N/A	0.21	N/A	N/A	N/A	1.06	N/A	N/A	N/A
Low EV Scenario MSE	0.01	0.01	0.01	0.01	0.30	0.27	0.25	0.20	0.86	0.69	0.55	0.27
High EV Scenario MSE	0.01	0.01	0.01	0.01	0.29	0.27	0.26	0.23	0.81	0.72	0.62	0 41
Low EV Scenario ASE	0.56	0.56	0.56	0.56	0.21	0.21	0.21	0.21	1.05	1.05	1 05	1.05
High EV Scenario ASE	0.55	0.55	0.55	0.55	0.21	0.21	0.21	0.21	1.04	1.04	1 04	1 04
Combustion Turbine												
Base Case ASE	0.57	N/A	N/A	N/A	0.21	N/A	N/A	N/A	1.06	N/A	N/A	N/A
Low EV Scenario MSE	0.01	0.01	0.01	0.01	0.30	0.28	0.26	0.20	0.88	0.71	0.57	0.28
High EV Scenario MSE	0.02	0.01	0.01	0.01	0.32	0.24	0.28	0.24	0.91	0.43	0.66	0.43
Low EV Scenario ASE	0.56	0.56	0.56	0.56	0.21	0.21	0.21	0.21	1.06	1.06	1.06	1.05
High EV Scenario ASE	0.55	0.55	0.55	0.55	0.21	0.21	0.21	0 21	1.06	1.05	1.05	1.04

	PM10 (lb/MWh)				ROG (lb/MWh)				C (lb/MWh)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	0.09	N/A	N/A	N/A	0.04	N/A	N/A	N/A	245.37	N/A	N/A	N/A
Low EV Scenario MSE	0.07	0.08	0.09	0.10	0.04	0.05	0.05	0.06	297.09	298.41	291.99	274.32
High EV Scenario MSE	0.07	0.07	0.08	0.10	0.04	0.04	0.05	0.06	293.94	289.77	293.36	289.71
Low EV Scenario ASE	0.09	0.09	0.09	0.09	0.04	0.04	0.04	0.04	245.59	245.79	245.75	245.59
High EV Scenario ASE	0.09	0.09	0.09	0.09	0.04	0.04	0.04	0.04	245.48	245.81	246.11	246.22
Combustion Turbine												
Base Case ASE	0.09	N/A	N/A	N/A	0.04	N/A	N/A	N/A	245.37	N/A	N/A	N/A
Low EV Scenario MSE	0.07	0.08	0.09	0.10	0.04	0.05	0.05	0.06	298.99	310.75	301.33	281.08
High EV Scenario MSE	0.07	0.10	0.09	0.10	0.04	0.06	0.05	0.06	324.78	299.73	312.87	299.73
Low EV Scenario ASE	0.09	0.09	0.09	0.09	0.04	0.04	0.04	0.04	245.90	246.03	245.93	245.72
High EV Scenario ASE	0.09	0.09	0.09	0.09	0.04	0.04	0.04	0.04	247.25	247.15	246.98	246.66

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The EV charging energy is:

	Charging Energy (MWh)
Low EV	333,000
High EV	795,352

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)	
	Low EV	High EV
Case 1	64	354
Case 2	48	226
Case 3	34	112

Table C.5.45 Los Angeles Dept. Of Water and Power - Year 2010 MSE

Scenario: Year 2010 - Combined Cycle - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	1.54	1.48	1.46	1.56	0.21	0.20	0.24	0.19	2.10	2.22	2.17	2.17
Low EV Scenario MSE			0.01				0.71				1.52	
High EV Scenario MSE			0.01				0.63				1.34	
Low EV Scenario ASE	1.20	1.46	1.44	1.53	0.21	0.20	0.23	0.19	2.04	2.18	2.12	2.14
High EV Scenario ASE	1.49	1.43	1.41	1.51	0.20	0.19	0.23	0.19	1.99	2.13	2.06	2.09

	PM10 (lb/MWh)				ROG (lb/MWh)				C (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.14	0.14	0.14	0.15	0.03	0.03	0.03	0.03	306.08	305.60	306.23	297.81
Low EV Scenario MSE			0.05				0.03				321.73	
High EV Scenario MSE			0.06				0.03				311.09	
Low EV Scenario ASE	0.14	0.15	0.14	0.15	0.04	0.04	0.03	0.04	303.61	306.49	304.58	299.12
High EV Scenario ASE	0.14	0.14	0.14	0.15	0.04	0.04	0.04	0.04	301.89	302.47	302.61	295.23

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	110,200	120,220	148,820	116,530
High EV	238,998	267,065	330,261	259,016

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	210
High EV	496

Table C.5.46 Los Angeles Dept. Of Water and Power - Year 2010 MSE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	1.54	1.48	1.46	1.56	0.21	0.20	0.24	0.19	2.10	2.22	2.17	2.17
Low EV Scenario MSE			0.01				0.72				2.14	
High EV Scenario MSE			0.01				0.68				2.01	
Low EV Scenario ASE	-1.52	1.46	1.44	1.53	0.22	0.21	0.25	0.20	2.10	2.21	2.16	2.16
High EV Scenario ASE	1.49	1.43	1.41	1.51	0.23	0.22	0.25	0.21	2.10	2.19	2.15	2.14

	PM10 (lb/MWh)				ROG (lb/MWh)				C (lb/MWh)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case ASE	0.14	0.14	0.14	0.15	0.03	0.03	0.03	0.03	306.08	305.60	306.23	297.81
Low EV Scenario MSE			0.03				0.01				355.61	
High EV Scenario MSE			0.04				0.02				355.17	
Low EV Scenario ASE	0.14	0.14	0.14	0.15	0.03	0.03	0.03	0.03	306.74	305.63	307.12	297.93
High EV Scenario ASE	0.14	0.14	0.14	0.15	0.03	0.03	0.03	0.03	307.52	305.76	308.13	298.18

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	110,200	120,220	148,820	116,530
High EV	238,998	267,065	330,261	259,016

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	210
High EV	496

Table C.5.47 Los Angeles Dept. Of Water and Power - Year 2010 Summer Off-Peak Charging MSE

Scenario: Year 2010 - Combined Cycle and Combustion Turbine - Summer Off-peak Charging Scenarios

	SO2 (lb/MWh)				CO (lb/MWh)				NOx (lb/MWh)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	1.46	N/A	N/A	N/A	0.24	N/A	N/A	N/A	2.17	N/A	N/A	N/A
Low EV Scenario MSE	0.01	0.01	0.01	0.01	0.71	0.60	0.42	0.27	1.52	1.29	1.77	1.90
High EV Scenario MSE	0.01	0.01	0.01	0.01	0.63	0.60	0.48	0.35	1.34	1.28	1.54	1.82
Low EV Scenario ASE	1.44	1.43	1.44	1.44	0.23	0.24	0.24	0.24	2.12	2.14	2.15	2.16
High EV Scenario ASE	1.41	1.41	1.40	1.41	0.23	0.24	0.24	0.24	2.06	2.09	2.12	2.15
Combustion Turbine												
Base Case ASE	1.46	N/A	N/A	N/A	0.24	N/A	N/A	N/A	2.17	N/A	N/A	N/A
Low EV Scenario MSE	0.01	0.01	0.01	0.01	0.72	0.59	0.43	0.27	2.14	2.21	2.11	1.94
High EV Scenario MSE	0.01	0.01	0.01	0.01	0.68	0.62	0.49	0.37	2.01	2.14	2.12	2.05
Low EV Scenario ASE	1.44	1.43	1.44	1.44	0.25	0.24	0.24	0.24	2.16	2.17	2.16	2.16
High EV Scenario ASE	1.41	1.41	1.41	1.41	0.25	0.25	0.25	0.24	2.15	2.16	2.16	2.16

	PM10 (lb/MWh)				ROG (lb/MWh)				C (lb/MWh)			
Combined Cycle	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3	Unconstrained	Case 1	Case 2	Case 3
Base Case ASE	0.14	N/A	N/A	N/A	0.03	N/A	N/A	N/A	306.23	N/A	N/A	N/A
Low EV Scenario MSE	0.05	0.06	0.03	0.04	0.03	0.03	0.01	0.02	321.73	307.43	331.49	329.96
High EV Scenario MSE	0.06	0.06	0.04	0.03	0.03	0.03	0.02	0.01	311.09	307.43	319.71	303.45
Low EV Scenario ASE	0.14	0.14	0.14	0.14	0.03	0.03	0.03	0.03	304.58	305.53	306.36	306.60
High EV Scenario ASE	0.14	0.14	0.14	0.14	0.04	0.03	0.03	0.03	302.61	304.27	305.76	306.69
Combustion Turbine												
Base Case ASE	0.14	N/A	N/A	N/A	0.03	N/A	N/A	N/A	306.23	N/A	N/A	N/A
Low EV Scenario MSE	0.03	0.03	0.04	0.04	0.01	0.01	0.01	0.02	355.61	350.14	341.45	331.12
High EV Scenario MSE	0.04	0.04	0.04	0.04	0.02	0.01	0.01	0.02	355.17	351.11	344.15	337.71
Low EV Scenario ASE	0.14	0.14	0.14	0.14	0.03	0.03	0.03	0.03	307.12	307.03	306.86	306.66
High EV Scenario ASE	0.14	0.14	0.14	0.14	0.03	0.03	0.03	0.03	308.13	307.99	307.70	307.43

Notes:

(1) The MSE calculation for a simulation period (a season) is the total cumulative change in an emission divided by the total cumulative change in energy production after adding and then removing the load presented by EVs. Both simulations are performed after capacity has been added to maintain reliability given the EV load. The ASE calculation is the ratio of the accumulated hourly emissions to the total energy produced during a single simulation period.

(2) The EV charging energy is:

	Charging Energy (MWh)
Low EV	148,820
High EV	330,261

(3) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)	
	Low EV	High EV
Case 1	65	231
Case 2	24	95
Case 3	3	35

C.6 Observations, Comments, and Conclusions

This section compares the emissions in different regions and examines whether there is a clear national pattern in the results. This section also comments on how the results may be interpreted for use in future policy decisions.

C.6.1 Regional Fuel Use Comparison

Tables C.6.1a to C.6.1c show the energy generation from different fuels to meet the native load and additional demand of EV charging in all the regions studied for the summer season. We have chosen the summer season to make certain observations as it represents the worst air quality season in the regions studied.

Table C.6.1a shows the fuel components to meet the system demand. The table also shows contracted imports of energy from outside the air quality region, and in some cases from entities outside the state. With the exception of PEPCO in the Washington, D.C., area, all the regions have a component of nuclear energy to supply the system demand. The highest percentage of nuclear energy is in the Chicago region. The generation mix in PEPCO and VEPCO are such that about half the system energy is derived from coal. HLP and SCE have significant energy generation from natural gas; a third of LADWP's demand is supplied by this fuel. Some 33% of LADWP's demand is met by coal generation situated outside the air basin. None of the utilities has a significant generation from oil except for PEPCO, which has some 22% of its demand supplied by oil-fired generation. Note that the price of oil per Btu is slightly less than that of natural gas in this region of the country.

The component fuels that supply the incremental EV charging demand for the summer season are shown in Tables C.6.1b and C.6.1c which were obtained as follows. The aggregated generation from different fuel types in the base case were subtracted from the generation from these fuels considering the addition of additional generation, and the EV charging load. In all regions, since the nuclear units are base load generators, there is no change to the nuclear component of incremental EV charging energy.

In all the utilities except CE and VEPCO, most of this incremental energy comes from natural gas in the case of the CC unit addition scenario (Table C.6.1b). This is not surprising as the CC unit added to meet the EV demand is assumed to be fired by natural gas (with the exception of CE). In VEPCO, a third of the charging energy comes from natural gas, and the rest from oil. In CE, all the charging energy comes from coal as the additional IGCC technology uses coal in an integrated gasifier. As mentioned earlier, this technology was used for CE because of its expression of intent to install this technology.

Table C.6.1c indicates the incremental energy shares for a CT unit addition. The fuel for a CT unit is also natural gas. Therefore, there is some similarity between Tables C.6.1b and C.6.1c. However, because of the higher cost of energy from a CT unit, its contribution to the incremental generation is less. This can be seen in the case of CE where the marginal generation from natural gas in the CT scenario is about 36%. In contrast, for the addition of IGCC, the incremental energy supplied by this technology showed an increase of some 120% (Table C.6.1b).

Table C.6.1 Comparison of Utility Fuel Burns for the Summer 2010 Unconstrained High EV[1]

Table C.6.1a. Total system energy for the base case scenario (no EVs).

Utility	System Generation (MWh)	System Energy by Fuel Type (% of Total)						
		Nuclear	Coal	NG	OIL	Hydro	Renewables	Imports
PEPCO	10,621,917		58.14	18.68	22.24		0.94**	
VEPCO	29,579,340	22.72	53.96	16.89	4.70	1.73		
CE	30,325,042	67.49	30.64	1.85	0.02			
HL&P	25,193,049	5.23	20.60	74.17				
LADWP	8,716,543	7.27	32.93	38.62		4.05	2.39	14.74
SCE	33,664,764	13.27	8.41	64.71	0.01	3.71	8.57	1.32

**Energy from MSW.

Table C.6.1b. Incremental system energy for the combined cycle scenario.

Utility	Incremental Generation (MWh)	Incremental Energy by Fuel Type (% of Total)						
		Nuclear	Coal	NG	OIL	Hydro	Renewables	Imports
PEPCO	60,089		0.09	92.52	7.39			
VEPCO	102,377		5.16	34.39	60.45			
CE (IGCC)	361,184		120.44	(20.27)	(0.17)			
HL&P	239,944		(21.00)	121.00				
LADWP	330,261			100.00				
SCE	795,352			99.94	0.06			

Table C.6.1c. Incremental system energy for the combustion turbine scenario.

Utility	Incremental Generation (MWh)	Incremental Energy by Fuel Type (% of Total)						
		Nuclear	Coal	NG	OIL	Hydro	Renewables	Imports
PEPCO	60,089		0.09	92.52	7.39			
VEPCO	102,306		5.17	21.03	73.8			
CE	361,184		63.67	36.50	(0.17)			
HL&P	240,027		17.19	82.81				
LADWP	330,261			100.00				
SCE	795,352			99.66	0.34			

[1]Economic dispatch procedure used for all utilities except CE (which used emission-constrained dispatch.)

C.6.2 Regional Comparison of Emissions

C.6.2.1 SO_2 Emissions

Tables C.6.2a and C.6.2b show the ISE of SO_2 in all the seasons for utilities serving the different regions. The indicated ISE is for the year 2010 for both the CC and CT additions in high EV penetration cases. The results were obtained by simulating emission constrained dispatch in the CE system of Chicago, and by simulating economic dispatch in the other systems after taking into account the mitigative measures planned, if needed. As discussed previously, the CE system of Chicago is the only utility that may resort to emission-constrained dispatch. Other utilities either are not affected by the emission caps of CAAA, or will use mitigative measures.

Except for Chicago, SO_2 emissions are the highest during summer in both the CT and CC scenarios. In Chicago, the highest SO_2 emissions occur during the winter in both scenarios. The tables do not show other pollutants. Nevertheless, our study indicated that the seasonal emissions of other pollutants were also similar to that of SO_2, that is that they were higher in the summer months, except in Chicago where higher emissions result during the winter. Such an accounting of seasonal emissions is the starting point for the assessment of seasonal air quality studies.

C.6.2.2 NO_x Emissions in California

Tables C.6.3 and C.6.4 (also shown in Section C.5) provide, in addition to the other criteria pollutants, the seasonal ISE NO_x amounts for the two Southern California utilities studied. These two tables are for the year 2010, high EV penetrations, and CT unit additions. The total incremental increase in NO_x emissions from the two utilities in the summer season is 667 tons. On the basis of 91 days per season, this works out to an average ISE of 7.32 tons/day, a small amount compared to the desired control policy of 399 tons/day (page 5-14 of Southern California Association of Governments, July 1991). It is to be noted further that the ISE does not emanate from out-of-basin plants (see Appendix C.7).

C.6.2.3 Marginal and Average Emissions of Pollutants

Tables C.6.5a and C.6.5b indicate the ISE, ASE and MSE of all pollutants for the cases of adding CC and CT units in the year 2010 high penetration scenarios. In Table C.6.6, the ISE, MSE and ASE for three selected pollutants are extracted from Tables C.6.5a and C.6.5b. Also shown are the amounts of capacity added to meet the EV demand at the same reliability as the base case and the energy generated from added units. The computations for three types of added generation technologies, CT, IGCC, and CC, are indicated in the tables. Also shown in the table as an inset are the generic emission rates for the generating units added.

First, we examine the average emissions confining our attention to SO_2 and NO_x emissions. The average emission rate is influenced by the emission rates of all units, and the fuels used for generation. Because the EV load is much less than the system load, these average rates of emission are indicative of the state of cleanliness of the present system. In that sense, PEPCO is the dirtiest utility because of a large component of generation from its coal plants. Next in order of dirtiness are VEPCO and CE. An examination of generator emission characteristics in these two latter utilities indicates that their coal units have similar or greater quantities of emission than those of PEPCO. But the average emission rate for these two utilities are lower than PEPCO because of the nuclear generation component (see Table C.6.1a). In CE, despite the fact that its generators have higher emission rates than the other two utilities under discussion, the average emission rates of these two pollutants are considerably lower than those for PEPCO. This is because close to 70% of CE's total energy is generated by nuclear power.

The reason for SO_2 and NO_x emissions being very low in HL&P, LADWP, and SCE is because of substantial generation from natural gas.

Table C.6.2 TSE SO2 Emissions for the Utilities Studied [2]

Table C.6.2a. Combined Cycle Scenario

	Tons SO2					Allocated
Utility	Winter	Spring	Summer	Fall	Total	Allowances
PEPCO	23,158	24,745	29,073	24,298	101,274	99,781
VEPCO	24,017	14,403	35,026	23,149	96,595	142,051
CE (IGCC)	46,314	17,575	33,907	44,464	142,260	142,690
HL&P	10,613	10,106	14,686	8,331	43,736	106,113
LADWP	5,530	551	6,156	5,813	18,050	38,265
SCE	9,116	7,161	9,346	9,323	34,946	65,506

Table C.6.2b. Combustion Turbine Scenario

	Tons SO2					Allocated
Utility	Winter	Spring	Summer	Fall	Total	Allowances
PEPCO	23,159	24,745	29,074	24,298	101,276	99,781
VEPCO	24,130	14,421	35,114	23,242	96,907	142,051
CE	44,287	19,942	35,238	43,709	143,176	142,690
HL&P	11,045	10,336	14,981	8,596	44,958	106,113
LADWP	5,531	5,551	6,156	5,813	23,051	38,265
SCE	9,121	7,162	9,348	9,324	34,955	65,506

[2]Economic dispatch was used for all utilities except CE (which used emission-constrained dispatch).

Table C.6.3 Southern California Edison - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	9,112	6,018	7,919	7,886	2,992	2,360	2,918	2,544	16,184	11,210	14,727	13,992
Low EV Scenario ISE	1	1	2	1	37	31	50	34	93	69	147	85
High EV Scenario ISE	3	3	8	3	98	78	127	82	317	178	358	214

	PM10 (tons)				ROG (tons)				C (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	1,360	1,062	1,250	1,145	544	472	556	509	3,542,689	2,805,672	3,408,947	3,086,112
Low EV Scenario ISE	11	11	12	11	6	7	7	5	40,684	37,111	49,820	37,295
High EV Scenario ISE	21	26	32	22	12	16	16	13	96,992	89,735	129,273	90,037

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	247,039	270,604	333,000	262,569
High EV	592,080	647,091	795,352	628,530

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	162
High EV	620

Table C.6.4 Los Angeles Dept. Of Water and Power - Year 2010 ISE

Scenario: Year 2010 - Combustion Turbine - Economic Dispatch - Unconstrained EV Charging

	SO2 (tons)				CO (tons)				NOx (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	5,484	5,507	6,122	5,787	748	744	1,006	705	7,478	8,261	9,099	8,050
Low EV Scenario ISE	1	1	1	1	36	33	51	32	123	76	146	73
High EV Scenario ISE	1	1	2	1	81	76	107	75	263	171	309	166

	PM10 (tons)				ROG (tons)				C (tons)			
	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall	Winter	Spring	Summer	Fall
Base Case TSE	499	521	587	556	107	112	126	111	1,089,906	1,137,177	1,284,066	1,104,818
Low EV Scenario ISE	2	4	3	3	1	2	1	2	19,272	18,484	26,570	17,808
High EV Scenario ISE	5	8	8	8	1	4	3	4	41,794	41,406	58,854	39,983

Notes:

(1) The TSE is the total tons of emissions during a simulation period(a season). The ISE calculation is the total difference between the accumulated hourly emissions of a base case scenario and an EV penetration scenario during a simulation period.

(2) The seasons are defined as follows:
Winter Season (1/1/10 - 3/31/10 : 2160 hr)
Spring Season (4/1/10 - 6/30/10 : 2184 hr)
Summer Season (7/1/10 - 9/31/10 : 2208 hr)
Fall Season (10/1/10 - 12/31/10 : 2208 hr)

(3) The EV charging energy for each season and scenario is:

	Charging Energy (MWh)			
	Winter	Spring	Summer	Fall
Low EV	110,200	120,220	148,820	116,530
High EV	238,998	267,065	330,261	259,016

(4) Capacity added to maintain same reliability as in the base case:

	Capacity (MW)
Low EV	210
High EV	496

Table C.6.5 Comparison of ISE, MSE, and ASE Emissions

All results are for high EV penetration in the summer of 2010 with unconstrained charging.
Economic dispatch was used for all utilities except CE (emission-constrained dispatch).

Table C.6.5a. Combined Cycle Scenario

	SO2			CO			NOx		
	ISE	MSE	ASE	ISE	MSE	ASE	ISE	MSE	ASE
Utility	(tons)	(lb/MWh)	(lb/MWh)	(tons)	(lb/MWh)	(lb/MWh)	(tons)	(lb/MWh)	(lb/MWh)
PEPCO	6	0.55	5.47	4	0.28	0.30	13	0.77	3.53
VEPCO	417	10.01	2.33	18	0.42	0.27	154	3.61	2.38
CE (IGCC)	-863	0.28	2.22	-114	0.62	0.10	-1,235	9.31	1.46
HL&P	-126	4.41	1.17	-61	0.56	0.80	-139	3.34	2.50
LADWP	2	0.01	1.41	-12	0.63	0.23	-97	1.34	2.06
SCE	4	0.01	0.55	68	0.29	0.21	68	0.81	1.04

	TSP			VOC			CO2		
	ISE	MSE	ASE	ISE	MSE	ASE	ISE	MSE	ASE
Utility	(tons)	(lb/MWh)	(lb/MWh)	(tons)	(lb/MWh)	(lb/MWh)	(tons)	(lb/MWh)	(lb/MWh)
PEPCO	5	0.18	0.41	2	0.07	0.05	28,298	1,094.46	1615.97
VEPCO	24	0.57	0.24	4	0.08	0.05	73,568	1,700.70	1419.93
CE (IGCC)	209	0.75	0.31	7	0.06	0.02	408,498	1,940.28	681.60
HL&P	16	0.03	0.06	8	0.04	0.05	68,462	1,675.00	1245.28
LADWP	21	0.06	0.14	13	0.03	0.04	34,691	311.09	302.61
SCE	40	0.07	0.09	24	0.04	0.04	99,447	293.94	245.48
	PM10			ROG			C		

Table C.6.5b. Combustion Turbine Scenario

	SO2			CO			NOx		
	ISE	MSE	ASE	ISE	MSE	ASE	ISE	MSE	ASE
Utility	(tons)	(lb/MWh)	(lb/MWh)	(tons)	(lb/MWh)	(lb/MWh)	(tons)	(lb/MWh)	(lb/MWh)
PEPCO	6	0.55	5.47	8	0.29	0.30	17	0.77	3.53
VEPCO	505	10.03	2.34	20	0.42	0.27	178	3.62	2.38
CE	468	3.97	2.31	126	0.67	0.12	1,031	5.98	1.61
HL&P	169	4.20	1.19	30	0.56	0.81	116	3.23	2.52
LADWP	2	0.01	1.41	107	0.68	0.25	309	2.01	2.15
SCE	8	0.02	0.55	127	0.32	0.21	358	0.91	1.04

	TSP			VOC			CO2		
	ISE	MSE	ASE	ISE	MSE	ASE	ISE	MSE	ASE
Utility	(tons)	(lb/MWh)	(lb/MWh)	(tons)	(lb/MWh)	(lb/MWh)	(tons)	(lb/MWh)	(lb/MWh)
PEPCO	5	0.18	0.41	2	0.07	0.05	31,548	1,102.14	1616.58
VEPCO	29	0.57	0.24	4	0.08	0.05	84,756	1,704.92	1420.68
CE	141	0.80	0.30	13	0.07	0.02	369,490	2,076.62	679.05
HL&P	14	0.04	0.06	10	0.04	0.05	178,546	1,650.43	1254.02
LADWP	8	0.04	0.14	3	0.02	0.03	58,854	355.17	308.13
SCE	32	0.07	0.09	16	0.04	0.04	129,273	324.78	247.25
	PM10			ROG			C		

Table C.6.6 Comparison of Incremental, Marginal, and Average System Emissions for the Utilities Studied[3].

					(tons)			(lb/MWh)					
					ISE			MSE			ASE		
Utility	Capacity Added to Maintain Reliability (MW)	EV Energy Demand (MWh)		Energy Generated by Additional Capacity (MWh)	SO_2	CO	NO_x	SO_2	CO	NO_x	SO_2	CO	NO_x
PEPCO	72	60,089	CC	17,013	6	4	13	0.55	0.28	0.77	5.47	0.30	3.53
			CT	9,142	6	8	17	0.55	0.29	0.77	5.47	0.30	3.53
VEPCO	59	102,377	CC	38,309	417	18	154	10.01	0.42	3.61	2.33	0.27	2.38
			CT	19,061	505	20	178	10.03	0.42	3.62	2.34	0.27	2.38
CE	417	273,386	IGCC	801,410	-2,864	-97	-1,463	14.94	0.51	7.43	2.62	0.1	1.45
			CT	38,648	2070	78	1,019	15.49	0.54	7.54	2.93	0.11	1.61
HLP	171	239,944	CC	340,209	-126	-61	-139	4.41	0.56	3.34	1.17	0.80	2.50
			CT	176,910	169	30	116	4.20	0.56	3.23	1.19	0.81	2.52
LADWP	496	330,261	CC	90,668	2	-12	-97	0.01	0.63	1.34	1.41	0.23	2.06
			CT	53,500	2	107	309	0.01	0.68	2.01	1.41	0.25	2.15
SCE	620	795,352	CC	1,104,934	4	68	68	0.01	0.29	0.81	0.55	0.21	1.04
			CT	14,208	8	127	358	0.02	0.32	0.91	0.55	0.21	1.04

	(lb/MWh)		
	SO_2	CO	NO_x
CC	0.01	0.17	0.14
IGCC	0.66	0.02	0.45
CT	0.01	0.17	0.14

[3]These results are for the CC and CT summer 2010 unconstrained high EV scenarios.

A comparison of ASE and MSE for each utility in Table C.6.6 indicates that the MSE can be higher or lower than ASE. In almost all cases, MSE is higher than the emission rate of the added generating unit (inset in Table C.6.6). The exception is that of California utilities where the SO_2 MSE is lower than the ASE, and is equal to that of the added unit. However, in these utilities, the MSE of CO and NO_x are higher than ASE. This observation substantiates that the use of average emission rates, or the emission rates of an added generating unit, as a short cut to the detailed analysis of MSE can give hopelessly incorrect results.

C.6.2.4 Effect of Capacity Addition on Emissions

The technology type of the unit added to the meet the EV demand strongly influences the ISEs presented in Section C.5. If the added technology is cleaner than the existing units and less expensive to operate (because of cheaper fuel and higher efficiency) than the existing peaking units, the added unit will be used to supply the demands of other loads as well. This is the case with a CC unit addition. We note that the ISEs are lower, in some cases negative, for a CC or IGCC unit addition. Correspondingly, the ISEs are higher for cases of a CT unit addition.

In contrast, ASEs are not affected significantly by the characteristics of the added units. Clearly, the average is swamped by the system demand which is much larger than the EV load and the generation from the added unit.

C.6.3 Potential Relevance of Marginal Emission Rates in Policy Decisions

The method of calculating ISE, MSE, and ASE rates was discussed previously (see the beginning of Section C.5.) In the following, we discuss the appropriateness of these and other methods in measuring the impact of EVs on emissions.

Consider the CE and HL&P results of Table C.6.6. The ISE figures for the case of IGCC and CC unit additions are negative. The fact the added units supply the system demand in addition to that of the EVs' results in a negative number. This is evident by a comparison of the charging energy and the energy generated by the added units. But, this result does not mean that the actual total emissions increase if EVs are not charged. In fact, emissions resulting from the charging energy traced to the generators that supply the energy are indicated by MSE. The interpretation and application of the ISE is as follows.

If the policy question concerns what the incremental emissions are by adopting a policy of penetrating a certain number of vehicles, then the use of the ISE shown in the tables, including the negative results, is appropriate. Because of such an EV policy initiative, new cleaner technology will be installed to meet the demand of EVs and the native system load because of their economic advantage. Consequently, the total system emissions decrease.

However, if the EVs did not penetrate the market because of either the absence of a policy initiative or other reasons, the natural growth in system demand will warrant the installation of the same new, cleaner technologies as time progresses. Consequently, the effect of promoting EVs results in the installation of cleaner technologies sooner. How does one quantify the economic benefits of adopting cleaner technologies sooner?

Given the financial parameters, such as discount rates, it is a simple matter to perform a cash flow analysis and compute the benefits of advancing or retarding a stream of expenses. However, a similar economic benefit calculation for reducing the effluents earlier cannot be made without heroic assumptions for costs associated with the effluents.

We now give an example of a case in which using the ISEs as reported in the earlier tables would be inappropriate. If one were to investigate the effect of replacing a certain number of EVs by hybrid vehicles or reformulated gasoline vehicles (RFG), then one would like to know the amount of reduced emissions from not charging EVs and compare this figure to the emissions from RFG vehicles. Under such circumstances, it may be incorrect to use the ISEs.

A CT, CC or IGCC unit will be added in anticipation of the projected EV demand. The construction of these units will be started before they are required on line to accommodate the construction lead time. This decision is irrevocable after the unit has been installed. If the anticipated EV loads do not materialize, or if for a contrived example all or some of the EVs are not charged on a certain day, the installed unit will still be dispatched to meet other system loads because of its cost advantage. Because the installed unit is cleaner than the existing units, total emissions in the system decrease even if EVs are not charged. Therefore, if we want to examine some perturbations, as, for example, the effect on emissions if the vehicle miles traveled (VMT) of EVs decreases by 10%, it may be inappropriate to use the ISEs shown in the tables. The use of ISEs could indicate increased emissions when VMT is decreased!

ISEs may not be appropriate to use when the intent of a study is to examine changes to the emissions when the additional unit installation is *a fait accompli*. Under those circumstances, if all the energy to the EVs comes from the added unit,[4] an approximation is to use the emission rate of the added generic unit to calculate changes in emissions resulting from such perturbations. But since all the charging energy seldom comes from the added generating unit, the MSE indicated in Table C.6.5 could be used to study such perturbations.

C.6.4 Extensions to the National Scene

One question arising from the regional analysis is: Is it possible to extrapolate the above results to other regions of the country? The tables show that ASEs, ISEs, and MSEs are dependent on the existing generation mix and can be strongly dependent on the type of units added to meet additional capacity needs. As a result, it would be incorrect to imply that the results obtained in these four metropolitan areas studied in this EVTECA are indicative of other regions in the country.

Notwithstanding this fact, one can assert that cleaner technologies will be added to meet the demand of EVs in all regions. Given that CC units are very promising for the future, even in regions which are relatively dirty, the new units reduce overall emissions.

As noted in the case of VEPCO, if the added capacity is intended more for reliability purposes and does not contribute much energy, the emissions are dependent on the characteristics of the existing units that actually supply the charging demand of EVs. However, if one plans for the promotion of a large number of EVs, it is very likely that the most economic resource expansion plan will call for the addition of a CC unit

[4] This assumption is not entirely valid. During certain times of the day, for example peak hours when EVs are charged, the unit on the margin may be some other unit on the system. Consequently, even though the energy produced by the added unit is equal to or greater than the EV demand, it may be as a result of dispatching this unit to meet the system demand at times other than during EV charging.

rather than a CT unit. In that sense, a large penetration of EVs is expected to reduce emissions in dirty regions. In cleaner regions, and if the penetration of EVs continues for a long time, given the retirement of older generating units, it is natural to expect that the emissions will asymptotically reach those of the new generating units added to the system.

C.6.5 Conclusions

C.6.5.1 Major Findings

The discussion above indicates that ISEs are strongly dependant on the capacity added to meet the charging load. In utility practice, capacity is added to maintain a certain level of reliability. We have conducted probabilistic analysis in our simulations. Therefore, even the off-peak charging cases demand capacity additions of a lesser quantity than those cases under unconstrained charging.

Several observations have been made in the previous sections, as summarized below:

- The first concern of a policy maker is to know the emissions due to EV charging. Arising from this is the allied issue as to whether EVs should be promoted on a national scale, and its effect on air quality. Our study has shown that there are no simple answers to these questions.

- The emissions from charging EVs vary from region to region. Emissions are greatly influenced by the technology of the generating units to be added to meet the charging demand. Emissions are also heavily influenced by the dispatch procedure. In regions of the country where the existing generating units are "dirty," promoting EVs accelerates the addition of newer generation, which is cleaner. Consequently, by using the added unit to meet the native system load in addition to that of EVs, the total system emissions could decrease. However, such is not the case in regions where the existing units are relatively clean, as in California.

- It is interesting to note that a reduction in TSE would result in due course as a result of the growth in system demand even without the penetration of EVs. Promoting the penetration of EVs merely advances the reductions in TSE over time.

- While the total system emissions may decrease in certain regions, the marginal emissions due to EV charging could be substantial. This occurs because the dispatch procedure determines which generating unit contributes to the energy that is put into the EVs during the charging hours. The units dispatched to meet the charging demand could have substantial marginal emissions.

- The range of MSEs is large. For example, in Table C.6.5 the marginal SO_2 emission varies from a high of 10.02 lb/MWh in VEPCO to a low of 0.01 lb/MWh in California utilities. Even within a utility, the range of variation in marginal emissions can be large depending on the dispatch procedure adopted, and the technology of the added generating unit.

- An important issue is whether off-peak charging should be encouraged. If the goal is to reduce the additional capacity needed to meet the charging demand, off-peak charging achieves this goal. However, does it reduce emissions? Not necessarily so. In some regions of the country, off-peak charging increases emissions. In fact, within the same region, the effect of off-peak charging on different utilities serving the region can be disparate. This was substantiated in the case of two utilities serving the Los Angeles area. Another important consideration of off-peak charging is to decide if the utilities should plan their system for least cost, for least emissions, or a combination of the two. If the goal is least cost, there is an incentive for off-peak charging to reduce additional capacity installation. If the goal is least emissions, off-peak charging could contradict the goal.

- Another related issue is the nature of existing /contemplated time-of-day, or real-time pricing initiatives. Such price structures encourage consumption during off-peak hours for all loads, including loads associated with EV charging. Certainly, this leads to lower peaking capacity requirements in the long run. But, off-peak consumption could increase emissions. However, if a significant amount of consumption in addition to that of EV charging is shifted to off-peak hours, the demand profile flattens, and the peak might even shift to a different hour. Under such circumstances, one has to conduct studies along the lines indicated in this report to assess how pricing mechanisms impinge on emissions.

- Emission-constrained dispatch to meet the requirements of CAAA reduces the annual SO_2 emissions. But EV charging under such a dispatch procedure could, under some circumstances, increase the emissions of SO_2 and other pollutants, including in seasons with the worst air quality.

- It is generally believed that addition of renewable energy resources to the generation mix of a utility will reduce emissions. It is true that the total system emissions will be reduced from such installations. But the marginal emissions may not be. We did not study renewable energy additions in detail. Such a study would have required a large effort, as it requires site-specific resource data, and information about the coincidence of output from such installations and charging times. Nonetheless, our study indicates that the charging energy need not come from the added generating unit. Therefore, while it might make sense to install renewable resources to reduce total emissions, marginal emissions due to charging may not be reduced by such action. In fact, we considered a biomass plant addition in Los Angeles. Our study indicated that if such a plant were to be located within the air basin, the emissions would increase compared to a CC or CT unit addition, adversely affecting the air quality.

- The results of a particular utility cannot be extrapolated to another utility. Each utility and region has to be studied considering its generation and fuel mix, demand pattern, and dispatch procedure. Therefore, we cannot offer any nostrums applicable to the "national scene." Even if one can find seemingly similar utilities in terms of generation, fuel mixes and load profiles such as winter and summer peaking, there can be other seminal differences that make the results of one utility inapplicable to another. For instance, the number of EVs in the two utilities may be different due to different population densities or driving habits. Then, the added capacity to meet the EV demand in the utilities will be different, making emissions in the two utilities different. Another complicating factor is that even if the fuel mixes are the same, the fuel prices in the regions could be different, as for example in VEPCO, where oil is cheaper than natural gas. Then the emissions in the two regions will be different because of the resulting differences in the dispatch order of machines in the two regions. Yet another difference might be the purchases and sales in the two utilities. One of them might have access to markets with surplus seasonal power and energy while the other may not. Then, because of the differing imports and exports of power, even in two seemingly identical utilities with identical number of EVs, the emissions can be vastly different.

C.6.5.2 Limitations of Results

Some caution should be exercised in using the ISEs reported. They are suitable for determining the change in emissions that will result from a policy designed to penetrate a certain number of EVs. They may not be suitable for computing the changes in emissions resulting from a perturbation in the expected EV penetration. Such perturbation studies may best be conducted by using the MSE presented in Section C.5.3.

Another uncertainty is that of economy energy interchanges among utilities. Some utilities exchange large quantities of energy on an hour-to-hour basis in response to fluctuating market prices and central dispatch procedures in pool operation. These exchanges are difficult to predict and model, because the future of the market is uncertain. These exchanges can be quite large compared to the EV charging energy calculated in these model runs. As a consequence, it is difficult to assert that the emissions resulting from generation will indeed result from the units modeled in a particular area. For instance, in a particular hour, PEPCO could be importing economy energy from a utility or IPP in Pennsylvania.

It is possible that there will be a breakthrough in the efficiency and energy density in the batteries the future. Additionally, some believe that breakthrough in fuel cells is to be expected soon. The latter may then offer an alternative to the charging of batteries from the conventional plants in a utility's grid. Another possibility is that battery technologies of the future will permit a very rapid charging as opposed to the slower charging profile assumed in our studies. Such changes in the future may not only influence our results drastically, but could also negate some major findings

Finally, we remark that the results obtained are very sensitive to the input data. There is some uncertainty regarding the data obtained from the utilities. The future load growth projections, the projections for the implementation of DSM programs, and the unfolding events regarding deregulation and open access in the electricity industry are all fraught with ever increasing uncertainties. The results of our computation are based on the best guesses of the industry and will not reflect reality if these guesses change.

C.6.5.3 Sensitivity Studies

The above indicates the need for sensitivity studies to ascertain which input parameters and assumptions influence the results the most. There are some assumptions about which it may not be beneficial to conduct sensitivity studies. For example, the assumption of temporal profiles for interruptible purchases and sales, and machine maintenance schedules are difficult to predict for the future. Our assumptions are based on our experience in the utility industry, and judgement.

As an example of a useful sensitivity study is that of the effect of DSM. There is some uncertainty about the extent of DSM for the future resulting in a disagreement between some utilities and their regulators. Additionally, fuel prices and their relativity may influence the emissions vastly. We suggest a sensitivity study on these and some other parameters for the future.

C.7 South Coast Air Basin Incremental System Emissions

This appendix section provides detailed printouts of certain results from the utility analysis.

Table C.7.1 provides ISE calculation for Southern California Edison for the summer of 2010.

Tables C.7.2 through C.7.5 present ISE and TSE for Southern California Edison. Each table lists the emissions that are projected to occur for the existing plants that are located in-basin, the existing plants that are located out-basin, for future plants that are needed by 2010 to meet native load, and for the plant that has been added to maintain reliability given the projected EV load. These last two categories have not been designated in- or out-basin because of the uncertainty associated with their location. Tables C.7.6 through C.7.9 correspond to Tables C.7.2 through C.7.5, but for the Los Angeles Department of Water and Power. The first table of each set indicates the results for the CC, high EV penetration scenario. The second table of the two sets presents the results for the CC, low EV penetration scenario. The last two tables of each set present the results for the high and low EV penetration CT scenarios, respectively. These results are discussed in Section C.5.

Table C.7.1 ISE Calculation for Southern California Edison

Utility	Date	Case #
SCE	Apr22'94	sum2010

Incremental Emission Calculation

Dispatch Order	Unit Name	Expected Generation (MWh)	CO	NOx	SO2	TSP	VOC	CO2
			-----Generation Emissions in Tons---					
1	Base EA Units*	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
2	Palo Verde #1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
3	Palo Verde #2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
4	Palo Verde #3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
5	San Onofre #2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
6	San Onofre #3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
7	Four Corners #4	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
8	Four Corners #5	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
9	Mojave #1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
10	Mojave #2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
11	San Onofre #1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
12	Cool Water #1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
13	Cool Water #2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
14	San Bern. Repower	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
15	New Capacity 1	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
16	New Capacity 2	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
17	New Capacity 3	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
18	New Capacity 4	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
19	New Capacity 5	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
20	New Capacity 6	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
21	New Capacity 7	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
22	New Capacity 8	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
23	New Capacity 9	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
24	New Capacity 10	-811.16984	-0.07	-0.05	0.00	-0.04	-0.02	-100.65
25	New Capacity 11	-871.96003	-0.07	-0.06	0.00	-0.04	-0.03	-108.19
26	New Capacity 12	-914.02797	-0.08	-0.06	0.00	-0.04	-0.03	-113.41
27	New Capacity 13	-932.23522	-0.08	-0.06	0.00	-0.05	-0.03	-115.67
28	New Capacity 14	-921.25253	-0.08	-0.06	0.00	-0.05	-0.03	-114.31
29	New Capacity 15	-875.68430	-0.07	-0.06	0.00	-0.04	-0.03	-108.65
30	New Capacity 16	-790.20741	-0.07	-0.05	0.00	-0.04	-0.02	-98.05
31	New Capacity 17	-659.72034	-0.05	-0.04	0.00	-0.03	-0.02	-81.86
32	New Capacity 18	-479.49765	-0.04	-0.03	0.00	-0.02	-0.01	-59.50
33	New Capacity 19	-245.34435	-0.02	-0.02	0.00	-0.01	-0.01	-30.44
34	New Capacity 20	46.25576	0.00	0.00	0.00	0.00	0.00	5.74
35	New Capacity 21	398.00398	0.03	0.03	0.00	0.02	0.01	49.38
36	New Capacity 22	811.66867	0.07	0.05	0.00	0.04	0.02	100.71
37	New EV Capacity	1104934.47541	91.40	74.78	4.15	54.01	33.24	137100.27
38	Huntington #3	-41811.24711	-3.46	-2.83	-0.16	-2.04	-1.26	-5187.94
39	Huntington #4	-44361.70222	-3.67	-3.00	-0.17	-2.17	-1.33	-5504.40
40	Alamitos #1	-43476.18656	-3.60	-2.94	-0.16	-2.13	-1.31	-5394.53
41	Mid EA Units*	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
42	Alamitos #2	-187214.26184	-15.49	-12.67	-0.70	-9.15	-5.63	-23229.55
43	Cool Water #3	-4001.10251	-0.45	-0.37	-0.02	-0.27	-0.16	-679.99
44	Cool Water #4	-3632.35330	-0.41	-0.34	-0.02	-0.24	-0.15	-617.32
45	Redondo #5	-2310.51320	-0.42	-2.97	-0.01	-0.03	-0.01	-364.38
46	Redondo #6	-1811.76320	-0.33	-1.95	-0.01	-0.03	-0.01	-285.73
47	Redondo #7	-3734.39938	-0.68	-1.86	-0.02	-0.05	-0.02	-588.94
48	Redondo #8	-1855.96091	-0.34	-0.96	-0.01	-0.03	-0.01	-292.70
49	Mandalay #1	-385.63577	-0.07	-0.35	0.00	-0.01	0.00	-64.03
50	Mandalay #2	-83.53537	-0.02	-0.07	0.00	0.00	0.00	-13.87
51	Ormond Beach #1	1586.17522	0.30	1.14	0.01	0.02	0.01	258.68
52	Ormond Beach #2	3845.24296	0.72	2.58	0.02	0.06	0.02	627.11
53	Huntington #1	1393.22311	0.27	1.14	0.01	0.02	0.01	235.12
54	Huntington #2	1531.60292	0.30	1.34	0.01	0.02	0.01	258.48
55	Huntington #5	870.83510	0.49	1.20	0.00	0.06	0.05	146.96
56	Huntington Bch1**	1440.62283	0.28	1.18	0.01	0.02	0.01	243.12
57	Huntington Bch2**	1531.90441	0.30	0.81	0.01	0.02	0.01	253.53
58	Highgrove 1**	218.67630	0.04	0.37	0.00	0.00	0.00	37.89
59	Highgrove 2**	225.64450	0.05	0.41	0.00	0.00	0.00	39.09
60	Highgrove 3**	300.97577	0.06	0.46	0.00	0.00	0.00	52.14

Table C.7.1 ISE Calculation for Southern California Edison (cont'd.)

61	Highgrove 4**	307.81969	0.06	0.68	0.00	0.00	0.00	53.33
62	Alamitos #4	2250.81346	0.44	1.22	0.01	0.03	0.01	381.11
63	Alamitos #5	3166.61372	0.62	1.28	0.02	0.05	0.02	536.18
64	Alamitos #6	2699.63263	0.53	1.12	0.01	0.04	0.01	457.11
65	Alamitos #7	748.30564	0.42	1.04	0.00	0.05	0.05	126.71
66	Alamitos 3**	1681.34676	0.33	0.90	0.01	0.03	0.01	284.63
67	El Segundo #1	842.56345	0.17	1.38	0.00	0.01	0.00	146.21
68	El Segundo #2	688.41226	0.14	0.76	0.00	0.01	0.00	119.46
69	El Segundo #3	1114.89771	0.22	0.77	0.01	0.02	0.01	193.47
70	El Segundo #4	1297.04192	0.26	0.88	0.01	0.02	0.01	225.08
71	Mandalay #3	461.30073	0.25	1.25	0.35	0.08	0.08	102.13
72	Etiwanda #3	935.15333	0.19	0.38	0.00	0.01	0.00	162.14
73	Etiwanda #4	796.85899	0.16	0.44	0.00	0.01	0.00	138.16
74	Etiwanda #5	258.25524	0.15	0.37	0.00	0.02	0.02	44.78
75	Etiwanda 2**	246.41119	0.05	0.14	0.00	0.00	0.00	42.72
76	Etiwanda 1**	222.79901	0.04	0.09	0.00	0.00	0.00	38.63
77	Long Beach #8	392.71495	0.05	0.04	0.00	0.03	0.02	78.30
78	Long Beach #9	236.72519	0.03	0.03	0.00	0.02	0.01	47.20
79	Ellwood #1	48.41783	0.04	0.16	0.00	0.00	0.00	11.06
Storage Units								
N/A	Chino BatStor	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
N/A	Eastwood PS	0.00000	0.00	0.00	0.00	0.00	0.00	0.00
	Totals	795351.62963	68.90	67.64	3.36	38.25	22.53	99447.58

Table C.7.2 Southern California Edison In-Basin and Out-of-Basin Emissions

Scenario: Year 2010 - Combined Cycle - Summer Season - Low EV Penetration

Existing In Basin Units

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C	Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
Unconstrained - low	11,150	0	6	30	-1	-1	3,203	7,395,369	83	909	1,737	285	179
Policy Case 1 - low	66,491	0	12	42	2	1	10,411	10,300,478	173	1,363	2,695	319	210
Policy Case 2 - low	73,327	0	11	33	2	1	10,680	10,307,313	173	1,362	2,686	319	211
Policy Case 3 - low	77,420	0	7	10	4	2	9,761	10,311,406	173	1,358	2,663	321	212

Existing Out Basin Units

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C	Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
Unconstrained - low	34,676	0	6	23	1	0	5,758	14,608,522	9,179	1,499	14,656	711	182
Policy Case 1 - low	151,281	1	19	38	7	4	23,145	11,875,360	9,090	1,062	13,726	685	156
Policy Case 2 - low	155,221	1	18	32	8	5	23,581	11,879,300	9,090	1,062	13,719	686	157
Policy Case 3 - low	138,152	1	14	13	8	5	20,315	11,862,231	9,090	1,057	13,700	686	157

New Units Required to Meet Native Load

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C	Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
Unconstrained - low	-5,303	0	0	0	0	0	-658	9,629,464	36	797	652	471	290
Policy Case 1 - low	3,846	0	0	0	0	0	477	9,638,613	36	797	652	471	290
Policy Case 2 - low	20,176	0	2	1	1	1	2,503	9,654,943	36	799	653	472	290
Policy Case 3 - low	55,035	0	5	4	3	2	6,829	9,689,802	36	802	656	474	291

Unit Added to Maintain Reliability with EV Load

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C	Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
Unconstrained - low	292,436	1	24	20	14	9	36,285	292,436	1	24	20	14	9
Policy Case 1 - low	115,579	0	10	8	6	3	14,341	115,579	0	10	8	6	3
Policy Case 2 - low	86,773	0	7	6	4	3	10,767	86,773	0	7	6	4	3
Policy Case 3 - low	61,845	0	5	4	3	2	7,674	61,845	0	5	4	3	2

Table C.7.3 Southern California Edison In-Basin and Out-of-Basin Emissions

Scenario: Year 2010 - Combustion Turbine - Summer Season - Low EV Penetration

Existing In Basin Units

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C	Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
Unconstrained - low	112,515	1	22	73	2	1	17,985	10,306,151	173	1,365	2,686	319	211
Policy Case 1 - low	162,457	1	23	62	6	3	23,138	7,506,326	83	917	1,729	290	183
Policy Case 2 - low	164,646	1	21	49	6	4	22,638	7,508,514	83	915	1,717	291	183
Policy Case 3 - low	171,540	1	16	25	8	5	21,967	7,515,408	83	910	1,693	293	184

Existing Out Basin Units

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C	Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
Unconstrained - low	222,602	2	28	73	9	5	31,887	11,987,032	9,091	1,080	13,800	687	157
Policy Case 1 - low	169,773	1	24	57	8	5	28,585	14,783,969	9,180	1,525	14,730	719	187
Policy Case 2 - low	149,853	1	21	44	8	5	25,266	14,764,050	9,180	1,521	14,717	718	186
Policy Case 3 - low	105,318	1	13	17	6	4	17,836	14,719,514	9,180	1,513	14,690	717	186

New Units Required to Meet Native Load

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C	Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
Unconstrained - low	-5,303	0	0	0	0	0	-658	9,629,464	36	797	652	471	290
Policy Case 1 - low	3,846	0	0	0	0	0	477	9,638,613	36	797	652	471	290
Policy Case 2 - low	20,176	0	2	1	1	1	2,503	9,654,943	36	799	653	472	290
Policy Case 3 - low	55,035	0	5	4	3	2	6,829	9,689,802	36	802	656	474	291

Unit Added to Maintain Reliability with EV Load

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C	Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
Unconstrained - low	3,145	0	0	0	0	0	597	3,145	0	0	0	0	0
Policy Case 1 - low	1,122	0	0	0	0	0	213	1,122	0	0	0	0	0
Policy Case 2 - low	822	0	0	0	0	0	156	822	0	0	0	0	0
Policy Case 3 - low	560	0	0	0	0	0	106	560	0	0	0	0	0

Table C.7.4 Southern California Edison In and Out-of-Basin Emissions

Scenario: Year 2010 - Combined Cycle - Summer Season - High EV Penetration

Existing In Basin Units

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	-304,149	-1	-23	-13	-15	-9	-37,003	7,080,070	81	879	1,694	270	171
Policy Case 1 - high	35,369	0	12	50	0	-1	7,170	10,269,355	173	1,363	2,703	317	209
Policy Case 2 - high	108,748	0	18	61	3	1	16,570	10,342,735	173	1,370	2,714	320	211
Policy Case 3 - high	167,838	1	19	46	7	4	22,642	10,401,825	173	1,371	2,699	324	213

Existing Out Basin Units

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	763	0	1	6	0	0	114	14,574,609	9,179	1,493	14,639	710	181
Policy Case 1 - high	121,651	1	17	44	5	3	18,671	11,845,730	9,090	1,060	13,732	683	155
Policy Case 2 - high	248,626	1	31	58	13	8	39,182	11,972,705	9,090	1,074	13,746	691	160
Policy Case 3 - high	343,135	2	39	51	20	12	53,985	12,067,214	9,091	1,082	13,738	698	164

New Units Required to Meet Native Load

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	-6,245	0	-1	0	0	0	-775	9,628,522	36	797	652	471	290
Policy Case 1 - high	5,569	0	0	0	0	0	691	9,640,336	36	797	652	471	290
Policy Case 2 - high	31,781	0	3	2	2	1	3,943	9,666,549	36	800	654	473	291
Policy Case 3 - high	79,781	0	7	5	4	2	9,899	9,714,548	37	804	657	475	292

Unit Added to Maintain Reliability with EV Load

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	1,104,934	4	91	75	54	33	137,100	1,104,934	4	91	75	54	33
Policy Case 1 - high	640,492	2	53	43	31	19	79,472	640,492	2	53	43	31	19
Policy Case 2 - high	412,758	2	34	28	20	12	51,215	412,758	2	34	28	20	12
Policy Case 3 - high	208,787	1	17	14	10	6	25,906	208,787	1	17	14	10	6

Table C.7.5 Southern California Edison In-Basin and Out-of-Basin Emissions

Scenario: Year 2010 - Combustion Turbine - Summer Season - High EV Penetration

Existing In Basin Units

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	339,523	2	59	181	9	5	51,930	7,683,392	84	953	1,848	294	185
Policy Case 1 - high	332,108	1	53	158	10	5	49,295	7,675,976	84	947	1,825	295	185
Policy Case 2 - high	332,702	1	48	132	11	6	47,700	7,676,571	84	942	1,799	296	186
Policy Case 3 - high	339,891	1	39	86	14	8	45,682	7,683,760	84	933	1,754	298	188

Existing Out Basin Units

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	447,817	4	67	178	20	12	75,409	15,062,014	14,851	9,183	1,568	731	194
Policy Case 1 - high	458,453	4	65	155	22	13	77,239	15,072,650	14,828	9,183	1,566	733	195
Policy Case 2 - high	433,207	3	60	128	22	13	73,065	15,047,403	14,801	9,182	1,560	733	195
Policy Case 3 - high	377,920	2	48	80	22	13	63,912	14,992,117	14,753	9,181	1,549	732	195

New Units Required to Meet Native Load

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	-6,245	0	-1	0	0	0	-775	9,628,522	36	797	652	471	290
Policy Case 1 - high	5,569	0	0	0	0	0	691	9,640,336	36	797	652	471	290
Policy Case 2 - high	31,781	0	3	2	2	1	3,943	9,666,549	36	800	654	473	291
Policy Case 3 - high	79,781	0	7	5	4	2	9,899	9,714,548	37	804	657	475	292

Unit Added to Maintain Reliability with EV Load

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	14,208	0	2	1	1	1	2,696	14,208	0	2	1	1	1
Policy Case 1 - high	6,951	0	1	1	1	0	1,319	6,951	0	1	1	1	0
Policy Case 2 - high	4,223	0	1	0	0	0	801	4,223	0	1	0	0	0
Policy Case 3 - high	1,950	0	0	0	0	0	370	1,950	0	0	0	0	0

Table C.7.6 Los Angeles Dept. Of Water and Power In-Basin and Out-of-Basin Emissions

Scenario: Year 2010 - Combined Cycle - Summer Season - Low EV Penetration

Existing In Basin Units

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - low	-246,661	-1	-34	-64	-9	-5	-33,371	2,938,315	13	520	947	135	80
Policy Case 1 - low	36,264	0	20	43	2	1	6,083	4,428,597	13	533	1,021	122	71
Policy Case 2 - low	103,127	1	22	112	2	1	17,731	4,495,459	13	536	1,090	122	71
Policy Case 3 - low	131,479	1	18	135	2	1	22,098	4,523,811	13	531	1,113	122	71

Existing Out Basin Units

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - low	0	0	0	0	0	0	0	5,201,306	6,140	447	8,114	447	56
Policy Case 1 - low	-7,610	0	-1	-1	0	0	-944	3,986,339	6,142	487	8,147	470	70
Policy Case 2 - low	828	0	0	0	0	0	103	3,994,778	6,142	488	8,147	471	70
Policy Case 3 - low	8,422	0	1	1	0	0	1,045	4,002,372	6,142	488	8,148	471	71

New Units Required to Meet Native Load

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - low	0	0	0	0	0	0	0	0	0	0	0	0	0
Policy Case 1 - low	0	0	0	0	0	0	0	0	0	0	0	0	0
Policy Case 2 - low	0	0	0	0	0	0	0	0	0	0	0	0	0
Policy Case 3 - low	0	0	0	0	0	0	0	0	0	0	0	0	0

Unit Added to Maintain Reliability with EV Load

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - low	395,481	1	33	27	19	12	49,071	395,481	1	33	27	19	12
Policy Case 1 - low	129,565	0	11	9	6	4	16,076	129,565	0	11	9	6	4
Policy Case 2 - low	47,892	0	4	3	2	1	5,942	47,892	0	4	3	2	1
Policy Case 3 - low	5,763	0	0	0	0	0	715	5,763	0	0	0	0	0

Table C.7.7 Los Angeles Dept. Of Water and Power In and Out-of-Basin Emissions

Scenario: Year 2010 - Combustion Turbine - Summer Season - Low EV Penetration

Existing In Basin Units

	Incremental	ISE (tons)					
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C
Unconstrained - low	128,447	1	48	144	2	1	22,704
Policy Case 1 - low	146,605	1	43	164	2	1	25,624
Policy Case 2 - low	148,175	1	32	157	3	1	25,282
Policy Case 3 - low	145,299	1	20	141	3	1	24,054

Total	TSE with EV (tons)				
Energy (MWh)	SO2	CO	NOx	PM10	ROG
3,313,423	15	602	1,155	146	86
3,331,581	15	597	1,175	146	86
3,333,151	15	586	1,168	146	86
3,330,275	15	574	1,152	147	86

Existing Out Basin Units

	Incremental	ISE (tons)					
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C
Unconstrained - low	0	0	0	0	0	0	0
Policy Case 1 - low	0	0	0	0	0	0	0
Policy Case 2 - low	0	0	0	0	0	0	0
Policy Case 3 - low	0	0	0	0	0	0	0

Total	TSE with EV (tons)				
Energy (MWh)	SO2	CO	NOx	PM10	ROG
5,201,306	6,140	447	8,114	447	56
5,201,306	6,140	447	8,114	447	56
5,201,306	6,140	447	8,114	447	56
5,201,306	6,140	447	8,114	447	56

New Units Required to Meet Native Load

	Incremental	ISE (tons)					
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C
Unconstrained - low	0	0	0	0	0	0	0
Policy Case 1 - low	0	0	0	0	0	0	0
Policy Case 2 - low	0	0	0	0	0	0	0
Policy Case 3 - low	0	0	0	0	0	0	0

Total	TSE with EV (tons)				
Energy (MWh)	SO2	CO	NOx	PM10	ROG
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

Unit Added to Maintain Reliability with EV Load

	Incremental	ISE (tons)					
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C
Unconstrained - low	20,373	0	3	2	2	1	3,866
Policy Case 1 - low	6,353	0	1	1	0	0	1,206
Policy Case 2 - low	2,244	0	0	0	0	0	426
Policy Case 3 - low	256	0	0	0	0	0	49

Total	TSE with EV (tons)				
Energy (MWh)	SO2	CO	NOx	PM10	ROG
20,373	0	3	2	2	1
6,353	0	1	1	0	0
2,244	0	0	0	0	0
256	0	0	0	0	0

Table C.7.8 Los Angeles Dept. Of Water and Power In and Out-of-Basin Emissions

Scenario: Year 2010 - Combined Cycle - Summer Season - High EV Penetration

Existing In Basin Units

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C
Unconstrained - high	-570,406	-86	-159	-2	-23	-13	-77,064
Policy Case 1 - high	-70,780	9	26	0	-3	-2	-7,623
Policy Case 2 - high	156,495	41	175	1	3	1	27,245
Policy Case 3 - high	253,061	44	269	1	4	2	43,049

Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
2,614,569	468	853	12	121	72
4,321,553	522	1,004	12	117	68
4,548,828	555	1,153	13	122	71
4,645,393	558	1,247	14	124	72

Existing Out Basin Units

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C
Unconstrained - high	0	0	0	0	0	0	0
Policy Case 1 - high	-24,520	-2	-2	0	-1	-1	-3,042
Policy Case 2 - high	-3,714	0	0	0	0	0	-461
Policy Case 3 - high	8,549	1	1	0	0	0	1,061

Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
5,201,306	447	8,114	6,140	447	56
3,969,429	486	8,146	6,142	469	70
3,990,235	487	8,147	6,142	470	70
4,002,498	488	8,148	6,142	471	71

New Units Required to Meet Native Load

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C
Unconstrained - high	0	0	0	0	0	0	0
Policy Case 1 - high	0	0	0	0	0	0	0
Policy Case 2 - high	0	0	0	0	0	0	0
Policy Case 3 - high	0	0	0	0	0	0	0

Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0

Unit Added to Maintain Reliability with EV Load

	Incremental Energy (MWh)	ISE (tons) SO2	CO	NOx	PM10	ROG	C
Unconstrained - high	900,668	75	61	3	44	27	111,755
Policy Case 1 - high	431,855	36	29	2	21	13	53,585
Policy Case 2 - high	187,790	16	13	1	9	6	23,301
Policy Case 3 - high	70,148	6	5	0	3	2	8,704

Total Energy (MWh)	TSE with EV (tons) SO2	CO	NOx	PM10	ROG
900,668	75	61	3	44	27
431,855	36	29	2	21	13
187,790	16	13	1	9	6
70,148	6	5	0	3	2

Table C.7.9 Los Angeles Dept. Of Water and Power In and Out-of-Basin Emissions

Scenario: Year 2010 - Combustion Turbine - Summer Season - High EV Penetration

Existing In Basin Units

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	276,762	1	100	304	4	1	48,703	3,461,737	16	654	1,315	148	86
Policy Case 1 - high	310,847	2	98	343	5	2	54,356	3,495,823	16	652	1,354	149	87
Policy Case 2 - high	324,186	2	80	347	6	2	55,702	3,509,161	16	634	1,358	149	87
Policy Case 3 - high	327,020	2	60	336	6	2	55,193	3,511,995	16	614	1,347	150	88

Existing Out Basin Units

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	0	0	0	0	0	0	0	5,201,306	6,140	447	8,114	447	56
Policy Case 1 - high	0	0	0	0	0	0	0	5,201,306	6,140	447	8,114	447	56
Policy Case 2 - high	0	0	0	0	0	0	0	5,201,306	6,140	447	8,114	447	56
Policy Case 3 - high	0	0	0	0	0	0	0	5,201,306	6,140	447	8,114	447	56

New Units Required to Meet Native Load

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	0	0	0	0	0	0	0	0	0	0	0	0	0
Policy Case 1 - high	0	0	0	0	0	0	0	0	0	0	0	0	0
Policy Case 2 - high	0	0	0	0	0	0	0	0	0	0	0	0	0
Policy Case 3 - high	0	0	0	0	0	0	0	0	0	0	0	0	0

Unit Added to Maintain Reliability with EV Load

	Incremental	ISE (tons)						Total	TSE with EV (tons)				
	Energy (MWh)	SO2	CO	NOx	PM10	ROG	C	Energy (MWh)	SO2	CO	NOx	PM10	ROG
Unconstrained - high	53,500	0	7	6	4	2	10,152	53,500	0	7	6	4	2
Policy Case 1 - high	25,708	0	3	3	2	1	4,878	25,708	0	3	3	2	1
Policy Case 2 - high	9,863	0	1	1	1	0	1,872	9,863	0	1	1	1	0
Policy Case 3 - high	3,396	0	0	0	0	0	644	3,396	0	0	0	0	0

C.8 References for Appendix C

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APPENDIX D
Detailed Documentation of Individual Processes

This appendix provides documentation of the input and output values for all non-utility, non-vehicle processes included in the EVTECA, which are described in Chapters 6 through 8 in the main body of the text. Appendix D.1 documents processes related to the production of RFG. Appendix D.2 documents processes involved in the production of electricity (i.e., the coal, natural gas and nuclear fuel cycles). As Chapter 3 of the main text describes, some overlap exists between processes involved in RFG production and those involved in electricity production. (Most notably, petroleum extraction, transportation and refining are involved in both segments of the energy cycle.) Rather than repeating the same information in both Appendix D.1 and D.2, one appendix was chosen for each overlapping process. (Chapters 6 and 7 explain this further.) Appendix D.3 explains the derivation of the material inputs to vehicle manufacture. Then, Appendix D.4 provides input and output values for all of the battery and vehicle materials included in the EVTECA.

D.1 Processes Involved in RFG Production

Appendix D.1 provides detail on each individual EVTECA process involved in the production of RFG, including crude oil refining and the upstream crude oil production and transportation processes, as well as MTBE production and the upstream methanol/butane processes. Each table presents quantitative estimates of inputs and outputs and values for environmental residuals that were used in the EVTECA. When available, a data quality index is also provided; a rating of A is the best possible estimate and a rating of D is the worst (see Appendix A.2). Values are presented per million Btu and on an annual basis (when data were available).

This Appendix corresponds to Chapter 6 in the text.

The data tables are organized in the following manner:

The top section briefly describes the major characteristics of the process including its location, the time period for which it was characterized, and a brief description of the process. If the plant is an average or typical plant, the location field will most likely say, "National Average." Otherwise, a specific location applicable to the process description will be noted. Although the time frame may be characterized as a historical year such as 1980, the EVTECA assumes, unless otherwise noted in the table, that the process has not changed over time and will not change significantly in the future. This is an oversimplification necessary under the constraints of the study.

The main body of the table first shows inputs to the process. These are shown as either total annual values, or values normalized per unit of output. The basis is recorded in the right-hand column heading. The normalized values are used for calculations for normalizing the data in the TEMIS modeling framework.

Quantities of outputs of both products and environmental residuals are shown next, using the same general approach -- quantity of outputs (e.g., nitrogen oxide emissions to the air) are divided by the quantity of the main product (e.g. steel) output to calculate the normalized values in the right-hand column (e.g. nitrogen oxides [in tons] per ton of steel produced).

The environmental residuals in the tables are as follows:

- Nitrogen oxides (NO_x)
- Sulfur oxides (SO_x)
- Carbon monoxide (CO)
- Lead (Pb)
- Particulate Matter equal to or less than 10 microns in diameter (PM-10)
- Total Suspended Particulate (TSP)
- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Non-Methane Volatile Organic Compounds (NMVOCs)
- Other Greenhouse Gases (Other GHGs)
- Wastewater
- Nonhazardous Solid Residuals
- Hazardous Solid Residuals

Not all processes are fully characterized with information on all inputs and outputs. The data included in the assessment are limited to those readily available through literature searches. Data quality index process was not used in the materials analysis. Information on the intended data gathering protocol for the EVTECA can be found in Appendix A.2. Sometimes, this protocol could not be fully implemented due to resource constraints of the study.

Table D.1.1 Oil Field Production

Process Name:	Oil Field Production
Geographic Location:	National Average Process
Timeframe:	2010
Process Description:	Production and processing in the oil field. Emissions allocated in proportion to the energy content of crude oil produced.

		Total Annual		per MMbtu of product		
		Value	Units	Value	Units	DQI
Inputs						
1	Electricity	1.97E+10	KWhr	1.028	KWhr	B
2	Water	3.01E+07	bbl	0.0016	bbl	B
Outputs						
3	Crude oil	3.30E+09	bbl	0.172	bbl	A
4	Natural gas	DNA	MMscf	DNA	MMscf	B
Airborne Residuals						
5	SO_2	3.01E+04	ton	1.57E-06	ton	B
6	NO_x	2.43E+05	ton	1.27E-05	ton	B
7	TSP	4.61E+03	ton	2.41E-07	ton	B
8	PM10		ton		ton	
9	CO	4.30E+04	ton	2.25E-06	ton	B
10	CO_2	2.85E+07	ton	1.49E-03	ton	B
11	NMVOCs	4.60E+04	ton	2.41E-06	ton	B
12	VOCs - total	7.62E+04	ton	3.98E-06	ton	B
13	isomers of hexane	7.38E+03	ton	3.85E-07	ton	C
14	isomers of heptane	9.53E+03	ton	4.98E-07	ton	C
15	isomers of octane	6.45E+03	ton	3.37E-07	ton	C
16	C-7 Cycloparaffins	1.32E+03	ton	6.90E-08	ton	C
17	C-8 Cycloparaffins	4.92E+02	ton	2.57E-08	ton	C
18	isomers of pentane	4.61E+03	ton	2.41E-07	ton	C
19	methane	1.47E+06	ton	7.67E-05	ton	C
21	propane	8.30E+03	ton	4.34E-07	ton	C
22	n-butane	6.15E+03	ton	3.21E-07	ton	C
23	benzene	8.30E+01	ton	4.34E-09	ton	C
24	iso-butane	3.38E+02	ton	1.77E-08	ton	C
25	formaldehyde	1.20E+03	ton	6.26E-08	ton	C
26	acetone	2.00E+02	ton	1.04E-08	ton	C
27	Pb		ton		ton	
Waterborne Residuals						
28	Wastewater	3.50E+09	bbl	1.83E-01	bbl	B
29	Oil & grease	3.69E+04	ton	1.93E-06	ton	B
30	Arsenic	1.23E+01	ton	6.42E-10	ton	C
31	Benzene	2.86E+02	ton	1.49E-08	ton	C
32	Boron	6.15E+03	ton	3.21E-07	ton	C
33	Sodium	5.84E+06	ton	3.05E-04	ton	C
34	Chloride	4.61E+06	ton	2.41E-04	ton	C
35	Mobile ions	1.41E+07	ton	7.39E-04	ton	C
Solid Residuals						
36	Nonhazardous	2.98E+03	ton	1.56E-07	ton	C
37	tank bottoms	2.12E+03	ton	1.11E-07	ton	C
38	tank sediment	8.61E+02	ton	4.50E-08	ton	C
39	Hazardous	6.17E+05	ton	3.23E-05	ton	C
40	FGD sludge	6.15E+05	ton	3.21E-05	ton	C
41	Steam generator ash	2.77E+03	ton	1.45E-07	ton	C

Note: Most data came from, "A Comparative Analysis of the Environmental Outputs of FutureBiomans-Ethanol Production Cycles and Crude Oil/Reformulated Gasoline Production Cycles," draft report prepared by S. Tyson et al National Energy Laboratory (NREL), Golden, Colorado. December 1991.
Note: Data quality assessment taken from self-assessment in the original NREL report; however, factors were downgraded due to questions of the applicability of 1980s and 1990s data to 2000 and 2010 oil well operation.

Table D.1.2 Oil Truck

Process Name	Oil Truck				
Geographic Location	National Average				
Timeframe	2000				
Process Description					
	per mmBtu (fuel in)		***per Ton-Mile***		
	Value	Units	Value	Units	DQI
Inputs					
1 diesel			1704	Btu	B
Outputs					
[illegible]					
8 CH_4	4.3	gm	0.0073272	gm	B
10 NMHC (total)	88.9	gm	0.1514856	gm	B
11 CO	466.4	gm	0.7947456	gm	B
12 NO_x	348.3	gm	0.5935032	gm	B
13 SO_x	184.1	gm	0.3137064	gm	B
14 PM	10.8	gm	0.0184032	gm	B
16 N_2O	2.6	gm	0.0044304	gm	B
17 CO_2	71616	gm	122.03366	gm	B

Note: Inputs: (DeLuchi 1991) based on literature review.
Air releases: (DeLuchi 1991) based on AP-42 (self-reported quality assessment) with adjustments for 1990 CAAA or DeLuchi's calculation based on mass balance and fuel composition.

Table D.1.3 Oil Train

Process Name	Oil Train				
Geographic Location	National Average				
Timeframe	2000				
Process Description					
	per mmBtu (fuel in)		*per Ton-Mile*		
	Value	Units	Value	Units	DQI
Inputs					
1 diesel			516	Btu	B
Outputs					
Airborne Residuals					
8 CH_4	15.4	gm	0.0079464	gm	B
10 NMHC (total)	147.5	gm	0.07611	gm	B
11 CO	212.8	gm	0.1098048	gm	B
12 NO_x	605.6	gm	0.3124896	gm	B
13 SO_x	184.1	gm	0.0949956	gm	B
14 PM	81.8	gm	0.0422088	gm	B
15 N_2O	2	gm	0.001032	gm	B
16 CO_2	71566	gm	36.928056	gm	B

Note: Inputs: (DeLuchi 1991) based on literature review.
Air releases: (DeLuchi 1991) based on AP-42 (self-reported quality assessment) with adjustments for 1990 CAAA or DeLuchi's calculation based on mass balance and fuel composition.

Table D.1.4 Oil Barge (domestic)

Process Name	Oil Barge (domestic)
Geographic Location	National Average
Timeframe	2000
Process Description	

	per mmBtu (fuel in)		*per Ton-Mile*		
	Value	Units	Value	Units	DQI
Inputs					
1 residual fuel			184	Btu	B
Outputs					
Airborne Residuals					
8 CH_4	15.2	gm	0.0027968	gm	C
10 NMHC (total)	136.4	gm	0.0250976	gm	C
11 CO	303	gm	0.055752	gm	C
12 NO_x	818.2	gm	0.1505488	gm	C
13 SO_x	472.3	gm	0.0869032	gm	C
14 PM	60.6	gm	0.0111504	gm	C
15 N_2O	2	gm	0.000368	gm	C
16 CO_2	71678	gm	13.188752	gm	B

Note: Inputs: (DeLuchi 1991) based on literature review.
Air releases: (DeLuchi 1991) based on AP-42 (self-reported quality assessment) with adjustments for 1990 CAAA or DeLuchi's calculation based on mass balance and fuel composition; emissions data for international tanker used here for domestic barge.

Table D.1.5 Oil Tanker (international)

Process Name	Oil Tanker (international)				
Geographic Location	National Average				
Timeframe	2000				
Process Description					
	per mmBtu (fuel in)		***per Ton-Mile***		
	Value	Units	Value	Units	DQI
Inputs					
1 residual fuel			114	Btu	B
Outputs					
Airborne Residuals					
8 CH_4	15.2	gm	0.0017328	gm	C
10 NMHC (total)	136.4	gm	0.0155496	gm	C
11 CO	303	gm	0.034542	gm	C
12 NO_x	818.2	gm	0.0932748	gm	C
13 SO_x	472.3	gm	0.0538422	gm	C
14 PM	60.6	gm	0.0069084	gm	C
15 N_2O	2	gm	0.000228	gm	C
16 CO_2	71678	gm	8.171292	gm	B

Note: Inputs: (DeLuchi 1991) based on literature review.
Airborne residuals: (DeLuchi 1991) based on AP-42 (self-reported quality assessment) with adjustments for 1990 CAAA or DeLuchi's calculation based on mass balance and fuel composition.

Table D.1.6 Crude Oil Pipeline

Process Name	Crude Oil Pipeline
Geographic Location	National Average
Timeframe	2000
Process Description	

	per mmBtu (fuel in)		*per Ton-Mile*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity			75	Btu	B
Outputs					
Airborne Residuals					
8 CH_4	2.67	gm	0.0002003	gm	C
10 N_2O	7.74	gm	0.0005803	gm	C
11 NMHC	3.28	gm	0.0002463	gm	C
12 CO	36.8	gm	0.0027572	gm	B
13 NO_x	448	gm	0.0335678	gm	B
14 SO_x	703	gm	0.0527561	gm	B
15 PM	37.3	gm	0.0028007	gm	C
16 CO_2	192304	gm	14.422773	gm	B

Note: Inputs: (DeLuchi 1991) based on thorough literature review.
Airborne residuals: (DeLuchi 1991) based on AP-42 (self-reported quality assessment) with adjustments for 1990 CAAA and assumption about future generating mix.

Table D.1.7 Refinery

Process Name:	Refinery
Geographic Location:	National Average Process
Timeframe:	2010
Process Description:	Baseline refinery operations.

		Total Annual		*per mmBtu of GBS*	
		Value	Units	Value	Units
Inputs					
1	Crude oil	3.33E+09	bbl	1.72E-01	bbl
2					
3	Natural gas	8.88E+05	MMscf	4.57E-05	MMscf
4	Electricity	2.36E+10	KWhr	1.21E+00	KWhr
Outputs					
5	C_2-C_4s	0	bbl	0	bbl
6	Gasoline Blendstocks	4.01E+09	bbl	2.06E-01	bbl
7	Jet/Kero (1)	0	bbl	0	bbl
8	Distillate (2/4)	0	bbl	0	bbl
9	Total Residual (6/7)	0	bbl	0	bbl
10	Petrochem Naphtha	0	bbl	0	bbl
11	Other Petrofeed	0	bbl	0	bbl
12	Lubes/Waxes	0	bbl	0	bbl
13	Asphalt/Road Oil	0	bbl	0	bbl
14	Other products	0	bbl	0	bbl
Airborne Residuals					
9	SO_2	2.49E+05	ton	1.28E-05	ton
10	NO_x	4.10E+05	ton	2.11E-05	ton
11	TSP	1.29E+04	ton	6.64E-07	ton
12	PM_{10}	0	ton	0	ton
13	CO	4.71E+04	ton	2.43E-06	ton
14	CO_2	1.69E+08	ton	8.71E-03	ton
15	CH_4	0	ton	0	ton
16	NMVOCs	0	ton	0	ton
17	Pb	0	ton	0	ton
18	NMHC	2.43E+04	ton	1.25E-06	ton
Waterborne Residuals					
19	Wastewater	9.02E+04	MMgal	4.64E-06	MMgal
20	BOD	1.24E+03	ton	6.38E-08	ton
21	COD	1.00E+04	ton	5.16E-07	ton
22	TOC	8.70E+03	ton	4.48E-07	ton
23	TSS	5.54E+03	ton	2.85E-07	ton
24	NO_3 N	1.71E+02	ton	8.82E-09	ton
25	Phenols	2.29E+01	ton	1.18E-09	ton
26	Oil and grease	4.48E+02	ton	2.31E-08	ton
27	Total chromium	1.45E+01	ton	7.47E-10	ton
Solid Residuals					
28	Nonhazardous	2.34E+06	ton	1.20E-04	ton
29	Hazardous or potentially hazardous	1.30E+06	ton	6.71E-05	ton

Note: Inputs and outputs were scaled to represent values per MMBtu of gasoline blend-stocks produced. See text in Chapter 6.

Table D.1.8 Butane Production

Process Name:		Butane Production			
Geographic Location:		National Average Process			
Timeframe:		2010			
Process Description:					
		Total Annual		*per MBtu of Methanol*	
		Value	Units	Value	Units
Inputs					
1	natural gas			1.03E+00	MBtu
2	electricity			0.00067	MBtu
Outputs					
3	butane			1.00E+00	MBtu
	Airborne Residuals				
4	SO2			NC	lb
5	NOx			0.003964758	lb
6	TSP			NC	lb
7	PM10			NC	lb
8	CO			0.001145374	lb
9	CO2			3.953744493	lb
10	CH4			8.81057E-05	lb
11	NMVOCs			NC	lb
12	Pb			NC	lb
13	NMHC			8.81057E-05	lb
14	N20			0.000154185	lb

Note: Data derived from M. DeLuchi, Greenhouse Gas Model (June 1996 version).

Table D.1.9 Methanol Production

Process Name:	Methanol Production				
Geographic Location:	National Average Process				
Timeframe:	2010				
Process Description:					

	Total Annual		*per MBtu of Methanol*	
	Value	Units	Value	Units
Inputs				
1 natural gas			1.50E+00	MBtu
2 electricity			0.003	MBtu
Outputs				
3 Methanol			1.00E+00	MBtu
Airborne Residuals				
4 SO_2			NC	lb
5 NO_x			0.226872247	lb
6 TSP			NC	lb
7 PM_{10}			NC	lb
8 CO			0.005066079	lb
9 CO_2			36.5154185	lb
10 CH_4			0.020264317	lb
11 NMVOCs			NC	lb
12 Pb			NC	lb
13 NMHC			0.000682819	lb
14 N_20			0.001651982	

Note: Data derived from M. DeLuchi, Greenhouse Gas Model (June 1996 version).

Table D.1.10 MTBE Production

Process Name:	MTBE Production				
Geographic Location:	National Average Process				
Timeframe:	2010				
Process Description:					
		Total Annual		***per MBtu of Methanol***	
		Value	Units	Value	Units
Inputs					
1	butane			0.761178	MBtu
2	methanol			0.605166	MBtu
3	natural gas			0.00836	MBtu
4	steam			0.0557	MBtu
5	electricity			0.00417	MBtu
Outputs					
6	MTBE			1.00E+00	MBtu
Airborne Residuals					
7	SO_2			NC	lb
8	NO_x			NC	lb
9	TSP			NC	lb
10	PM_{10}			NC	lb
11	CO			NC	lb
12	CO_2			NC	lb
13	CH_4			NC	lb
14	NMVOCs			NC	lb
15	Pb			NC	lb
16	NMHC			NC	lb
17	N_20			NC	lb

Note: Emissions from natural gas and electricity used in the MTBE process are included as upstream-process emissions. The authors are aware of an error in the value for the methanol input. This will be updated in a future version.

NC: Not Calculated

D.2 Processes Involved in Production of Electricity

Appendix D.2 provides detail on each individual EVTECA process upstream of coal-fired, gas-fired, and nuclear power plants. Each table presents quantitative estimates of inputs and outputs and values for environmental residuals that were used in the EVTECA. When available, a data quality index is also provided; a rating of A is the best possible estimate and a rating of D is the worst (See Appendix A.2). Values are presented per million Btu and on an annual basis (when data were available).

This Appendix corresponds to Chapter 7 in the text.

The data tables are organized in the following manner:

The top section briefly describes the major characteristics of the process including its location, the time period for which it was characterized, and a brief description of the process. If the plant is an average or typical plant, the location field will most likely say, "National Average." Otherwise, a specific location applicable to the process description will be noted. Although the time frame may be characterized as a historical year such as 1980, the EVTECA assumes, unless otherwise noted in the table, that the process has not changed over time and will not change significantly in the future. This is an oversimplification necessary under the constraints of the study.

The main body of the table first shows inputs to the process. These are shown as either total annual values, or values normalized per unit of output. The basis is recorded in the right-hand column heading. The normalized values are used for calculations for normalizing the data in the TEMIS modeling framework.

Quantities of outputs of both products and environmental residuals are shown next, using the same general approach -- quantity of outputs (e.g., nitrogen oxide emissions to the air) are divided by the quantity of the main product (e.g. steel) output to calculate the normalized values in the right-hand column (e.g. nitrogen oxides [in tons] per ton of steel produced).

The environmental residuals in the tables are as follows:

- Nitrogen oxides (NO_x)
- Sulfur oxides (SO_x)
- Carbon monoxide (CO)
- Lead (Pb)
- Particulate Matter equal to or less than 10 microns in diameter (PM-10)
- Total Suspended Particulate (TSP)
- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Non-Methane Volatile Organic Compounds (NMVOCs)
- Other Greenhouse Gases (Other GHGs)
- Wastewater
- Nonhazardous Solid Residuals
- Hazardous Solid Residuals

Not all processes are fully characterized with information on all inputs and outputs. The data included in the assessment are limited to those readily available through literature searches. Data quality index process was not used in the materials analysis. Information on the intended data gathering protocol for the EVTECA can be found in Appendix A.2. Sometimes, this protocol could not be fully implemented due to resource constraints of the study.

Table D.2.1 Surface Coal Mining-East

Process Name	Surface Coal Mining
Geographic Location	Regional Average - East
Timeframe	1980
Process Description	Eastern surface mine with 36 inch seam thickness. Contour mining, auger, and on-site coal preparation. 470,000 tons (raw coal)/yr or 340,750 tons (clean coal)/yr

	Total Annual		*per Ton(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	2,980,000	kWh	8.745414527	kWh	C
2 diesel	1.42E+06	gal	4.167278063	gal	C
Outputs					
Products					
3 coal (clean)	340750	ton	1	ton	
Airborne Residuals					
4 NO_x	6.10E+05	lb	1.790168745	lb	C
5 SO_x	4.44E+04	lb	0.130300807	lb	C
6 CO	1.27E+05	lb	0.373587674	lb	C
7 HC	3.96E+04	lb	0.116214233	lb	C
8 TSP	3.15E+04	lb	0.09244314	lb	C
9 PM_{10}			NA		
10 CO_2			100.5122465	lb	
11 CH_4*			1.71	lb	
12 other GHGs			NA		
13 aldehydes	9.90E+03	lb	0.029053558	lb	C
14 fugitive dust			1.87E-03	ton	D
Water Emissions					
15 total effluent - acidic drainage			3340	liter	D
Solid Waste					
16 total	1.30E+05	tons	0.381511372	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Fugitive dust: From (DOE 1988)
Water emissions: From (DOE 1988)
CH_4 emissions estimates from (DOE 1995)

Table D.2.2 Surface Coal Mining-West

Process Name	Surface Coal Mining
Geographic Location	Regional Average - West
Timeframe	1980
Process Description	Western surface mine with 23.1 foot seam thickness. Strip mine with on-site coal preparation. Reclamation of stripped land by backfilling. production: 9.7e6 tons (raw coal)/yr or8.73e6 tons (clean coal)/yr

	Total Annual		*per Ton(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	900,000	kWh	0.103092784	kWh	C
2 diesel	3.80E+06	gal	0.435280641	gal	C
Outputs					
Products					
3 coal	8.73E+06	ton	1	ton	
Airborne Residuals					
4 NO_x	734	ton	0.168155785	lb	C
5 SO_x	48		0.010996564	lb	C
6 CO	147		0.033676976	lb	C
7 HC	47		0.010767468	lb	C
8 TSP	39		0.008934708	lb	C
9 PM_{10}			NA		
10 CO_2			10.4987079	lb	
11 CH_4			1.71	lb	
12 other GHGs			NA		
13 aldehydes	12		0.002749141	lb	C
14 fugitive dust	107		0.024513173	lb	C
Water Emissions					
15 total effluent - alkaline drainage			40	liter	D
Solid Waste					
16 total	9.70E+05	ton	0.111111111	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Water emissions: From (DOE 1988)
CH_4 emissions estimate from (DOE 1995)

Table D.2.3 Underground Coal Mine-East

Process Name	Underground Coal Mine
Geographic Location	Regional Average - East
Timeframe	1980
Process Description	Eastern underground mine. On-site coal preparation. On-site solid waste idsposal and water treatment. production: 1.5e6 tons (raw coal)/yr or 1.125e6 tons (clean coal)/yr

	Total Annual		*per Ton(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	58900000	kWh	52.35555556	kWh	C
2 diesel	5.73E+04	gal	0.050933333	gal	C
3 water	1.51E+08	gal	134.2222222	gal	C
Outputs					
Products					
4 coal	1.13E+06	ton	1	ton	
Airborne Residuals					
5 NO_x	9.4	ton	0.016711111	lb	
6 SO_x	0.89		0.001582222	lb	C
7 CO	2.5		0.004444444	lb	C
8 HC	0.72		0.00128	lb	C
9 TSP	0.72		0.00128	lb	C
10 PM_{10}			NA		
11 CO_2			1.22848144	lb	
12 CH_4			19.21	lb	
13 other GHGs			NA		
14 toxics			NA		
15 fugitive dust			NA		
Water Emissions					
16 total effluent - acidic drainage			2540	liter	D
Solid Waste					
17 total	4.45E+05	ton	0.395555556	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Water emissions: From (DOE 1988)
CH_4 emissions estimate from (DOE 1995)

Table D.2.4 Surface Coal Mining-Bituminous (West)

Process Name	Surface Coal Mining
Geographic Location	Regional Average - West
Timeframe	1980
Process Description	Surface mining of Bituminous Coal. Derived from baselind "Surface coal mine" characterized files using a heating value of 12,250 Mbtu/lb strip mine with on-site coal preparation. Reclamation of stripped land by backfilling production: 9.7E6 tons (raw coal)/yr or8.73E6 tons (clean coal)/yr.

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity			0.004207869	kWh	C
2 diesel			0.017766557	gal	C
Outputs					
Products					
3 coal			0.040816327	ton	
Airborne Residuals					
4 NO_x			0.006863501	lb	C
5 SO_x			0.000448839	lb	C
6 CO			0.00137457	lb	C
7 HC			0.000439489	lb	C
8 TSP			0.000364682	lb	C
9 PM_{10}			NA		
10 CO_2			0.42851869		
11 CH_4			0.06963815		
12 other GHGs			NA		
13 aldehydes			0.00011221	lb	C
14 fugitive dust			0.001000538	lb	C
Water Emissions					
15 total effluent - alkaline drainage			1.632653061	liter	D
Solid Waste					
16 total			0.004535147	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Water emissions: From (DOE 1988)

Table D.2.5 Surface Coal Mining-Bituminous (East)

Process Name	Surface Coal Mining
Geographic Location	Regional Average - East
Timeframe	1980
Process Description	Surface mining of Bituminous Coal. Derived from baselind "Surface coal mine" characterized files using a heating value of 12,250 Mbtu/lb contour mining, auger, and on-site coal preparation. 470,000 tons (raw coal)/yr or 340,750 tons (clean coal)/yr

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity			0.356955695	kWh	C
2 diesel			0.170092982	gal	C
Outputs					
Products					
3 coal (clean)			0.040816327	ton	
Airborne Residuals					
4 NO_x			0.073068112	lb	C
5 SO_x			0.0053184	lb	C
6 CO			0.015248476	lb	C
7 HC			0.004743438	lb	C
8 TSP			0.003773189	lb	C
9 PM_{10}			NA		
10 CO_2			4.102540674		
11 CH_4			0.06963815		
12 other GHGs			NA		
13 aldehydes			0.00118586	lb	C
14 fugitive dust			7.63265E-05	ton	D
Water Emissions					
15 total effluent - acidic drainage			136.3265306	liter	D
Solid Waste					
16 total			0.015571893	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Fugitive dust: From (DOE 1988)
Water emissions: From (DOE 1988)

Table D.2.6 Underground Coal Mine-Bituminous (East)

Process Name	Underground Coal Mine
Geographic Location	Regional Average - East
Timeframe	1980
Process Description	Uuderground mining of Bituminous Coal. Derived from baseline "Underground coal mine," converted files using a heating value of 12,250 MBtu/lb on-site solid waste disposal and water treatment. production: 1.5E6 tons (raw coal)/yr or 1.125E6 tons (clean coal)/yr.

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	58900000	kWh	2.136961451	kWh	C
2 diesel	5.73E+04	gal	0.002078912	gal	C
3 water	1.51E+08	gal	5.47845805	gal	C
Outputs					
Products					
4 coal	1.13E+06	ton	0.040816327	ton	
Airborne Residuals					
5 NO_x	9.4	ton	0.000682086	lb	
6 SO_x	0.89		6.45805E-05	lb	C
7 CO	2.5		0.000181406	lb	C
8 HC	0.72		5.22449E-05	lb	C
9 TSP	0.72		5.22449E-05	lb	C
10 PM_{10}			NA		
11 CO_2			0.0501421		
12 CH_4			0.7842577		
13 other GHGs			NA		
14 toxics			NA		
15 fugitive dust			NA		
Water Emissions					
16 total effluent - acidic drainage			103.6734694	liter	D
Solid Waste					
17 total	4.45E+05	ton	0.016145125	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Water emissions: From (DOE 1988)

Table D.2.7 Surface Coal Mining-Subbituminous (West)

Process Name	Surface Coal Mining
Geographic Location	Regional Average - West
Timeframe	1980
Process Description	Surface mining of Subituminous Coal. Derived from baseline "Surface coal mine," converted files using a heating value of 12,250 MBtu/lb strip mine with on-site coal preparation. Reclamation of stripped land by backfilling. production: 9.7E6 tons (raw coal)/yr or 8.73E6 tons (clean coal)/yr.

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity			0.005053568	kWh	C
2 diesel			0.021337286	gal	C
3 raw coal			0.067613252	ton	
Outputs					
Products					
3 coal			0.049019608	ton	
Airborne Residuals					
4 NO_x			0.008242931	lb	C
5 SO_x			0.000539047	lb	C
6 CO			0.001650832	lb	C
7 HC			0.000527817	lb	C
8 TSP			0.000437976	lb	C
9 PM_{10}			NA		
10 CO_2			0.514642544		
11 CH_4			0.083634053		
12 other GHGs			NA		
13 aldehydes			0.000134762	lb	C
14 fugitive dust			0.001201626	lb	C
Water Emissions					
15 total effluent - alkaline drainage			1.960784314	liter	D
Solid Waste					
16 total			0.005446623	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Water emissions: From (DOE 1988)

Table D.2.8 Surface Coal Mining-Subbituminous (East)

Process Name	Surface Coal Mining
Geographic Location	Regional Average - East
Timeframe	1980
Process Description	Surface mining of Subituminous Coal. Derived from baseline "Surface coal mine," converted using a heating value of 10,200 MBtu/lb contour mining, auger, and on-site coal preparation. production: 470,000 tons (raw coal)/yr or 340,750 tons (clean coal)/yr.

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity			0.428696791	kWh	C
2 diesel			0.204278336	gal	C
3 raw coal			0.067613252	ton	
Outputs					
Products					
4 coal (clean)			0.049019608	ton	
Airborne Residuals					
5 NO_x			0.08775337	lb	C
6 SO_x			0.006387294	lb	C
7 CO			0.018313121	lb	C
8 HC			0.005696776	lb	C
9 TSP			0.004531526	lb	C
10 PM_{10}			NA		
11 CO_2			4.927070908		
12 CH_4			0.083634053		
13 other GHGs			NA		
14 aldehydes			0.001424194	lb	C
15 fugitive dust			9.16667E-05	ton	D
Water Emissions					
16 total effluent - acidic drainage			163.7254902	liter	D
Solid Waste					
17 total			0.018701538	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Fugitive dust: From (DOE 1988)
Water emissions From (DOE 1988)

Table D.2.9 Underground Coal Mine-Subbituminous (East)

Process Name	Underground Coal Mine
Geographic Location	Regional Average - East
Timeframe	1980
Process Description	Underground mining of Subituminous Coal. Derived from baseline "Underground coal mine," converted files using a heating value of 10,200 MBtu/lb on-site solid waste disposal and water treatment. production: 1.5E6 tons (raw coal)/yr or 1.125E6 tons (clean coal)/yr

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	58900000	kWh	2.566448802	kWh	C
2 diesel	5.73E+04	gal	0.002496732	gal	C
3 water	1.51E+08	gal	6.579520697	gal	C
4 raw coal			0.065359477	ton	
Outputs			0.586167		
Products					
5 coal	1.13E+06	ton	0.049019608	ton	
Airborne Residuals					
6 NO_x	9.4	ton	0.000819172	lb	
7 SO_x	0.89		7.75599E-05	lb	C
8 CO	2.5		0.000217865	lb	C
9 HC	0.72		6.27451E-05	lb	C
10 TSP	0.72		6.27451E-05	lb	C
11 PM_{10}			NA		
12 CO_2			0.060219678		
13 CH_4			0.94187812		
14 other GHGs			NA		
15 toxics			NA		
16 fugitive dust			NA		
Water Emissions					
17 total effluent - acidic drainage			124.5098039	liter	D
Solid Waste					
18 total	4.45E+05	ton	0.019389978	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Water emissions From (DOE 1988)

Table D.2.10 Surface Coal Mining-Lignite (West)

Process Name	Surface Coal Mining
Geographic Location	Regional Average - West
Timeframe	1980
Process Description	Surface mining of Lignite Coal. Derived from baseline "Surface coal mine," converted using a heating value of 7,300 MBtu/lb strip mine with on-site coal preparation. Reclamation of stripped land by backfilling. Production: 9.7E6 tons (raw coal)/yr or 8.73E6 tons (clean coal)/yr.

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity			0.00706115	kWh	C
2 diesel			0.029813743	gal	C
3 raw coal			0.094473311	ton	
Outputs					
Products					
4 coal			0.068493151	ton	
Airborne Residuals					
5 NO_x			0.011517519	lb	C
6 SO_x			0.000753189	lb	C
7 CO			0.002306642	lb	C
8 HC			0.000737498	lb	C
9 TSP			0.000611966	lb	C
10 PM_{10}			NA		
11 CO_2			0.719089582		
12 CH_4			0.116858539		
13 other GHGs			NA		
14 aldehydes			0.000188297	lb	C
15 fugitive dust			0.001678984	lb	C
Water Emissions					
16 total effluent - alkaline drainage			2.739726027	liter	D
Solid Waste					
17 total			0.00761035	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Water emissions From (DOE 1988)

Table D.2.11 Surface Coal Mining-Lignite (East)

Process Name	Surface Coal Mining
Geographic Location	Regional Average - East
Timeframe	1980
Process Description	Surface mining of Lignite Coal. Derived from baseline "Surface coal mine," converted files using a heating value of 7,300 MBtu/lb contour mining, auger, and on-site coal preparation. Production: 470,000 tons (raw coal)/yr or 340,750 tons (clean coal)/yr.

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity			0.599000995	kWh	C
2 diesel			0.285430004	gal	C
3 raw coal			0.094473311	ton	
Outputs					
Products					
4 coal (clean)			0.068493151	ton	
Airborne Residuals					
5 NO_x			0.122614298	lb	C
6 SO_x			0.008924713	lb	C
7 CO			0.025588197	lb	C
8 HC			0.007959879	lb	C
9 TSP			0.006331722	lb	C
10 PM_{10}			NA		
11 CO_2			6.884400446	lb	
12 CH_4			0.116858539	lb	
13 other GHGs			NA		
14 aldehydes			0.00198997	lb	C
15 fugitive dust			0.000128082	ton	D
Water Emissions					
16 total effluent - acidic drainage			228.7671233	liter	D
Solid Waste					
17 total			0.026130916	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Fugitive dust: From (DOE 1988)
Water emissions From (DOE 1988)

Table D.2.12 Underground Coal Mine-Lignite (East)

Process Name	Underground Coal Mine
Geographic Location	Regional Average - East
Timeframe	1980
Process Description	Underground mining of Lignite Coal. Derived from baseline "Underground coal mine," converted from a heating value of 7,300 MBtu/lb on-site solid waste disposal and water treatment. Production: 1.5E6 tons (raw coal)/yr or 1.125E6 tons (clean coal)/yr,

	Total Annual		*per Mbtu(clean coal)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	58900000	kWh	3.585996956	kWh	C
2 diesel	5.73E+04	gal	0.003488584	gal	C
3 water	1.51E+08	gal	9.193302892	gal	C
4 raw coal			0.091324201	ton	
Outputs					
Products					
5 coal	1.13E+06	ton	0.068493151	ton	
Airborne Residuals					
6 NO_x	9.4	ton	0.001144597	lb	
7 SO_x	0.89		0.000108371	lb	C
8 CO	2.5		0.000304414	lb	C
9 HC	0.72		8.76712E-05	lb	C
10 TSP	0.72		8.76712E-05	lb	C
11 PM_{10}			NA		
12 CO_2			0.084142564		
13 CH_4			1.32		
14 other GHGs			NA		
15 toxics			NA		
16 fugitive dust			NA		
Water Emissions					
17 total effluent - acidic drainage			173.9726027	liter	D
Solid Waste					
18 total	4.45E+05	ton	0.027092846	ton	C

Note: Inputs/Outputs: Primarily from (DOE 1983)
Fugitive dust: From (DOE 1988)
Water emissions From (DOE 1988)

Table D.2.13 Coal Truck

Process Name	Coal Truck
Geographic Location	National Average
Timeframe	2000
Process Description	truck from minemouth to power plant avg. haul: 24 tons/truck (ORNL)

	Total per mmBtu (fuel in)		*per Ton-Mile*		
	Value	Units	Value	Units	DQI
Inputs					
1 diesel			2072	Btu	B
Outputs					
Airborne Residuals					
2 CH_4	4.3	gm	0.0089096	gm	B
3 NMHC (total)	88.9	gm	0.1842008	gm	B
4 CO	466.4	gm	0.9663808	gm	B
5 NO_x	348.3	gm	0.7216776	gm	B
6 SO_x	184.1	gm	0.3814552	gm	B
7 PM	10.8	gm	0.0223776	gm	B
8 N_2O	2.6	gm	0.0053872	gm	B
9 CO_2	71616	gm	148.38835	gm	B

Note: Inputs: DeLuchi, 1991: based on literature review.
Airborne residuals: DeLuchi, 1991: based on AP-42 (self-reported quality assessment) with adjustments for 1990 CAAA or DeLuchi's calculation based on mass balance and fuel composition.

Table D.2.14 Coal Train

Process Name	Coal Train
Geographic Location	National Average
Timeframe	2000
Process Description	Train from minemouth to power plant avg. haul: 100 tons/car, 100 cars/train; 5 diesel engines (Gotchy 1987)

	Total per mmBtu (fuel in)		*per Ton-Mile*		
	Value	Units	Value	Units	DQI
Inputs					
1 diesel			270	Btu	B
Outputs					
Airborne Residuals					
2 CH_4	15.4	gm	0.004158	gm	B
3 NMHC (total)	147.5	gm	0.039825	gm	B
4 CO	212.8	gm	0.057456	gm	B
5 NO_x	605.6	gm	0.163512	gm	B
6 SO_x	184.1	gm	0.049707	gm	B
7 PM	81.8	gm	0.022086	gm	B
8 N_2O	2	gm	0.00054	gm	B
9 CO_2	71566	gm	19.32282	gm	B

Note: Inputs: DeLuchi, 1991: based on literature review.
Airborne residuals: DeLuchi, 1991: based on AP-42 (self-reported quality assessment) with adjustments for 1990 CAAA or DeLuchi's calculation based on mass balance and fuel composition.

Table D.2.15 Natural Gas Extraction (Gas Field Production)

Process Name	Natural Gas Extraction (Gas Field Production)
Geographic Location	National Average Process
Timeframe	
Process Description	Based on current practices and onshore/offshore mix.

	Total Annual		*per mmBtu (gas)*		
	Value	Units	Value	Units	DQI
Inputs					
2 diesel	7.79E+11	Btu	7.21E+04	Btu	C
3 water			2.82502444	gal	C
Outputs					
4 Natural gas	1.08E+04	mmscf	1.00E-03	mmscf	
Airborne Residuals					
5 SO_2	2.93E+00	ton	2.71E-07	ton	C
6 NO_x	145	ton	1.34E-05	ton	C
7 TSP	2.46	ton	2.27E-07	ton	C
8 PM_{10}		ton		ton	
9 CO	139	ton	1.29E-05	ton	C
10 CO_2	16,116	ton	1.49E-03	ton	
11 NMOCs	1.13E+01	ton	1.05E-06	ton	
12 CH_4	828.76	ton	7.67E-05	ton	B
Water Emissions					
28 BOD	1.85E+01	ton	1.71E-06	ton	C
29 COD	1.21E+02	ton	1.12E-05	ton	C
30 Oil and Grease	3.70E+02	ton	3.43E-05	ton	C
31 Chromium	1.00E+00	ton	9.26E-08	ton	C
32 Zinc	3.20E-01	ton	2.96E-08	ton	C
33 Total DS	4.94E+03	ton	4.57E-04	ton	C
34 Chloride	9.25E+02	ton	8.56E-05	ton	C
35 Sulfate	7.40E+02	ton	6.85E-05	ton	C
Solid Residuals					
36 Drill cuttings			3.364E-03	ton	C

Note: Water input: Based on lifecycle requirements allocated over lifetime gas production
Water emissions: From (DOE 1983)

Table D.2.16 Gas Processing

Process Name	Gas Processing
Geographic Location	National Average Process
Timeframe	1980
Process Description	Processing of raw natural gas to remove water, sulfur, and carbon dioxide before placement in pipeline. Production: 250 mmscf/day or 82E9 scf/yr.

	Total Annual		*per mmBtu (gas)*		
	Value	Units	Value	Units	DQI
Inputs					
2 fuel	9.18E+10	scf	1.12E-03	mmscf	C
3 water	133594005	gal	1.63E+00	gal	C
Outputs					
4 Natural gas	8.20E+04	mmscf	1.00E-03	mmscf	
Airborne Residuals					
5 SO_2	651.47	ton	7.94E-06	ton	C
6 NO_x	3,350	ton	4.09E-05	ton	C
7 TSP	6.60	ton	8.05E-08	ton	C
8 PM_{10}		ton		ton	
9 CO	0.30	ton	3.60E-09	ton	C
10 CO_2	106,600	ton	1.300E-03	ton	
11 NMVOC	1,439	ton	1.76E-05	ton	C
12 aldehydes	2.21	ton	2.70E-08	ton	C
13 CH_4	2,844	ton	3.47E-05	ton	

Note: Water input: Based on lifecycle requirements allocated over lifetime gas production

Table D.2.17 Natural Gas Transmission via Pipeline

Process Name	Natural Gas Transmission via Pipeline
Geographic Location	National Average
Timeframe	2000
Process Description	Long distance, high pressure (1200 psig) pipeline centrifugal compressors located at 100 mile intervals

	per mmBtu (fuel in)		*per mmBtu-mi*		
	Value	Units	Value	Units	DQI
Inputs					
1 natural gas	3.13E+00	Btu	0.0052167	Btu	C
Ouputs					
Airborne Residuals					
8 CH_4	524.7	gm	0.8745	gm	B
10 NMHC (total)	49.1	gm	0.0818333	gm	B
11 CO	267.6	gm	0.446	gm	B
12 NO_x	616.1	gm	1.0268333	gm	B
13 SO_x	0.28	gm	0.0004667	gm	B
14 PM			0		
16 N_2O	2	gm	0.0033333	gm	B
17 CO_2	51612	gm	86.02	gm	B

Note: Inputs: (DOE 1983). Energy use for gas turbine compressors; data may be somewhat outdated; reference pipeline length is 600 miles
Airborne residuals: (DeLuchi 1991). Emissions for engine-driven compressors (dominant form) CH_4 releases includes leaks

Table D.2.18 Open Pit Uranium Mine

Process Name	Open Pit Uranium Mine
Geographic Location	National Average
Timeframe	1980
Process Description	Open pit mine, uranium at depths up to 120 m; includes mine water and spoils storage Annual production: 528E3 tons (ore)

	Total Annual		*per Ton(uranium ore)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	1320000.0	kWh	2.5	kWh	B
2 diesel	1.46E+06	gal	2.765151515	gal	B
3 water	6.52E+08	gal	1234.238771	gal	B
Outputs					
Products					
4 uranium ore	5.28E+05	ton	1	ton	
Airborne Residuals					
5 NO_x	2.90E+01	ton	0.109848485	lb	B
6 SO_x	4.90E+01	ton	0.185606061	lb	B
7 CO	1.20E-01	ton	0.000454545	lb	B
8 HC	2.30E+00	ton	0.008712121	lb	B
9 TSP	3.10E+01	ton	0.117424242	lb	B
10 PM_{10}			NA		
11 CO_2			NA		
12 CH_4			NA		
13 other GHGs			NA		
14 Radon + daughters	3.37E+03	Ci	0.006382576	Ci	B
Water Emissions					
15					
Solid Waste					
16 total (overburden)	1.60E+07	tons	30.3030303	ton	B

Note: Inputs/Outputs: (DOE 1983). Engineering estimate; probably has not changed substantially given moderate expansion of industry since 1980s

Table D.2.19 Underground Uranium Mine

Process Name	Underground Uranium Mine
Geographic Location	National Average
Timeframe	1980
Process Description	Underground mine for uranium under impenetrable rock or at depths greater than 120 m; includes spoils storage. Annual production: 0.15e6 tons (ore)

	Total Annual		*per Ton(uranium ore)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	9490000.0	kWh	63.2666667	kWh	B
2 diesel	5.90E+04	gal	0.39333333	gal	B
natural gas	2.60E+07	scf	173.333333	scf	B
water	1.96E+06	gal	13.0335614	gal	B
Outputs					
Products					
3 uranium ore	1.50E+05	ton	1	ton	
Airborne Residuals					
4 NO_x	1.00E+01	ton	0.13333333	lb	B
5 SO_x	7.00E-01	ton	0.00933333	lb	B
6 CO	6.20E+00	ton	0.08266667	lb	B
7 HC	1.00E+00	ton	0.01333333	lb	B
8 TSP	3.30E-01	ton	0.0044	lb	B
9 PM_{10}			NA		
10 CO_2			NA		
11 CH_4			NA		
12 other GHGs			NA		
13 Radon + daughters	8.00E+03	Ci	0.05333333	Ci	B
Water Emissions					
14					
Solid Waste					
16 total (rock)	3.90E+06	ft3	26	ft3	B

Note: Inputs/Outputs: (DOE 1983). Engineering estimate; probably has not changed substantially given moderate expansion of industry since 1980s

Table D.2.20 Uranium Milling

Process Name	Uranium Milling
Geographic Location	National Average
Timeframe	1980
Process Description	Uranium mill for producing yellowcake (at 90% U3O8). Includes tailings control and disposal in retention basin, evabporation pond, solids filtration, and earth cover. Annual production: 635 tons/yr (yellowcake)

	Total Annual		*per Ton(yellowcake)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	10800000	kWh	17007.87402	kWh	B
2 uranium ore	620000	ton	976.3779528	ton	B
natural gas	274000000	scf	431496.063	scf	B
water	104268491.4	gal	164202.3486	gal	B
sulfuric acid	28000	ton	44.09448819	ton	B
Outputs					
Products					
3 yellowcake (90% U3O8)	635	ton	1	ton	
Airborne Ressiduals					
4 NOx	28	ton	88.18897638	lb	B
5 SOx	0.34	ton	1.070866142	lb	B
6 CO			NA		
7 HC			NA		
8 TSP	370	ton	1165.354331	lb	B
9 PM10			NA		
10 CO2			NA		
11 CH4			NA		
12 other GHGs			NA		
13 Radon + daughters	4500	Ci	7.086614173	Ci	B
U238,U234	160	Ci	0.251968504	Ci	B
14 Th230	122	Ci	0.192125984	Ci	B
Water Emissions					
total (discharge)	106223525.6	gal	167281.1426	gal	B
sulfate	1.30E+04	ton	20.47244094	ton	B
iron	440	ton	0.692913386	ton	B
manganese	22	ton	0.034645669	ton	B
selenium	0.88	ton	0.001385827	ton	B
U	1.3	Ci	0.002047244	Ci	B
Ra226	0.1	Ci	0.00015748	Ci	B
Th230	36	Ci	0.056692913	Ci	B
Solid Waste					
16 total (tailings)	6.10E+05	ton	960.6299213	ton	B
17 U	1.3	Ci	0.002047244	Ci	B
18 Ra226	156	Ci	0.245669291	Ci	B
19 Th230	156	Ci	0.245669291	Ci	B
20 Pb210, Po210,Bi210	0.3	Ci	0.000472441	Ci	B

Note: Inputs/Outputs: (DOE 1983). Engineering estimate; probably has not changed substantially given moderate expansion of industry since 1980s

Table D.2.21 Uranium Hexafluoride Conversion

Process Name	Uranium Hexafluoride Conversion
Geographic Location	National Average
Timeframe	1980
Process Description	Conversion of yellowcake into a volatile UF6 compound for input to a gas diffusion plant. Offgas treatment and wastewater treatment and impoundment included. Annual production: 5.5E3 tons/yr (UF6)

	Total Annual		*per Ton(natural UF6)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	4.60E+07	kWh	8363.636364	kWh	B
2 yellowcake	1.28E+04	ton	2.334545455	ton	B
natural gas	5.40E+08	scf	98181.81818	scf	B
water	716845878	gal	130335.6142	gal	B
Outputs					
Products					
3 natural UF6	5.50E+03	ton	1	ton	
Airborne Residuals					
4 NO_x	300	ton	109.0909091	lb	B
5 SO_x	850	ton	309.0909091	lb	B
6 CO	7		2.545454545	lb	B
7 HC	30		10.90909091	lb	B
8 TSP			NA		
9 PM_{10}			NA		
10 CO_2			NA		
11 CH_4			NA		
12 other GHGs			NA		
13 Radon + daughters			NA		
U	4.10E-03	Ci	7.45455E-07	Ci	B
14 fluoride	3.3	ton	1.2	lb	B
Water Emissions					
fluoride	790	ton	0.143636364	gal	B
sulfate	1.40E+02	ton	0.025454545	ton	B
iron	1.3	ton	0.000236364	ton	B
ammonium	50	ton	0.009090909	ton	B
sodium	105	ton	0.019090909	ton	B
U	1.2	Ci	0.000218182	Ci	B
Ra226	9.20E-02	Ci	1.67273E-05	Ci	B
Th230	4.10E-02	Ci	7.45455E-06	Ci	B
Solid Waste					
16 ash	1.20E+03	ton	0.218181818	ton	B
17 low/int. radioactive	24	Ci	0.004363636	Ci	B

Note: Inputs/Outputs: (DOE 1983). Engineering estimate; probably has not changed substantially given moderate expansion of industry since 1980s.
UF6 Input: combination of 75% U308 and purified (100%) U308.

Table D.2.22 Uranium Enrichment-Gaseous Diffusion

Process Name	Uranium Enrichment - Gaseous Diffusion
Geographic Location	National Average
Timeframe	1980
Process Description	Conversion of natural UF6 into enriched UF6 using compressors and porous barriers. Water treatment, waste burial, and product recovery systems included. Annual production: 12E3 tons/yr (enriched UF6)

	Total Annual		*per Ton(enriched UF6)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	2.80E+10	kWh	2333333.333	kWh	B
2 natural UF6	1.80E+04	ton	1.5	ton	B
natural gas	0.00E+00	scf	0	scf	B
water	8080808081	gal	673400.6734	gal	B
Outputs					
Products					
3 enriched UF6	1.20E+04	ton	1	ton	
Airborne Residuals					
4 NO_x	1.13E+05	ton	18833.33333	lb	B
5 SO_x	4.31E+05	ton	71833.33333	lb	B
6 CO	2.80E+03		466.6666667	lb	B
7 HC	1.10E+03		183.3333333	lb	B
8 TSP	1.13E+05		18833.33333	lb	
9 PM_{10}			NA		
10 CO_2			NA		
11 CH_4			NA		
12 other GHGs			NA		
13 Radon + daughters			NA		
U	1.80E-01	Ci	0.000015	Ci	B
Tc99	7.40E-01	Ci	6.16667E-05	Ci	
Ru106	1.00E-02	Ci	8.33333E-07	Ci	
14 fluoride	4.40E+01	ton	7.333333333	lb	B
Water Emissions					
calcium	700	ton	0.058333333	gal	B
sulfate	7.00E+02	ton	0.058333333	ton	B
iron	44	ton	0.003666667	ton	B
chloride	900	ton	0.075	ton	B
sodium	900	ton	0.075	ton	B
U	1.8	Ci	0.00015	Ci	B
Tc99	9.60E+00	Ci	0.0008	Ci	B
nitrate	2.60E+02	ton	0.021666667	ton	B
Solid Waste					
16			NA		

Note: Inputs/Outputs: (DOE 1983). Engineering estimate; probably has not changed substantially given moderate expansion of industry since 1980s.

Table D.2.23 Fuel Fabrication Plant

Process Name	Fuel Fabrication Plant
Geographic Location	National Average
Timeframe	1980
Process Description	Conversion of UF6 to UO2 and pellet production Annual production: 990 tons/yr (UO2)

	Total Annual		*per Ton(UO2)*		
	Value	Units	Value	Units	DQI
Inputs					
1 electricity	4.40E+07	kWh	44444.4444	kWh	B
2 enriched UF6	3.40E+03	ton	3.43434343	ton	B
natural gas	9.30E+07	scf	93939.3939	scf	B
water	133594005	gal	134943.439	gal	B
Outputs					
Products					
3 UO2	9.90E+02	ton	1	ton	
Airborne Residuals					
4 NO_x	1.70E+02	ton	343.434343	lb	B
5 SO_x	6.81E+02	ton	1375.75758	lb	B
6 CO	6.20E+00		12.5252525	lb	B
7 HC					
8 TSP					
9 PM_{10}			NA		
10 CO_2			NA		
11 CH_4			NA		
12 other GHGs			NA		
13 Radon + daughters			NA		
U	5.10E-03	Ci	5.1515E-06	Ci	B
Water Emissions					
ammonia	280	ton	0.28282828	gal	B
nitrate	6.81E+02	ton	0.68787879	ton	B
fluoride	120	ton	0.12121212	ton	B
U	0.51	Ci	0.00051515	Ci	B
Th234	2.60E-01	Ci	0.00026263	Ci	B
Solid Waste					
16 calcium fluoride	7.43E+02	ton	0.75050505	ton	B
17 U	5.9	Ci	0.0059596	Ci	B

Note: Inputs/Outputs: (DOE 1983). Engineering estimate; probably has not changed substantially given moderate expansion of industry since 1980s.

Table D.2.24 Truck

Process Name	Truck				
Geographic Location	National Average				
Timeframe	2000				
Process Description					
	per mmBtu (fuel in)		*per Ton-Mile*		
	Value	Units	Value	Units	DQI
Inputs					
1 diesel			2072	Btu	B
Outputs					
Airborne Residuals					
8 CH_4	4.3	gm	0.0089096	gm	B
10 NMHC (total)	88.9	gm	0.1842008	gm	B
11 CO	466.4	gm	0.9663808	gm	B
12 NO_x	348.3	gm	0.7216776	gm	B
13 SO_x	184.1	gm	0.3814552	gm	B
14 PM	10.8	gm	0.0223776	gm	B
16 N_2O	2.6	gm	0.0053872	gm	B
17 CO_2	71616	gm	148.38835	gm	B

Note: Inputs: DeLuchi, 1991: based on literature review
Airborne residuals: DeLuchi, 1991: based on AP-42 (self-reported quality assessment) with adjustments for 1990 CAAA or DeLuchi's calculation based on mass balance and fuel composition

Table D.2.25 Generic Electricity (Fuel in, to point of use)

Segment Name	Generic Electricity (Fuel in, to point of use)
Geographic Location	National Average - U.S.
Timeframe	2010
Process Description	Includes: a generic mix of coal, gas, and oil-fired electricity generation technologies; and T&D

	Total Annual		*per 10^{12} Btu*		
	Value	Units	Value	Units	DQI
Inputs					
1 coal-subbituminous			1.53E+06	MBtu	
2 natural gas			390000	MBtu	
3 fuel oil 1			105000	MBtu	
Outputs					
Products					
5 electricity			1	10^{12} Btu	
Airborne Residuals					
6 NO_x			603000	lb	
7 SO_x			1.41E+06	lb	
8 CO			90500	lb	
9 Pb			0	lb	
10 PM_{10}			NC	lb	
11 TSP			14600	lb	
12 CO_2			3.73E+08	lb	
13 CH_4			NC	lb	
14 NMVOCs			29900	lb	
15 Other Greenhouse Gases			0	lb	
Water Emissions					
16 Wastewater			NC		
Solid Waste					
17 Nonhazardous			NC		
18 Hazardous			NC		

* Includes the national mix of coal-, gas-, and oil-fired electricity generation technologies and transmission/distribution losses; for the electricity used in the aluminum industry (Table D.2.26), also includes a share of hydroelectric power. Note that 31% total of generic electricity is assumed to be supplied by non-fossil sources that have no emissions. Thus, the generic electricity serving the aluminum industry (shown in Table D.2.26) has the 31% plus an additional amount of hydroelectricity as shown in the column.

NC: Not Calculated

Table D.2.26 Generic Electricity-Aluminum (Fuel in, to point of use)

Segment Name	Generic Electricity-Aluminum (Fuel in, to point of use)					
Geographic Location	National Average - U.S.					
Timeframe	2010					
Process Description	Includes: a generic mix of coal, gas, and oil-fired electricity generation technologies; and T&D					
	Total Annual		*per 10^{12} Btu*			
	Value	Units	Value	Units	DQI	
Inputs						
1 coal-subbituminous			1.26E+06	MBtu		
2 natural gas			3.21E+05	MBtu		
3 fuel oil 1			8.67E+04	MBtu		
4 other electricity			4.53E+05	MBtu		
Outputs						
Products						
5 electricity*			1	10^{12} Btu		
Airborne Residuals						
6 NO_x			498000	lb		
7 SO_x			1.16E+06	lb		
8 CO			74700	lb		
9 Pb			0	lb		
10 PM_{10}			NC	lb		
11 TSP			12000	lb		
12 CO_2			3.08E+08	lb		
13 CH_4			NC	lb		
14 NMVOCs			24700	lb		
15 Other Greenhouse Gases			0	lb		
Water Emissions						
16 Wastewater			NC			
Solid Waste						
17 Nonhazardous			NC			
18 Hazardous			NC			

* Includes national mix shown in Table D.2.25 plus an additional share of hydroelectric power.

D.2.1 References for Appendix D.2

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U.S. Department of Energy (DOE), *Energy Technologies and the Environment: Environmental Information Handbook*, DOE/EH-0077, Argonne National Laboratory, Argonne, IL, (October 1988).

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D.3 Derivation of Material Content of Automobiles

This appendix explains how the material contents of the various types of vehicles in various future years were derived.

D.3.1 Methodology and Assumptions for Derivation of Amount of Non-Battery Materials in EVs and CVs

The material "content" analysis is closely correlated with the "simulation" analysis to estimate EV and CV fuel efficiency. The vehicle simulation involved a variety of vehicle types (mini-minivan, compact car, etc.), each with their own weight and performance characteristics. The weight of the vehicles used in the simulation was projected using parametric relationships that estimate how the weight of the various vehicles are expected to change between 1998 and 2010. For the "content" analysis, it was necessary to know the weight by component (e.g., steel, aluminum, rubber). This required taking the weight of all the simulated vehicles and breaking it down into components.

The material composition of the future electric vehicles was derived from that of current gasoline vehicles, with proper allowance made for replacement of internal combustion engine (ICE) components with electric powertrain equivalents, plus expected normal development changes, such as replacement of heavier ferrous materials with lighter metals and plastics. We started with current vehicles that are as close as practical to the expected EVs.

The first step was to find current vehicles that come close in size and architecture to the expected EVs, and then, their total mass was distributed among the major systems integrating the vehicle. Table D.3.1 shows the distribution among current vehicle types, their specification for different pieces of the vehicle and its total weight.

Next, these vehicles were "converted" to electrical, by removing the "engine & auxiliaries" and replacing it with an electric drivetrain. The chassis is then adjusted to reflect the heavier suspension etc.; the transmission is adjusted to reflect the simpler, one speed, simple gear reduction used; and the (engine) fluids are reduced. The results **(not including batteries)** are as shown on the Table D.3.2.

The material distribution in an automobile is not uniform throughout the car, in other words, certain materials predominate in some systems (mild steel in the body, cast iron in the engine, etc.). Therefore, it was necessary to examine the systems being removed (engine, etc.) and the systems being added (electric traction motors, etc.), in order to make an estimate of the net change in materials content obtained when the vehicle is converted to electric. The following assumptions were made:

Engine & Auxiliaries -

- engine ratio of mass to power is; 2.5 lbs./hp
- engine material composition is:
  - 50% iron
  - 25% steel
  - 20% aluminum
  - 5% other

- mid-size car exhaust system weighs 75 lbs, including 15 lbs of stainless steel
- fuel storage system of mid-size car weighs 30 lbs, and its all-steel
- cooling system of mid-size car weighs 30 lbs, and its material composition is 70% aluminum, 20% plastic, 10% steel
- an automatic transmission weighs 150 lbs and its material content is 20% alum., 70% steel, and 10% fluids .
- a manual transmission weighs 70 lbs, and its material content is 30% alum., 60% steel, 10% others, including fluids

<u>Electric Powertrain Components</u> -

- a traction motor for a mid-size car weighs 100 lbs, and its material composition is as follows:
  65% magnet steel (high-silicone steel laminations)
  20% copper conductor
  8% alum
  7% steel
- the controller for a mid-size car weighs 70 lbs, and its material composition is as follows:
  30% alum
  30% plastics
  15% copper
  15% steel
  3% lead/tin
  12% other
- additional components going into the EVs (brackets, battery trays, cables, etc.), have an overall material composition of:
  50% steel
  20% aluminum
  20% plastics
  10% copper

Table D.3.3 presents the material composition of the conventional ICE-powered mid-sized car. Table D.3.4 presents the material composition of an equivalent mid-sized "converted" EV using the mass and material assumptions for components added and removed just discussed.

The material compositions for all the other car-like electric vehicles (2-seater, mini-compact, compact, mini-minivan), was obtained by scaling the basic material composition estimated for the mid-size passenger car shown on the table above. However, since the vans have a larger body and a slightly heavier chassis than equivalent passenger cars, an adjustment was made on these two systems that resulted in a higher relative content for steel, although the bulk of the rest of the materials have a similar distribution.

Finally, a small (4% on cars, 5% on vans) evolutionary mass reduction which takes place primarily by material substitution. Essentially, cast iron is reduced in the chassis and replaced primarily with aluminum, and steel (mostly from the body) is replaced primarily with plastic composites (SMC, etc.) and wrought aluminum. The mass reduction in each type of vehicle was achieved as follows:

- For the **mini-compact,** 50 lbs of mild steel and 90 lbs of cast iron are replaced by 45 lbs of aluminum and 23 lbs. of plastics

- For the **compact,** 120 lbs. of cast iron and 70 lbs. of mild steel are replaced with 66 lbs. of aluminum and 35 lbs. of plastics

- For the **minivan,** 145 lbs. of cast iron and 165 lbs. of steel are replaced with 115 lbs. of aluminum, and 35 lbs. of plastics

- For the **full-size van,** 205 lbs of steel and 170 lbs. of cast iron are replaced by 120 lbs. of aluminum and 65 lbs. of plastics, plus there is a small reduction in the amounts of zinc die castings, and powder metal.

D.3.2 Results of Non-Battery Materials Analysis

Tables D.3.5 - D.3.7 present the materials content of CVs used in the EVTECA analysis. Tables D.3.8 - D.3.10 present the non-battery material content of EVs.

D.3.3 Battery Weights and Materials

Following the initial phase of the content analysis, Table D.3.11 was compiled. It compares the vehicle weights used in the simulation analysis, which were based on a top-down parametric approach, and the vehicle weights derived in the initial content analysis extrapolating from existing vehicle content data. Table D.3.11 shows slight mismatches in total vehicle weight by vehicle type between the two approaches. To adjust for this difference, the material content percentage breakdowns shown in Tables D.3.5 through Table D.3.10 were applied to the total vehicle weights used in the simulation analysis to generate final vehicle content weights. These weights are the ones summarized in Tables 8.1 through 8.6 in the main body of the text. The EV battery weights appended to Tables 8.4 through 8.6 are directly from the vehicle simulation data described elsewhere in this study.

Table D.3.1 CVs: Current Weight of Vehicle Shell

System	Two-seater	Compact	Sub-compact	Minivan	Full-size van
Body-in white	495 lbs	650 lbs.	610 lbs.	1160 lbs.	1400 lbs
Body trim	355	470	460	550	500
Chassis	490	650	593	800	1100
Transmission	150	210	190	250	350
Fluids	60	80	70	120	140
Engine & auxiliaries	420	545	498	700	950
TOTAL	**1970 lbs.**	**2605 lbs.**	**2420 lbs.**	**3580 lbs.**	**4440 lbs.**

Table D.3.2 EVs: Projected Weight of Vehicle Shell

System	Two-seater*	Compact	Mini-minivan	Minivan	Full-size van
Body-in white	495 lbs	650 lbs.	610 lbs.	1160 lbs.	1400 lbs.
Body trim	355	470	460	550	500
Chassis	525	700	635	880	1200
Transmission	100	120	110	150	175
Fluids	25	30	25	50	60
Electrical comp.	282	300	290	400	500
TOTAL	**1782 lbs**	**2270 lbs.**	**2130 lbs.**	**3190 lbs.**	**3835 lbs.**

*The so-called mini-compact and the two-seater are assumed to have the same material composition

Table D.3.3 Material Composition of a Typical Current CV

Material	Mass (lbs)	Percentage
Mild Steel	1388.5	43.8
High-Strength Steel	263.0	8.3
Stainless Steel	45.0	1.4
Other Steels	42.5	1.3
Total Steel	1739.0	54.8
Cast Iron	408.0	12.9
Total Ferrous Metals	2147.0	67.7
Aluminum	182.0	5.7
Copper & Brass	42.0	1.3
Zinc Die Casting	16.0	0.5
Powder Metals	27.0	0.9
Lead	25.0	0.8
Total Metals	2439.0	76.9
Plastics and Composites	245.5	7.7
Rubber	134.0	4.2
Glass	89.0	2.8
Fluids/Lubricants	189.5	6.0
Other (paper, fabric, etc.)	74.0	2.3
TOTAL	**3171.0**	**99.9**

*Source: American Metal Market (quoted from "AAMA Motor Vehicle Facts and Figures, 1994")

Table D.3.4 Material Composition of Near-term EVs Without Batteries

Material	Mass in lbs	Percentage
Mild Steel	1305	49.8
High-Strength Steel	183.	7.
Stainless Steel	30.	1.1
Magnet Core Steel	65.	2.5
Other Steels	40.	1.5
Total Steel	1623.	61.9
Cast Iron	206.	7.9
Total Ferrous Metals	1829.	69.8
Aluminum	126.	4.8
Copper & Brass	75.	2.9
Zinc Die Casting	15.	0.6
Powder Metals	15.	0.6
Total Metals	2060.	78.6
Plastics and Composites	240.	9.2
Rubber	126.	4.8
Glass	86.	3.3
Fluids/Lubricants	35.	1.3
Other (paper, fabric, etc.)	74.	2.8
TOTAL	**2620.**	**100.**

Table D.3.5 ICE Powered Cars Pre-2003: Materials and Weight Percentages of Six Types of Cars

	Midsize ICE Car		Two-seater		Compact		Mini-minivan		Minivan		Full-size Van	
Material	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%
Mild Steel	1388.5	43.8	895	45.4	1150	44.1	1120	46.3	1690	47.2	2160	48.6
High Strength Steel	263	8.3	162	8.2	216	8.3	200	8.3	290	8.1	350	7.9
Stainless Steel	45	1.4	25	1.3	37	1.4	35	1.4	50	1.4	63	1.4
Other Steels	42.5	1.3	25	1.3	35	1.3	30	1.2	45	1.3	57	1.3
Total Steel	1739	54.8	1107	56.2	1438	55.2	1385	57.2	2075	58.0	2630	59.2
Cast Iron	408	12.9	245	12.4	335	12.9	300	12.4	425	11.9	550	12.4
Total Ferrous Metals	2147	67.7	1352	68.6	1773	68.1	1685	69.6	2500	69.8	3180	71.6
Aluminum	182	5.7	110	5.6	150	5.8	130	5.4	185	5.2	230	5.2
Copper and Brass	42	1.3	25	1.3	35	1.3	30	1.2	45	1.3	55	1.2
Zinc Die Casting	16	0.5	10	0.5	12	0.5	10	0.4	20	0.6	25	0.6
Powder Metals	27	0.9	15	0.8	23	0.9	20	0.8	30	0.8	40	0.9
Lead	25	0.8	15	0.8	22	0.8	20	0.8	25	0.7	32	0.7
Total Metals	2439	76.9	1527	77.5	2015	77.4	1895	78.3	2805	76.4	3562	80.2
Plastics and Composites	245.5	7.7	150	7.6	200	7.7	180	7.4	270	7.5	330	7.4
Rubber	134	4.2	83	4.2	110	4.2	100	4.1	145	4.1	175	3.9
Glass	89	2.8	50	2.5	75	2.9	65	2.7	100	2.8	120	2.7
Fluids/Lubricants	189.5	6.0	110	5.6	140	5.4	130	5.4	180	5.0	143	3.2
Other (paper, fabric, etc.)	74	2.3	50	2.5	65	2.5	50	2.1	80	2.2	110	2.5
TOTAL	3171	100.0	1970	100.0	2605	100.0	2420	100.0	3580	100.0	4440	100.0

Table D.3.6 ICE Powered Cars - 2003 to 2007: Materials and Weight Percentages of Five Types of Cars

	Midsize ICE Car		Minicompact		Compact		Minivan		Full-size Van	
Material	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%
Mild Steel	1388.5	43.8	895	45.4	1150	44.1	1690	47.2	2160	48.6
High Strength Steel	263	8.3	162	8.2	216	8.3	290	8.1	350	7.9
Stainless Steel	45	1.4	25	1.3	37	1.4	50	1.4	63	1.4
Other Steels	42.5	1.3	25	1.3	35	1.3	45	1.3	57	1.3
Total Steel	1739	54.8	1107	56.2	1438	55.2	2075	58.0	2630	59.2
Cast Iron	408	12.9	245	12.4	335	12.9	425	11.9	550	12.4
Total Ferrous Metals	2147	67.7	1352	68.6	1773	68.1	2500	69.8	3180	71.6
Aluminum	182	5.7	110	5.6	150	5.8	185	5.2	230	5.2
Copper and Brass	42	1.3	25	1.3	35	1.3	45	1.3	55	1.2
Zinc Die Casting	16	0.5	10	0.5	12	0.5	20	0.6	25	0.6
Powder Metal	27	0.9	15	0.8	23	0.9	30	0.8	40	0.9
Lead	25	0.8	15	0.8	22	0.8	25	0.7	32	0.7
Total Metals	2439	76.9	1527	77.5	2015	77.4	2805	76.4	3562	80.2
Plastics and Composites	245.5	7.7	150	7.6	200	7.7	270	7.5	330	7.4
Rubber	134	4.2	83	4.2	110	4.2	145	4.1	175	3.9
Glass	89	2.8	50	2.5	75	2.9	100	2.8	120	2.7
Fluids/Lubricants	189.5	6.0	110	5.6	140	5.4	180	5.0	143	3.2
Other (paper, fabric, etc.)	74	2.3	50	2.5	65	2.5	80	2.2	110	2.5
TOTAL	3171	100.0	1970	100.0	2605	100.0	3580	100.0	4440	100.0

Table D.3.7 ICE Powered Cars - 2008 to 2010: Materials and Weight Percentages of Five Types of Cars

	Midsize ICE Car		Minicompact		Compact		Minivan		Full-size Van	
Material	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%	Mass (lb.)	%
Mild Steel	1238	40.7	845	44.5	1080	42.9	1525	44.6	1955	46.0
High Strength Steel	263	8.6	162	8.5	216	8.6	290	8.5	350	8.2
Stainless Steel	45	1.5	25	1.3	37	1.5	50	1.5	63	1.5
Other Steels	42	1.4	25	1.3	35	1.4	45	1.3	57	1.3
Total Steel	1588	52.2	1057	55.7	1388	54.4	1910	55.8	2425	57.1
Cast Iron	315	10.4	155	8.2	215	8.5	280	8.2	380	8.9
Total Ferrous Metals	1903	62.6	1212	63.9	1583	62.9	2190	64.0	2805	66.1
Aluminum	262	8.6	155	8.2	216	8.6	300	8.8	350	8.2
Copper and Brass	42	1.4	25	1.3	35	1.4	45	1.3	55	1.3
Zinc Die Casting	16	0.5	10	0.5	12	0.5	20	0.6	23	0.5
Powder Metals	27	0.9	15	0.8	23	0.9	30	0.9	38	0.9
Lead	25	0.8	15	0.8	22	0.9	25	0.7	32	0.8
Total Metals	2275	74.8	1432	75.4	1891	75.2	2610	76.3	3303	77.8
Plastics and Composites	285	9.4	173	9.1	235	9.3	305	8.9	395	9.3
Rubber	134	4.4	83	4.4	110	4.4	145	4.2	175	4.1
Glass	89	2.9	50	2.6	75	3.0	100	2.9	120	2.8
Fluids/Lubricants	185	6.1	110	5.8	140	5.6	180	5.3	143	3.4
Other (paper, fabric, etc)	74	2.4	50	2.6	65	2.6	80	2.3	110	2.6
TOTAL	3042	100.0	1898	100.0	2516	100.0	3420	100.0	4246	100.0

Table D.3.8 Material Content of EVs Pre-2003 Period (Not Including Battery Materials)

Material	Two- seater		Compact		Mini-minivan		Minivan		Full-size van	
Mild Steel	890 lbs.	50.0 %	1140 lbs.	50.2 %	1100 lbs	51.6 %	1660 lbs.	52.0 %	2050 lbs.	53.5 %
High Strength Steel	125	7.0	160	7.0	150	7.0	230	7.2	270	7.0
Stainless Steel	20	1.0	25	1.0	20	0.9	35	1.1	35	0.9
Magnet Steel	47	2.6	60	2.6	55	2.6	80	2.5	85	2.2
Other Steel	10	0.6	13	0.6	10	0.5	20	0.6	30	0.8
Cast Iron	140	7.9	180	7.9	160	7.5	220	6.9	250	6.5
Aluminum	90	5.0	110	4.8	100	4.7	150	4.7	180	4.7
Copper/Brass	53	3.0	65	2.9	60	2.8	90	2.8	100	2.6
Zinc Die Casting	10	0.6	13	0.6	10	0.5	16	0.5	20	0.5
Powder Metal	10	0.6	13	0.6	10	0.5	15	0.5	20	0.5
Plastic	167	9.4	210	9.3	200	9.4	285	8.9	330	8.6
Rubber	85	4.8	110	4.8	100	4.7	150	4.7	175	4.6
Glass	60	3.4	75	3.3	65	3.1	100	3.1	120	3.1
Fluids	25	1.5	30	1.3	30	1.4	50	1.6	60	1.6
Other	50	2.8	65	2.9	60	2.8	90	2.8	110	2.9
TOTAL	1782	100.2	2269	99.9	2130	100	3191	99.9	3835	100

Table D.3.9 Material Content of EVs in 2003 - 2007 Period (Not Including Battery Materials)

Material	Mini-compact		Compact		Minivan		Full-size van	
Mild Steel	890 lbs.	50.0 %	1140 lbs.	50.2 %	1660 lbs.	52.0 %	2050 lbs.	53.5 %
High Strength Steel	125	7.0	160	7.0	230	7.2	270	7.0
Stainless Steel	20	1.0	25	1.0	35	1.1	35	0.9
Magnet Steel	47	2.6	60	2.6	80	2.5	85	2.2
Other Steel	10	0.6	13	0.6	20	0.6	30	0.8
Cast Iron	140	7.9	180	7.9	220	6.9	250	6.5
Aluminum	90	5.0	110	4.8	150	4.7	180	4.7
Copper/Brass	53	3.0	65	2.9	90	2.8	100	2.6
Zinc Die Casting	10	0.6	13	0.6	16	0.5	20	0.5
Powder Metal	10	0.6	13	0.6	15	0.5	20	0.5
Plastic	167	9.4	210	9.3	285	8.9	330	8.6
Rubber	85	4.8	110	4.8	150	4.7	175	4.6
Glass	60	3.4	75	3.3	100	3.1	120	3.1
Fluids	25	1.5	30	1.3	50	1.6	60	1.6
Other	50	2.8	65	2.9	90	2.8	110	2.9
TOTAL	1782	100.2	2269	99.9	3191	99.9	3835	100

Table D.3.10 Material Content of EVs 2008 - 2010 Period (Not Including Battery Materials)

Material	Mini-compact		Compact		Minivan		Full-size van	
Mild Steel	840 lbs.	49.1 %	1070 lbs.	49.1 %	1500 lbs.	49.5 %	1850 lbs.	50.8 %
High Strength Steel	125	7.3	160	7.3	225	7.4	265	7.3
Stainless Steel	20	1.2	25	1.1	35	1.2	35	1.0
Magnet Steel	47	2.7	60	2.8	80	2.6	85	2.3
Other Steel	10	0.6	13	0.6	20	0.7	30	0.8
Cast Iron	50	2.9	60	2.8	75	2.5	80	2.2
Aluminum	135	7.9	176	8.1	265	8.7	300	8.2
Copper/Brass	53	3.1	65	3.0	90	3.0	100	2.7
Zinc Die Casting	10	0.6	13	0.6	15	0.5	18	0.5
Powder Metal	10	0.6	13	0.6	15	0.5	18	0.5
Plastic	190	11.1	245	11.2	320	10.6	395	10.8
Rubber	85	5.0	110	5.0	150	5.0	175	4.8
Glass	60	3.5	75	3.4	100	3.3	120	3.3
Fluids	25	1.5	30	1.4	50	1.7	60	1.6
Other	50	2.9	65	3.0	90	3.0	110	3.0
TOTAL	1710	100.	2180	100.	3030	100.1	3641	99.9

Table D.3.11 EV Weights (Not Including Batteries)

Pre-2003 Period (mass in lbs.)			2003 to 2007 Period (mass in lbs.)			2008 to 2010 Period (mass in lbs.)		
Vehicle type	Initial Content Analysis	Simulation Analysis	Vehicle type	Initial Content Analysis	Simulation Analysis	Vehicle type	Initial Content Analysis	Simulation Analysis
Two-seater	1782	1784	Mini-compact	1782	1784	Mini-compact	1710	1711
Compact	2269	2122	Compact	2269	2122	Compact	2180	2034
Mini-minivan	2130	1858						
Minivan	3191	2515	Minivan	3191	2515	Minivan	3030	2384
Full-size van	3835	4454	Full-size van	3835	4454	Full-size van	3641	4230

D.4 Processes Involved in Producing Vehicles and Batteries

Appendix D.4 provides the unit process inventories used in used in the EVTECA that relate to the manufacture of conventional vehicles, electric vehicles, and batteries. Each table presents for one process, all of the material and energy inputs and outputs quantified and analyzed in the EVTECA.

Chapter 8 of the main body includes an explanation of how these data were derived and a description of each of the processes.

The data tables are organized in the following manner:

The top section briefly describes the major characteristics of the process including its location, the time period for which it was characterized, and a brief description of the process. If the plant is an average or typical plant, the location field will most likely say, "National Average." Otherwise, a specific location applicable to the process description will be noted. Although the time frame may be characterized as a historical year such as 1980, the EVTECA assumes, unless otherwise noted in the table, that the process has not changed over time and will not change significantly in the future. This is an oversimplification necessary under the constraints of the study.

The main body of the table first shows inputs to the process. These are shown as either total annual values, or values normalized per unit of output. The basis is recorded in the right-hand column heading. The normalized values are used for calculations for normalizing the data in the TEMIS modeling framework.

Quantities of outputs of both products and environmental residuals are shown next, using the same general approach -- quantity of outputs (e.g., nitrogen oxide emissions to the air) are divided by the quantity of the main product (e.g. steel) output to calculate the normalized values in the right-hand column (e.g. nitrogen oxides [in tons] per ton of steel produced).

The environmental residuals in the tables are as follows:

- Nitrogen oxides (NO_x)
- Sulfur oxides (SO_x)
- Carbon monoxide (CO)
- Lead (Pb)
- Particulate Matter equal to or less than 10 microns in diameter (PM-10)
- Total Suspended Particulate (TSP)
- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Non-Methane Volatile Organic Compounds (NMVOCs)
- Other Greenhouse Gases (Other GHGs)
- Wastewater
- Nonhazardous Solid Residuals
- Hazardous Solid Residuals

Not all processes are fully characterized with information on all inputs and outputs. The data included in the assessment are limited to those readily available through literature searches. Data quality index process was not used in the materials analysis. Information on the intended data gathering protocol for the EVTECA can be found in Appendix A.2. Sometimes, this protocol could not be fully implemented due to resource constraints of the study.

Table D.4.1 Coking

Process Name	Coking
Geographic Location	National Average - U.S.
Timeframe	1990
Process Description	Thermal processing of coal to produce coke.

	Total Annual		*per Ton of Coke*	
	Value	Units	Value	Units
Inputs				
1 bituminous coal			1.41	ton
2 natural gas			911130	Btu
3 coke oven gas			185020	Btu
4 blast furnace gas			3.85E+03	Btu
5 electricity			38	kWh
Outputs				
Products				
6 coke			1	ton
7 coke oven gas			8.30E+06	Btu
Airborne Emissions				
8 NO_x			0.3	lb
9 SO_x*			1.5	lb
10 CO**			0.111	lb
11 Pb***			0	lb
12 PM_{10}			NA	
13 TSP****			2.1	lb
14 CO_2			320	lb
15 CH_4			0.008	lb
16 NMVOCs			0.211	lb
17 Other GHGs			NC	

Note: CH_4 emissions are from fuel combustion.
* 0.6lb Process + 0.9lb Combustion = 1.5 lb
** 0.07lb Process + 0.041lb Combustion = 0.111 lb
*** Pb emissions occur, but not neligible.
**** 2lb Process + 0.1lb Combustion = 2.1 lb

Table D.4.2 Sintering

Process Name	Sintering			
Geographic Location	National Average - U.S.			
Timeframe	1985			
Process Description	Sintering			

	Total Annual		***per Ton of Sinter***	
	Value	Units	Value	Units
Inputs			NC	
Outputs				
Product				
1 sinter			1	ton
Airborne Residuals				
2 NO_x			NC	
3 SO_x			NC	
4 CO			NC	
5 Pb			NC	
6 PM_{10}			NC	
7 TSP			0.3	lb
8 CO_2			NC	
9 CH_4			NC	
10 NMVOCs			NC	
11 Other GHGs			NC	

Source: AP-42, Table 12.5-1 (10/86)
NC = not calculated.

Table D.4.3 Pig Iron Production via Blast Furnace

Process Name	Pig Iron Production
Geographic Location	National Average - U.S.
Timeframe	1990
Process Description	Reduction of iron ore to pig iron via a blast furnace

	Total Annual		*per Ton of Pig Iron*	
	Value	Units	Value	Units
Inputs				
1 iron ore pellets			0.8	ton
2 sinter			0.8	ton
3 coke			0.525	ton
4 natural gas			3.0	Btu
5 electricity			20	kWh
Outputs				
[redacted]				
6 pig iron			1	ton
7 blast furnace gas			4.62E+06	Btu
[redacted]				
8 NO_x			0.9	lb
9 SO_x			2.4	lb
10 CO			0.11	lb
11 Pb			0	lb
12 PM_{10}			NA	
13 TSP**			2.7	lb
14 CO_2			540	lb
15 CH_4			0.02	lb
16 NMVOCs			0.03	lb
17 Other GHGs			NC	

Note: ** 2.4 lb Process + 0.3 Combustion = 2.7 lb
NA = not applicable.
NC = not calculated.

Table D.4.4 Steel Production via Basic Oxygen Process

Process Name	Steel Production #1
Geographic Location	National Average - U.S.
Timeframe	1990
Process Description	Conversion of pig iron to raw steel via the basic oxygen process (BOP)

	Total Annual		*per Ton of Raw Steel*	
	Value	Units	Value	Units
Inputs				
1 pig iron			0.83	ton
2 oxygen			1.70E+03	ft^3
3 refractories**			9.60E+04	Btu
4 lime			1.50E+02	lb
5 steel scrap			2.80E-01	ton
6 electricity			3.00E+01	kWh
Outputs				
Product				
7 steel			1	ton
Airborne Residuals				
8 NO_x			NC	lb
9 SO_x			NC	lb
10 CO			110	lb
11 Pb			NC	lb
12 PM_{10}			NA	
13 TSP			0.7	lb
14 CO_2			2200	lb
15 CH_4			NC	lb
16 NMVOCs			NC	lb
17 Other GHGs			NC	

Note: ** Refractories use was incorrectly included as 9.6E04 rather than 9.6E06. This error is not expected to impact study conclusions.

Table D.4.5 Steel Production via Electric Arc Furnace

Process Name	Steel Production #2
Geographic Location	National Average - U.S.
Timeframe	1990
Process Description	Production of steel by scrap electric are steelmaking (EAF)

	Total Annual		*per Ton of Steel*	
	Value	Units	Value	Units
Inputs				
1 steel scrap			1.06	ton
2 electrode materials			9.60E+05	lb
3 refractories			3.30E+05	Btu
4 lime			1.00E+02	lb
5 oxygen			177	ft^3
6 alloying elements			8.00E+05	Btu
7 fuel oil 6/7			1.00E+05	Btu
8 electricity			5.00E+02	kWh
Outputs				
Products				
7 raw steel			1	ton
Airborne Emissions				
8 NO_x			0.02	lb
9 SO_x			0.98	lb
10 CO			0.004	lb
11 Pb			0	lb
12 PM_{10}			NA	
13 TSP*			0.31	lb
14 CO_2			20	lb
15 CH_4			0.00007	lb
16 NMVOCs			0.001	lb
17 Other GHGs			NC	

Note: * 0.30 lb process + .01 lb combustion = 0.31 lb.

Table D.4.6 Steel Sheet Production

Process Name	Steel Sheet Production			
Geographic Location	National Average - U.S.			
Timeframe	1990			
Process Description	Casting, annealing, and cold-rolling of raw steel			
	Total Annual		*per Ton of Raw Steel*	
	Value	Units	Value	Units
Inputs				
1 raw steel			1.22	ton
2 natural gas			5.63E+06	Btu
3 electricity			3.05E+02	kWh
Outputs				
Product				
4 steel sheet			1	ton
5 steel scrap			0.22	ton
[illegible]				
6 NO_x			1.1	lb
7 SO_x			4.5	lb
8 CO			0.21	lb
9 Pb			0.00002	lb
10 PM_{10}			NA	
11 TSP			0.56	lb
12 CO_2			1040	lb
13 CH_4			0.39	lb
14 NMVOCs			0.056	lb
15 Other GHGs			NC	

Note: NO_x emissions of 1.1 lbs are from fuel combustion.
SO_x emissions of 4.5 lbs are from fuel combustion.
CO emissions are 0.21 lbs from fuel combustion.
Pb emissions of 0.00002 lbs are from fuel combustion.
TSP emissions of 0.56 lbs are from fuel combustion.
CO_2 emissions of 0.52 tons are from fuel combustion.
CH_4 emissions of 0.39 lbs are from fuel combustion.
NMVOC emissions of 0.056 lbs are from fuel combustion.

Table D.4.7 Steel Parts Stamping

Process Name	Steel Parts Stamping
Geographic Location	National Average - U.S.
Timeframe	Unknown
Process Description	Stamping of automobile parts out of steel

	Total Annual		*per Ton of Parts*	
	Value	Units	Value	Units
Inputs				
1 steel sheet			1.4	ton
2 fuel oil 6/7			4.30E+06	Btu
Outputs				
Products				
3 steel stamped parts			1	ton
4 steel scrap			0.4	ton
[illegible]				
5 NO_x			0.86	lb
6 SO_x			3.4	lb
7 CO			0.14	lb
8 Pb			0	lb
9 PM_{10}			NA	
10 TSP			0.43	lb
11 CO_2			500	lb
12 CH_4			0.13	lb
13 NMVOCs			0.01	lb
14 Other GHGs			NC	

Note: TSP emissions of 0.43 lbs are from fuel combustion.
CO2 emissions of 0.25 tons are from fuel combustion.
CH4 emissions of 0.13 lbs are from fuel combustion.
NMVOC emissions of 0.01 lbs are from fuel combustion.

Table D.4.8 Iron Casting

Process Name	Iron Casting			
Geographic Location	National Average - U.S.			
Timeframe				
Process Description	Cupula furnace processing of iron and steel scrap			
	Total Annual		***per Ton of Castings***	
	Value	Units	Value	Units
Inputs				
1 pig iron			0.13	ton
2 scrap steel			0.87	ton
3 coke			3.20E+07	Btu
Outputs				
Products				
4 iron castings			1	ton
Airborne Emissions				
5 NO_x			22.4	lb
6 SO_x			38.4	lb
7 CO			0.64	lb
8 Pb			0.016	lb
9 PM_{10}			NA	
10 TSP*			3.2	lb
11 CO_2			9200	lb
12 CH_4			0.032	lb
13 NMVOCs			0.096	lb
14 Other GHGs			NC	

Note: NO_x emissions of 22.4 lbs are from fuel combustion.
SO_x emissions of 38.4 lbs are from fuel combustion.
CO emissions of 145 lbs are process related and 0.64 lbs from fuel combustion.
Pb emissions of 0.016 lbs are from fuel combustion.
CO_2 emissions of 4.6 tons are from fuel combustion.
CH_4 emissions of 0.032 lbs are from fuel combustion.
NMVOC emissions of 0.096 lbs are from fuel combustion.
* TSP emissions of 3.1 lbs (0.7-8.0) are process related and 3.2 lbs are from fuel combustion. However, TSP was incorrectly included in final study calculations as 3.2 rather than 6.3. This error is not expected to impact study conclusions.

Table D.4.9 Bauxite Extraction

Process Name	Bauxite Extraction
Geographic Location	Overseas
Timeframe	1980 materials, 1995 emissions
Process Description	Mining of bauxite ore, including blasting and transportation

	Total Annual		*per Ton of Bauxite*	
	Value	Units	Value	Units
Inputs				
1 fuel oil 2/4			625000	Btu
2 explosives			0.09	lb
Outputs				
[illegible]				
3 bauxite ore			1	ton
[illegible]				
4 NO_x			0.75	lb
5 SO_x			0.5	lb
6 CO			0.03	lb
7 Pb			0.0001	lb
8 PM_{10}			NA	
9 TSP			0.36	lb
10 CO_2			120	lb
11 CH_4			0.003	lb
12 NMVOCs			0.006	lb
13 Other GHGs			NC	

Note: NO_x emissions are from fuel combustion.
SO_x emissions are from fuel combustion.
CO emissions are from fuel combustion.
TSP emissions of 0.30 lbs (range 0.21-0.38) and 0.06 lbs are from fuel combustion.
CO_2 emissions are 0.06 from fuel combustion.
CH_4 emissions of 0.003 lbs are from fuel combustion.
NMVOC emissions are from fuel combustion.

Table D.4.10 Alumina Production

Process Name	Alumina Production
Geographic Location	National Average - U.S.
Timeframe	1989
Process Description	Refining of bauxite ore to alumina via the Bayer process

	Total Annual		*per Ton of Alumina*	
	Value	Units	Value	Units
Inputs				
1 bauxite ore			2.53	ton
2 lime			92	lb
3 caustic soda			451	lb
4 bituminous coal			3.90E+05	Btu
5 natural gas			9.39E+06	Btu
6 electricity			2.05E+02	kWh
7 fuel oil 6/7			3.00E+04	Btu
Outputs				
Products				
8 alumina			1	ton
Airborne Residuals				
9 NO_x			2.2	lb
10 SO_x			8	lb
11 CO			0.32	lb
12 Pb			0.00015	lb
13 PM_{10}			NA	
14 TSP			17.78	lb
15 CO_2			1200	lb
16 CH_4			0.029	lb
17 NMVOCs			0.027	lb
18 Other GHGs			NC	
Liquid-borne Residuals				
19 Wastewater			NC	
Solid-borne Residuals				
20 Nonhazardous			2080	lb
21 Hazardous			NC	

Note: NO_x, SO_x, CO, CO_2, CH_4, and NMVOC emissions are from fuel combustion.
TSP emissions are 16.81 lbs (range 2.1-31.6 controlled) process and 0.98 lbs from fuel combustion.
Non-Hazardous wastes include 2000 lbs of red mud and 80 lbs of spent liquid TDS.

Table D.4.11 Aluminum Ingot Production via Hall-Heroult Process

Process Name	Aluminum Ingot Production (Hall Process)
Geographic Location	National Average - U.S.
Timeframe	1989 materials, 1995 emissions
Process Description	Electroltic reduction of alumina to aluminum via the Hall-Heroult process

	Total Annual		*per Ton of Alumina*	
	Value	Units	Value	Units
Inputs				
1 alumina			1.9	ton
2 aluminum flouride			0.019	ton
3 cryolite			0.01	ton
4 coke*			4.78E-01	ton
5 natural gas			3.10E+06	Btu
6 electricity			1.44E+04	kWh
7 bituminous coal			3.80E+05	Btu
8 pitch			3.60E+06	Btu
Outputs				
[illegible]				
9 aluminum ingot			1	ton
[illegible]				
10 NO_x			9	lb
11 SO_x			47.3	lb
12 CO			0.254	lb
13 Pb			0	lb
14 PM_{10}			NA	
15 TSP			41.5	lb
16 CO_2			3740	lb
17 CH_4			0.024	lb
18 NMVOCs			0.21	lb
19 Other GHGs			NC	
20 gaseous flouride			11.7	lb
21 particulate flouride			7.7	lb
22 HF			1.13	lb
[illegible]				
23 Wastewater			NC	
[illegible]				
24 Nonhazardous			NC	
25 Hazardous			71	lb

Note: NO_x emissions are 9 lbs process from fuel combustion.
SO_x emissions are 30.4 lbs process and 16.9 lbs from fuel combustion.
CO, CO_2, CH_4, and NMVOC emissions are from fuel combustion.
TSP emissions are 40 lbs (19.3-60) process and 1.5 lbs from fuel combustion.
Gaseous flouride emissions range from 6.6-17.8 lbs.
Particulate flouride emissions range from 3.2-12.2 lbs.
Hazardous wastes are 71 lbs of spent pot liner.

* Coke was incorrectly included in the final study calculations as 4.78E-01 rather than 4.25E-01. This error is not expected to impact study conclusions.

Table D.4.12 Virgin Aluminum Castings Production

Process Name	Aluminum Casting Production #1			
Geographic Location	National Average - U.S.			
Timeframe	1989			
Process Description	Melting of aluminum ingots to produce castings (Aluminum melt and cast)			
	Total Annual		*per Ton of Castings*	
	Value	Units	Value	Units
Inputs				
1 aluminum ingots			1.43	ton
2 natural gas			4.20E+06	Btu
3 fuel oil 6/7			1.30E+05	Btu
4 electricity			73	kWh
Outputs				
[illegible]				
5 aluminum castings			1	ton
6 aluminum scrap			0.43	ton
[illegible]				
7 NO_x			0.88	lb
8 SO_x			3.5	lb
9 CO			0.14	lb
10 Pb			0	lb
11 PM_{10}			NA	
12 TSP			0.43	lb
13 CO_2			500	lb
14 CH_4			0.014	lb
15 NMVOCs			0.0013	lb
16 Other GHGs			NC	

Note: All emissions are from fuel combustion.

Table D.4.13 Fabrication of Aluminum Mill Products

Process Name	Fabrication of Aluminum Mill Products			
Geographic Location	National Average - U.S.			
Timeframe	1989			
Process Description	Rolling of aluminum sheet			
	Total Annual		***per Ton of Mill Prdts***	
	Value	Units	Value	Units
Inputs				
1 aluminum castings			1.45	ton
2 natural gas			6.05E+06	Btu
3 fuel oil 6/7			4.90E+05	Btu
4 electricity			7.20E+02	kWh
Outputs				
Products				
5 aluminum mill products (sheet)			1	ton
6 aluminum scrap			0.45	ton
[illegible]				
7 NO_x			1.4	lb
8 SO_x			5.2	lb
9 CO			0.22	lb
10 Pb			0	lb
11 PM_{10}			NA	
12 TSP			0.65	lb
13 CO_2			780	lb
14 CH_4			0.021	lb
15 NMVOCs			0.005	lb
16 Other GHGs			NC	

Note: All emissions are from fuel combustion.

Table D.4.14 Aluminum Parts Stamping

Process Name	Aluminum Parts Stamping			
Geographic Location	National Average - U.S.			
Timeframe	Unknown			
Process Description	Stamping of automobile parts out of aluminum			
	Total Annual		***per Ton of Parts***	
	Value	Units	Value	Units
Inputs				
1 aluminum mill products (sheet)			1.4	ton
2 fuel oil 6/7			4.30E+06	Btu
Outputs				
Products				
3 aluminum stamped parts			1	ton
4 aluminum scrap			0.4	ton
[illegible]				
5 NO_x			0.86	lb
6 SO_x			3.4	lb
7 CO			0.14	lb
8 Pb			0	lb
9 PM_{10}			NA	
10 TSP			0.43	lb
11 CO_2			500	lb
12 CH_4			0.13	lb
13 NMVOCs			0.01	lb
14 Other GHGs			NC	

Note: Pb emissions are negligible.
TSP emissions of 0.43 lbs are from fuel combustion.
CO_2 emissions of 0.25 tons are from fuel combustion.
CH_4 emissions of 0.13 lbs are from fuel combustion.
NMVOC emissions of 0.01 lbs are from fuel combustion.

Table D.4.15 Recycled Aluminum Castings Production

Process Name	Aluminum Casting Production #2
Geographic Location	National Average - U.S.
Timeframe	1990
Process Description	Melting of aluminum scrap to produce castings

	Total Annual		*per Ton of Castings*	
	Value	Units	Value	Units
Inputs				
1 aluminum scrap			1	ton
2 natural gas			3.85E+07	Btu
Outputs				
[redacted]				
3 aluminum castings			1	ton
[redacted]				
4 NO_x			7.7	lb
5 SO_x			31	lb
6 CO			1.27	lb
7 Pb			0	lb
8 PM_{10}			NA	
9 TSP			5.2	lb
10 CO_2			4400	lb
11 CH_4			0.12	lb
12 NMVOCs			0.1	lb
13 Other GHGs			NC	

Note: TSP emissions are 1.3 lb process and 3.9 lb from fuel combustion. All other emissions are from fuel combustion.

Table D.4.16 Recycled Aluminum Ingot Production

Process Name	Aluminum Ingot Production #2 (from scrap)
Geographic Location	National Average - U.S.
Timeframe	1989
Process Description	Melting of aluminum ingots to produce ingots

	Total Annual		*per Ton of Castings*	
	Value	Units	Value	Units
Inputs				
1 aluminum scrap			1	ton
2 natural gas			3.85E+07	Btu
Outputs				
Products				
3 aluminum ingots			1	ton
[illegible]				
4 NO_x			7.7	lb
5 SO_x			31	lb
6 CO			1.27	lb
7 Pb			0	lb
8 PM_{10}			NA	
9 TSP			5.2	lb
10 CO_2			4400	lb
11 CH_4			0.12	lb
12 NMVOCs			0.1	lb
13 Other GHGs			NC	

Note: TSP emissions are 1.3 lb process and 3.9 lb from fuel combustion. All other emissions are from fuel combustion.

Note: This process is assumed to be identical to the Recycled Aluminum Castings Production Process.

Table D.4.17 Copper Production

Process Name	Copper Mining through Wire Production
Geographic Location	Regional Average - Southwest
Timeframe	1980
Process Description	Copper sulfide ore mining; concentration, pyro-metallurgical processing, and production of copper wire

	Total Annual		*per Ton of Wire*	
	Value	Units	Value	Units
Inputs				
1 copper sulfide ore			164	ton
2 explosives			171	lb
3 lime			792	lb
4 steel balls/rods			300	lb
5 limestone			513	lb
6 silica ore			1640	lb
7 natural gas			2.83E+07	Btu
8 fuel oil 6/7			2.60E+07	Btu
9 electricity			5.01E+03	kWh
Outputs				
[illegible]				
10 copper wire			1	ton
11 gold			0.25	troy oz.
12 silver			10.5	troy oz.
13 sulfuric acid			2.3	ton
[illegible]				
14 NO_x			19.9	lb
15 SO_x			839.5	lb
16 CO			11.2	lb
17 Pb			0.201	lb
18 PM_{10}			NA	
19 TSP			92.4	lb
20 CO_2			8120	lb
21 CH_4			0.21	lb
22 NMVOCs			2.47	lb
23 Other GHGs			NC	
[illegible]				
24 Wastewater			NC	
25 liquid effluents			1350	ton
[illegible]				
26 Nonhazardous			NA	
27 tailings			160	ton
28 slag			3.1	ton
29 Hazardous			NA	
30 anode mud			12	lb

Note: NOx emissions of 19.9 lbs are from fuel combustion. SOx emissions of 800 lbs are process-related and 39.5 lbs are from fuel combustion. Process-related emissions are based on 90% emission control plus fugitives. CO emissions are 11.2 lbs from fuel combustion. Pb emissions are 0.2 lbs process-related and 0.001 lbs from combustion. TSP emissions are 86 lbs process-related and 6.4 lbs from fuel combustion. Process-related emissions are based on 90% control plus fugitives. CO2, CH4, and NMVOC emissions are from fuel combustion.

Table D.4.18 Plastics-Miscellaneous

Process Name	Plastics-Miscellaneous			
Geographic Location				
Timeframe				
Process Description	Average of 24% PP, 14% PET, 10% HDPE			
	Total Annual		***per Ton of Plastics***	
	Value	Units	Value	Units
Inputs				
1 fuel oil 6/7			4.28E+07	btu
Outputs				
Products				
4 plastic (avg)			1	ton
Airborne Residuals				
5 NO_x			8.2	lb
6 SO_x			45	lb
7 CO			1.3	lb
8 Pb			0.0012	lb
9 PM_{10}			NA	
10 TSP			4	lb
11 CO_2			7817	lb
12 CH_4			0.29	lb
13 NMVOCs			0.49	lb
14 Other GHGs			NC	

Table D.4.19 PP Production

Process Name	Propylene Polymerization			
Geographic Location				
Timeframe				
Process Description				
	Total Annual		***per Ton of PP***	
	Value	Units	Value	Units
Inputs				
1 propylene			1.05	ton
2 fuel oil 6/7			2.84E+07	btu
Outputs				
Products				
3 polypropylene			1	ton
Airborne Residuals				
4 NO_x			5.4	lb
5 SO_x			30	lb
6 CO			0.9	lb
7 Pb			0.0008	lb
8 PM_{10}			NA	
9 TSP			2.64	lb
10 CO_2			5200	lb
11 CH_4			0.19	lb
12 NMVOCs			0.05	lb
13 Other GHGs			NC	
14 Propylene			0.4	lb
Waterborne Residuals				
15 Wastewater			NC	
Solid Waste Residuals				
16 Nonhazardous			NC	
17 Hazardous			0.2	lb

Note: Hazardous wastes of 0.2 lbs are catalysts and treatment beds.

Table D.4.20 PET Production

Process Name	PET Production			
Geographic Location	National Average - U.S.			
Timeframe				
Process Description				
	Total Annual		***per Ton of Polyester***	
	Value	Units	Value	Units
Inputs				
1 mixed xylenes			0.79	ton
2 methanol			0.05	ton
3 ethylene glycol			0.7	ton
4 fuel oil 6/7			7.46E+07	Btu
Outputs				
Products				
5 PET			1	ton
6 light ends			0.15	
Airborne Residuals				
7 NO_x			14.2	lb
8 SO_x			79	lb
9 CO			2.2	lb
10 Pb			0.0021	lb
11 PM_{10}			NA	
12 TSP			7.04	lb
13 CO_2			13600	lb
14 CH_4			0.5	lb
15 NMVOCs			1.54	lb
16 Other GHGs			NC	

Table D.4.21 Rubber Production

Process Name	Styrene-Butadiene Rubber Production
Geographic Location	National Average - U.S.
Timeframe	1980 materials, 1995 residuals
Process Description	Cold emulsion process for styrene-butadiene rubber (SBR) production

	Total Annual		*per Ton of SBR*	
	Value	Units	Value	Units
Inputs				
1 styrene			0.22	ton
2 butadiene			0.71	ton
3 soap			0.07	ton
4 fuel oil 6/7			3.84E+07	Btu
Outputs				
[illegible]				
5 SBR			1	ton
[illegible]				
6 NO_x			7.3	lb
7 SO_x			41	lb
8 CO			1.2	lb
9 Pb			0.0011	lb
10 PM_{10}			NA	
11 TSP			3.5	lb
12 CO_2			7000	lb
13 CH_4			0.26	lb
14 NMVOCs			11.67	lb
15 Other GHGs			NC	

Note: NO_x emissions of 3 lbs are from fuel combustion.
SO_x emissions of 8 lbs process are from fuel combustion.
CO emissions of 0.37 lbs are from fuel combustion.
TSP emissions are 40 lbs (19.3-60) process and 1.5 lbs from fuel combustion.
CO_2 emissions of 0.91 tons are from fuel combustion.
CH_4 emissions of 0.07 lbs are from fuel combustion.
NMVOC emissions of 11.6 lbs are process-related and 0.1 are from fuel combustion.
Process-related emissions are mainly styrene and butadiene (emissions are uncontrolled).

Table D.4.22 Float Glass Production

Process Name	Float Glass Production			
Geographic Location	National Average - U.S.			
Timeframe	1985 materials, 1995 emissions			
Process Description	Melting of batch materials in reverberatory furnace, followed by flotation on molten tin			
	Total Annual		***per Ton of Glass***	
	Value	Units	Value	Units
1 sand			0.64	ton
2 limestone			0.2	ton
3 soda ash			0.22	ton
4 feldspar			0.1	ton
5 natural gas			1.49E+07	Btu
6 electricity			5.07E+02	kWh
7 fuel oil 6/7			4.60E+05	Btu
Outputs				
Products				
8 float glass			1	ton
[illegible]				
9 NO_x			11.1	lb
10 SO_x			14.1	lb
11 CO			0.49	lb
12 Pb			0	lb
13 PM_{10}			NA	
14 TSP			2.5	lb
15 CO_2			2100	lb
16 CH_4			0.045	lb
17 NMVOCs			0.4	lb
18 Other GHGs			NC	

Note: NO_x emissions are 8 lbs process and 3.1 lbs from fuel combustion.
SO_x emissions 1.8 lbs process and 12.3 from fuel combustion.
CO emissions are from fuel combustion.
TSP emissions are 1.0 lbs process and 1.5 lbs from fuel combustion.
CO_2 emissions of 0.15 tons process and 0.90 tons from fuel combustion.
CH_4 emissions are 0.045 lbs from fuel combustion.
NMVOC emissions are from fuel combustion.

Table D.4.23 Glass Fiber Production

Process Name	Glass Fiber Production			
Geographic Location	U.S. Average			
Timeframe	1985			
Process Description				

	Total Annual		*per Ton of Glass Fiber*	
	Value	Units	Value	Units
Inputs				
1 sand			0.64	ton
2 limestone			0.2	ton
3 soda ash			0.22	ton
4 feldspar			0.1	ton
5 natural gas			1.17E+07	btu
6 electricity			9.81E+02	kWh
7 fuel oil 6/7			3.10E+05	btu
Outputs				
[illegible]				
8 glass fiber			1	ton
[illegible]				
9 NO_x			25.4	lb
10 SO_x			25.6	lb
11 CO			3.1	lb
12 Pb			0.0004	lb
13 PM_{10}			NA	
14 TSP			1.2	lb
15 CO_2			1700	lb
16 CH_4			0.037	lb
17 NMVOCs			0.035	lb
18 Other GHGs			NC	
19 fluorides			2	lb

Note: NO_x emissions of 23 lbs are process-related and 2.4 lbs are from fuel combustion.
SO_x emissions of 16 lbs are process-related and 9.6 lbs are from fuel combustion.
CO emissions of 2.7 lbs (range of 2.0-3.5 lbs) are process-related and 0.40 lbs are from fuel combustion.
Pb emissions of 0.0004 lbs are from fuel combustion.
TSP emissions of 1.2 lbs are from fuel combustion.
CO_2 emissions of 0.51 tons are process-related and 0.70 tons are from fuel combustion.
CH_4 emissions of 0.037 lbs are from fuel combustion.
NMVOC emissions of 0.035 lbs are from fuel combustion.

Table D.4.24 Primary Lead Smelting

Process Name	Primary Lead Smelting
Geographic Location	National Average - U.S. (primarily Missouri)
Timeframe	1995
Process Description	Smelting of sulfide ore in blast furnace

	Total Annual		*per Ton of Lead*	
	Value	Units	Value	Units
Inputs				
1 lead sulfide ore			NA	
2 coke			9.55E-01	ton
Outputs				
Product				
3 lead			1	ton
Airborne Residuals				
4 NO_x			16.4	lb
5 SO_x*			19	lb
6 CO			0.47	lb
7 Pb**			0.19	lb
8 PM_{10}			NA	
9 TSP			1.9	lb
10 CO_2			6600	lb
11 CH_4			0.023	lb
12 NMVOCs			0.07	lb
13 Other GHGs			NC	

Note: NO_x emissions of 16.4 lbs are from fuel combustion.
CO emissions of 0.47 lbs are from fuel combustion.
TSP emissions of 1.9 lbs are from fuel combustion.
CO_2 emissions of 3.3 tons are from fuel combustion.
CH_4 emissions of 0.023 lbs are from fuel combustion.
NMVOC emissions of 0.07 lbs are from fuel combustion.

* SO_x emissions of 4.5 lbs are process-related and 28.1 lbs are from fuel combustion. However, SO_x was incorrectly included in the final study calculations as 19 lb rather than 32.6 lb. This error is not expected to impact study conclusions.

** Pb emissions of 0.07 lbs are process-related (expecially lead oxides) and 0.012 lbs are from fuel combustion. However, Pb was incorrectly included in the final study calculation as 0.19 rather than 0.082. This error could affect magnitude of final numerical study results, but it is unlikely that the conclusions of the study would be different.

Table D.4.25 Secondary Lead Smelting

Process Name	Secondary Lead Smelting			
Geographic Location	National Average - U.S.			
Timeframe	1992; emission factors 1995			
Process Description	Smelting of lead from scrap			
	Total Annual		***per Ton of Lead***	
	Value	Units	Value	Units
Inputs				
1 lead scrap		. . .	NA	
2 fuel oil 6/7			4.60E+06	Btu
Outputs				
Product				
3 lead			1	ton
Airborne Residuals				
4 NO_x			1.3	lb
5 SO_x			11.7	lb
6 CO			0.17	lb
7 Pb			0.2901	lb
8 PM_{10}			NA	
9 TSP			1.17	lb
10 CO_2			840	lb
11 CH_4			0.032	lb
12 NMVOCs			0.046	lb
13 Other GHGs			NC	

Note: NO_x emissions of 1.3 lbs are from fuel combustion.
SO_x emissions of 8 lbs are process-related and 3.7 lbs are from fuel combustion.
CO emissions of 0.17 lbs are from fuel combustion.
Pb emissions of 0.29 lbs are process-related (especially lead oxides) and 0.0001 lbs from fuel combustion.
TSP emissions include 0.71 lbs from process and 0.46 lbs from fuel combustion.
Lead emissions are not counted in TSP total.
CO_2 emissions of 0.42 tons are from fuel combustion.
CH_4 emissions of 0.032 lbs are from fuel combustion.
NMVOC emissions of 0.046 lbs are from fuel combustion.

Table D.4.26 Sulfuric Acid Production

Process Name	Sulfuric Acid Production
Geographic Location	Best Process - U.S.
Timeframe	1995
Process Description	Contact process for production of sulfuric acid from sulfur dioxide

	Total Annual		*per Ton of Lead*	
	Value	Units	Value	Units
Inputs				
1 sulfur dioxide			0.68	ton
Outputs				
[illegible]				
2 sulfuric acid			1	ton
[illegible]				
3 NO_x			NC	
4 SO_x			4	lb
5 CO			NC	
6 Pb			NC	
7 PM_{10}			NC	
8 TSP			NC	
9 CO_2			NC	
10 CH_4			NC	
11 NMVOCs			NC	
12 Other GHGs			NC	

Note: SO_x emissions of 4 lbs are process-related.
Not all inputs are accounted for.

Table D.4.27 Beta Alumina Production (Ceramic)

Process Name	Beta Alumina Production
Geographic Location	
Timeframe	1995
Process Description	Mining and refining of bauxite, reaction of alumina with sodium salts, sintering, and pressing into tubes

	Total Annual		*per Ton of Lead*	
	Value	Units	Value	Units
Inputs				
1 bauxite ore			NC	
2 explosives			NC	
3 lime			NC	
4 caustic soda			NC	
5 sodium salts			NC	
6 fuel oil 6/7			2.30E+08	Btu
Outputs				
Product				
7 electrolyte-beta alumina			1	ton
Waste/Byproduct				
8 NO_x			96	lb
9 SO_x			184	lb
10 CO			8.5	lb
11 Pb			0.007	lb
12 PM_{10}			NA	
13 TSP			23	lb
14 CO_2			42000	lb
15 CH_4			1.6	lb
16 NMVOCs			2.3	lb
17 Other GHGs			NC	

Note: NO_x emissions of 96 lbs are from fuel combustion.
SO_x emissions of 184 lbs process are from fuel combustion.
CO emissions of 8.5 lbs are from fuel combustion.
Pb emissions of 0.007 lbs are from fuel combustion.
TSP emissions of 23 lbs are from fuel combustion.
CO_2 emissions of 21 tons are from fuel combustion.
CH_4 emissions of 1.6 lbs are from fuel combustion.
NMVOC emissions of 2.3 lbs are from fuel combustion.

Table D.4.28 Cadmium Production

Process Name	Cadmium Production				
Geographic Location	National Average - U.S. (most zinc in Alaska)				
Timeframe	1976				
Process Description	Production as by-product of roasting and smelting or leaching of Zinc Sulfide ores				
	Total Annual		***per Ton of Cadmium***		
	Value	Units	Value	Units	
Inputs					
1 zinc ore			NC		
2 FO6/7			1.60E+08	btu	
Outputs					
Product					
3 sulfuric acid					
4 cadmium			1	ton	
Airborne Residuals					
4 NO_x			NC		
5 SO_x			4	lb	
6 CO			NC		
7 Pb			NC		
8 PM_{10}			NC		
9 TSP			NC		
10 CO_2			NC		
11 CH_4			NC		
12 NMVOCs			NC		
13 Other GHGs			NC		

Note: SO_x emissions of 4 lbs are process-related.
NC = Not calculated.

Table D.4.29 Nickel Production

Process Name	Nickel Production
Geographic Location	National Average - Canada
Timeframe	1994
Process Description	Underground mining, concentration, and smelting of metallic nickel from sulfide ores. Pruification by carbonyl process

	Total Annual		*per Ton of Lead*	
	Value	Units	Value	Units
Inputs				
1 nickel sulfide ore			50	ton
2 fuel oil 6/7			1.05E+08	Btu
Outputs				
Product				
3 lead			1	ton
4 platinum				
5 palladium				
Airborne Residuals				
6 NO_x			31.5	lb
7 SO_x			3284	lb
8 CO			3.9	lb
9 Pb			0.003	lb
10 PM_{10}			NA	
11 TSP			10.5	lb
12 CO_2			19200	lb
13 CH_4			0.74	lb
14 NMVOCs			1.1	lb
15 Other GHGs			NC	

Note: NO_x emissions of 31.5 lbs are from fuel combustion.
SO_x emissions of 3200 lbs process-related and 84 lbs are from fuel combustion.
CO emissions of 3.9 lbs are from fuel combustion.
Pb emissions of 0.003 lbs are from fuel combustion.
TSP emissions of 10.5 lbs are from fuel combustion.
CO_2 emissions of 9.6 tons are from fuel combustion.
CH_4 emissions of 0.74 lbs are from fuel combustion.
NMVOC emissions of 1.1 lbs are from fuel combustion.
NC = Not calculated.