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Modeling CO_2 Emissions Impact of Energy Efficiency

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Modeling CO_2 Emissions Impact of Energy Efficiency

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EPRI Project Manager
O. Siddiqui

ELECTRIC POWER RESEARCH INSTITUTE

3420 Hillview Avenue
Palo Alto, CA 94304-1338
USA

PO Box 10412
Palo Alto, CA 94303-0813
USA

800.313.3774
650.855.2121

askepri@epri.com

www.epri.com

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The following organization, under contract to EPRI, prepared this report:

Electric Power Research Institute

Cascade Consulting Partners

Charles Clark Group

NOTE

For further information about EPRI, call the EPRI Customer Assistance Center at 800.313.3774 or
e-mail askepri@epri.com.

Acknowledgments

The following organization, under contract to the Electric Power Research Institute (EPRI), prepared this report:

EPRI
3420 Hillview Avenue
Palo Alto, CA 94304

Principal Investigator
O. Siddiqui

Cascade Consulting Partners
240 East 15th Avenue
Eugene, OR 97401

Principal Investigators
T. Guardino
J. Kosic
T. Raterman

Charles Clark Group
163 Park Avenue
Palo Alto, CA 94306

Principal Investigator
C. Clark

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Product Description

This report details EPRI's continued efforts to model the marginal carbon dioxide (CO_2) emissions impact of energy efficiency. Though energy efficiency is intuitively recognized to reduce carbon emissions, a key barrier to its broader application is the lack of precision in attributing emissions reductions to specific program activities based on average emissions factors. This study refines and expands marginal CO_2 intensities of energy efficiency established as proof-of-concept by EPRI in 2008 (EPRI report 1016085) and subsequently expanded to a greater number of residential, commercial, and industrial end-uses under a variety of scenarios in 2009 (1017874). The objective of this research is to establish a standard methodology, set of CO_2 emissions intensities, and versatile calculator tool that may be sufficiently rigorous to calculate expected carbon emissions reductions that may be achieved by implementing specific types of end-use energy efficiency programs in different regions of the US.

Results & Findings

Marginal emissions values for end-use-specific energy efficiency measures were modeled using the EPRI National Electric System Simulation Integrated Evaluator (NESSIE), which simulates least-cost generation dispatch and capacity expansion over time. The project team updated the NESSIE model used in the 2009 study with the latest load and generation data from the EIA Annual Energy Outlook for 2010, and updated the model's representation of the future role of renewable resources. These enhancements included improved data sources describing regional wind and biomass resources, model enhancements to better reflect wind variability and economics of regional transfers, and sensitivity analyses to assess alternative scenarios for development of renewable generation.

In 2009, EPRI used the model to estimate CO_2 intensity of a broad range of residential, commercial, and industrial energy efficiency (EE) programs. These estimates were for programs targeted at twenty-three different end uses, using program-specific load shapes to specify impacts of energy efficiency on electric loads and system operation. In addition, the research investigated CO_2 intensity under several assumptions about how electric companies are likely to update their generation capacity requirements in response to EE savings.

A key extension of the 2010 study is the development of a user-friendly CO_2 Intensity Calculator as a stand-alone Microsoft Excel application. In 2009, the team designed alternative methods for understanding CO_2 impact of EE programs and integrated these methods into NESSIE. These approaches allowed flexible definition of how perception of EE impacts is likely to influence capacity planning decisions in the U.S. electric sector.

However, using NESSIE as an analysis tool requires significant application-specific modeling and programming knowledge.

This Calculator is a flexible tool that uses the full U.S. electric sector perspective of the NESSIE model, but is much simpler and more efficient to use. It leverages results of NESSIE simulations directly through a database that contains the hourly marginal CO_2 emissions produced by a series of carefully designed NESSIE simulation runs, under different CO_2 policies and EE perception levels. In addition, it leverages all EPRI regional data describing EE electric load impacts for the twenty-three energy efficiency measures developed in the 2009 study. This report simultaneously documents enhancements to the NESSIE model and serves as a user guide for operation of the CO_2 Intensity Calculator.

Challenges & Objective(s)

This report is appropriate for utility energy efficiency program planners and designers, as well as utility strategic planners and policy analysts involved in developing strategies to address greenhouse gas emissions. The analysis is intended to quantify the causal link between energy efficiency activities and reductions in greenhouse gas emissions on a marginal basis rigorous enough to pass market and regulatory scrutiny, yet practical enough for utilities to implement.

Applications, Values & Use

Continued EPRI research in this area is intended to eventually establish an industry-standard framework for calculating the carbon reduction impact of energy efficiency programs. The development roadmap calls for refinement of the modeling approach, improved customization to utility requirements, utility validation of methodology, and public review before industry stakeholders for eventual adoption as a standard basis to attribute emission reduction value to energy efficiency programs.

EPRI Perspective

While resource-conservation and economic benefits of energy efficiency to utilities and customers are well understand and generally measurable, societal benefits of energy efficiency have proven more elusive for policy stakeholders to quantify. The absence of a standard approach to quantify the emissions impact of energy efficiency poses an obstacle to its more widespread adoption. EPRI seeks to establish an analytically rigorous and credible framework to quantify the emissions impact of energy efficiency activities in a manner that balances the analytical rigor required of carbon policy regimes with the practicality for utilities and other program administrators to implement.

Approach

EPRI's NESSIE model was used to simulate the economic dispatch of resources and capacity expansion over time in scenarios with and without energy efficiency by major end-use category. The net difference in emissions between the two sets of simulations represents a reasonable proxy for the marginal carbon emissions intensity of energy efficiency as a function of end use, region, and time. The CO_2 Intensity Calculator provides a standalone platform for incorporating both NESSIE production simulation results and the best available information on EE measure impacts to define and evaluate a wide range of utility energy efficiency programs.

Keywords

Energy efficiency, End use, Carbon, Carbon-dioxide (CO_2), Greenhouse gas (GHG), Emissions, Load dispatch, Load shapes

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Section 1: Overview

Objective

This report details the third annual volume in an ongoing series of EPRI work to model the marginal carbon dioxide (CO_2) emissions impact of energy efficiency measures. Though energy efficiency is intuitively recognized to reduce carbon emissions, a key barrier to its broader application is the lack of precision in attributing emissions reductions to specific program activities based on average emissions factors. Chief among the barriers to inclusion of energy efficiency as an eligible category is the lack of precision in emissions reduction estimates based on average emissions factors.[1] This study builds on previous EPRI work that has established a proof-of-concept and advanced an approach to quantifying the marginal CO_2 impact of energy efficiency that may be sufficiently rigorous for regulators and carbon markets, while practical for utilities and other implementers of energy efficiency programs to adopt.[2] The specific extensions in 2010 featured in this third volume are:

1. Enhancements to the EPRI National Electric System Simulation Integrated Evaluator (NESSIE) used to calculate marginal CO_2 emissions through simulation of the US electric system; and
2. Development of a stand-alone CO2 Intensity Calculator to enable EPRI members to evaluate the CO2 impacts of their own energy efficiency measures.

In his chapter, we review the overall modeling approach for quantifying the CO_2 impacts of energy efficiency, and introduce the modeling structure of the CO_2 Intensity Calculator which incorporates this general methodology.

Modeling Approach

The general methodology used in this and earlier studies is designed to calculate the marginal CO_2 impact of energy efficiency measures. Emissions values for energy efficiency cannot be considered *marginal* unless they:

a) are end-use specific and account for *when* energy savings occur (i.e. end-use load shapes);

b) account for regional variations in electricity consumption due to underlying variations in weather and usage patterns;

c) account for region-specific generation mix, and by proxy, region-specific carbon-intensity of generation;

d) are based on a realistic simulation of economic generation dispatch;

e) are projected into the future under realistic assumptions of evolving capacity expansion.

The EPRI NESSIE model is the central modeling tool underlying this approach because it models least-cost generation dispatch and capacity expansion over time. EPRI originally developed NESSIE to study the impacts of regulations restricting the emission of greenhouse gases on the electric sector.

The process begins with the NESSIE base case, which simulates capacity expansion and dispatch results by NERC[3] region for the 2010 to 2050 time frame[4]. NESSIE models capacity additions to the existing

[1] The following EPRI report provide further information on the current treatment of energy efficiency in carbon emissions trading/offset markets and barriers to its more widespread inclusion: *Energy Efficiency in CO2 Emissions Trading: Giving Credit Where Credit Is Due*. EPRI, Palo Alto, CA: 2008. 1016903.

[2] Previous volumes in this series: (1) Modeling CO_2 Emissions Impact of Energy Efficiency: Proof of Concept. EPRI, Palo Alto, CA: 2008. 1016085. (2) Modeling CO_2 Emissions Impact of Energy Efficiency: Volume 2. EPRI, Palo Alto, CA: 2009. 1017874.

[3] North American Electric Reliability Corporation (NERC)

[4] Though NESSIE provides simulation runs in five year increments from 2010 to 2050, results through 2030 are emphasized since (a) this is the time horizon for the Energy Information Administration 2008 Annual Energy Outlook and (b) the longer the time period the greater the inherent uncertainty.

capacity net of retirements in a production simulation that estimates the dispatch of the electric system as it serves customer loads. The dispatch estimates many measures of interest, including the metric central to this study – CO_2. The base case is assumed to reflect a scenario in which a broad portfolio of energy efficiency programs has been deployed. In this regard, *the base case simulates load growth, capacity expansion, generation dispatch, and resultant CO_2 emissions, in the presence of multiple energy efficiency programs and measures*.

NESSIE provides the flexibility to adjust the projected growth in electricity demand, which drives capacity expansion, with demand-side measures such as energy efficiency programs. An energy efficiency measure can be modeled in NESSIE with its characteristic end use load shape, which can vary by NERC region in accordance to differences in climate, daylight hours, and other factors that affect usage patterns.

This study focused on energy efficiency measures addressing twenty-three major end uses in the residential, commercial, and industrial sectors, as depicted in Table 1-1:

Table 1-1
End Uses Modeled

Residential (10)	Commercial (8)	Industrial (5)
Central air conditioning	Space cooling	Motors (machine drive)
Space heating	Space heating	HVAC
Water heating	Ventilation	Lighting
Lighting	Water heating	Process Heating
Refrigerator	Lighting, interior	Other process uses
Dishwasher	Lighting, exterior	
Clothes washer	Office equipment[5]	
Clothes dryer	Refrigeration	
Television		
Personal computer		

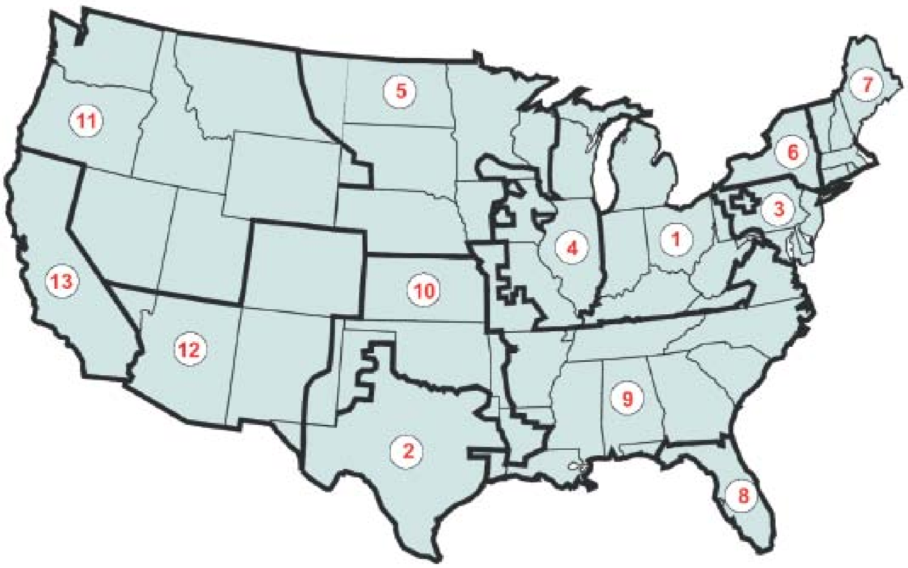
[5] Includes personal computers, servers, and related information technology (IT) equipment

Regional Variation

NESSIE reflects the informed judgments of both the Energy Information Administration and EPRI on how the current mix of generation assets is presently dispatched and how it will evolve on a regional basis, as defined by NERC regional designations. While NERC restructured its regional designations on January 1, 2006, generation and emissions data is still maintained using NERC's thirteen pre-2006 regional and sub-regional designations, which, accordingly, were applied in this study and are listed below and illustrated in Figure 1-1.[6]

1. East Central Area Reliability Council (ECAR)
2. Electric Reliability Council of Texas (ERCOT)
3. Mid-Atlantic Area Council (MAAC)
4. Mid-America Interconnected Network (MAIN)
5. Mid-Continent Area Power Pool (MAPP)
6. Northeast Power Coordinating Council – New York (NPCC-NY)
7. Northeast Power Coordinating Council – New England (NPCC-NE)
8. Southwest Power Pool (SPP)
9. Southeast Electric Reliability Council – Florida (SERC-FL)
10. Southeast Electric Reliability Council – non-Florida (SERC-STV)
11. Western States Coordinating Council – Pacific Northwest (WSCC-NWP)
12. Western States Coordinating Council – Rocky Mountain & Arizona areas (WSCC-RA)
13. Western States Coordinating Council – California & Southern Nevada area (WSCC-CNV)

[6] Does not include the separate NERC regions of Alaska and Hawaii, respectively, which each have distinct generation profiles, climates, and end-use load shapes.



Regions	
1	ECAR
2	ERCOT
3	MAAC
4	MAIN
5	MAPP
6	NPCC/NY
7	NPCC/NE
8	SERC/FL
9	SERC/STV
10	SPP
11	WSCC/NWP
12	WSCC/RA
13	WSCC/CNV

Figure 1-1
Map of U.S. NERC Regions

NESSIE includes detailed assumptions of how the generation mix will evolve in each region, taking into account relative costs of generation, potential renewable resources and portfolio standards, and considerations of CO_2 policy. In this way, a run of NESSIE's load dispatch simulation yields region-specific emissions rates.

The NERC region is an appropriate boundary territory within which to quantify marginal emissions rates. A NERC region represents a contiguous geographical boundary within which electricity is sold by generators – i.e. those who own and operate generation facilities, such as vertically integrated utilities or independent power producers – to load serving entities such as utilities, cooperatives, or municipalities. As such, it represents a boundary within which an incremental reduction in load (through energy efficiency activities) yields to an incremental reduction in generation output. An incremental reduction in load may not effect generation output within a more confined area (such as a utility service territory or even a state) because incremental generation could still be sold *outside* of the area; in this case the net emissions within the area would remain the same. The NERC region is a broad enough territory to overcome this parameter known as *leakage* in carbon emissions markets; overcoming leakage is generally considered a pre-requisite to inclusion of any project for emissions abatement credit[7].

The EPRI CO_2 Intensity Calculator

In 2009 EPRI used the NESSIE model to estimate the CO_2 intensity of a broad range of residential, commercial, and industrial energy efficiency programs. These estimates were for programs targeted at twenty-three different end uses, using program-specific load shapes to specify the impacts of energy efficiency on electric loads and system operation. In addition, the research investigated CO_2 intensity under several assumptions about how electric companies are likely to update their generation capacity requirements in response to energy efficiency savings.

A key extension of this study is to develop a user-friendly CO_2 Intensity Calculator as a stand-alone Microsoft Excel application. In 2009, the team designed alternative methods for understanding the CO_2 impact of EE programs and integrated these methods into NESSIE. These approaches allowed flexible definition of how the perception of EE impacts is likely to influence capacity planning decisions in the US electric

[7] More information on the issue of leakage is available from the following EPRI report: *Energy Efficiency in CO_2 Emissions Trading: Giving Credit Where Credit Is Due*. EPRI, Palo Alto, CA: 2008. 1016903.

sector. However, using NESSIE as an analysis tool requires significant application-specific modeling and programming knowledge.

The CO_2 Intensity Calculator developed in this study is designed to offer the following benefits to users:

1. accounts for capacity-expansion impacts from the EE programs,
2. allows flexible definition of EE impacts and EE impact perception levels (from zero perception, or marginal approach, to perfect perception,
3. customizes analysis to the specific characteristics of the EPRI member's company, and
4. runs quickly and easily.

This Calculator represents a flexible tool that utilizes the full US electric sector perspective of the NESSIE model, but is much simpler and more efficient to use. In addition, the CO_2 Intensity Calculator provides a sound blueprint for any future enhancements, such as implementation of a web-based application, or a customized implementation that directly incorporates member data for marginal CO_2 emissions and measure electricity impacts.

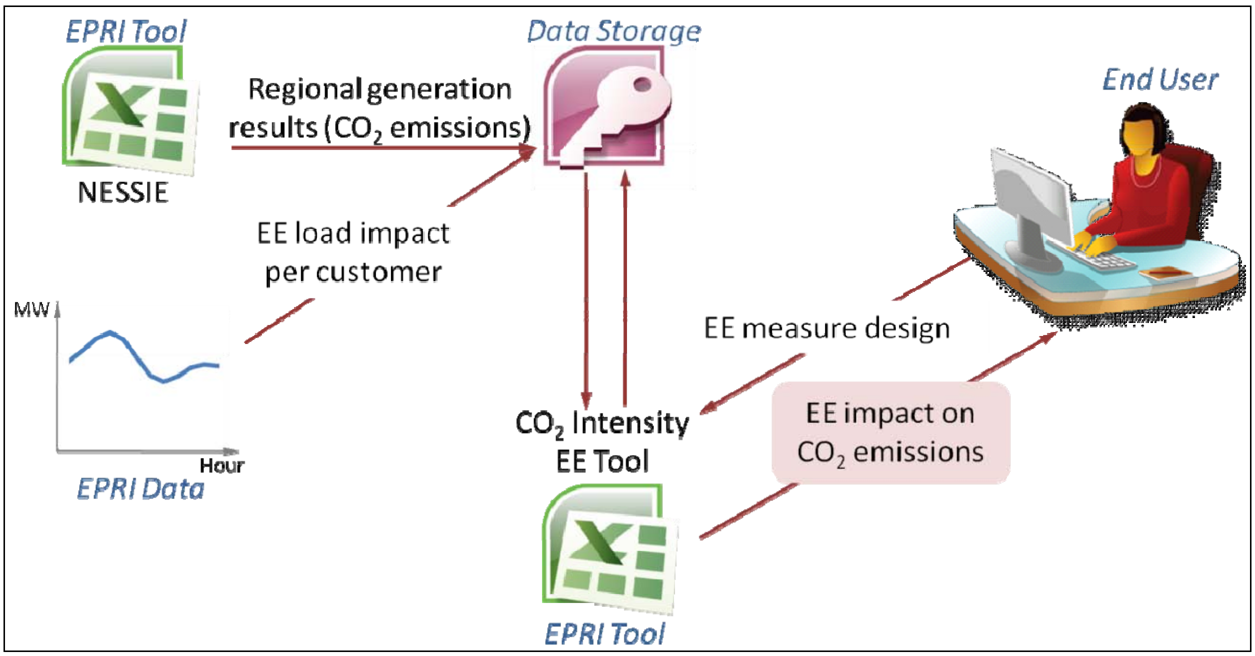


Figure 1-2
Conceptual Overview of CO_2 Intensity Calculator

Figure 1-2 illustrates the principal components of the EPRI CO_2 Intensity Calculator. As the figure shows, two key data elements are stored in the Calculator database

1. Regional generation results, including marginal CO_2 emissions, produced by a series of NESSIE simulation runs, and
2. Energy efficiency electric load impacts for the twenty-three energy efficiency measures developed in the 2009 study.

The CO_2 Intensity Calculator contains EPRI estimates of both total kWh impacts and hourly load profiles for each of the energy efficiency programs stored in the Calculator database. However, the Calculator allows users to override these EPRI estimates with company-specific data that better capture the impact of their own programs. The user can then select among the options for capturing the perceived savings from energy efficiency programs in future capacity planning - marginal, hybrid or full capacity expansion methods. In addition, the user can select whether to evaluate the impact of energy efficiency with or without a CO_2 policy, as well as select the planning region used to provide the marginal CO_2 intensity for the electric system. The Calculator outputs include CO_2 intensity (metric tons of CO_2 avoided per MWh of energy efficiency savings), total CO_2 saved, and kWh savings for each of the energy efficiency programs specified by the user.

Report Roadmap

The remainder of this report is organized as follows:

Chapter 2 Provides a detailed description of the enhancements to the data and methodology used in the NESSIE model;

Chapter 3 Presents the high-level results obtained with the updated NESSIE model, including base case capacity expansion, generation mix, and CO_2 emissions and key sensitivity cases;

Chapter 4 Contains an illustrated User's Guide to operating the CO_2 Intensity Calculator, including the screen layout, Calculator functionality, and interpretation of model results;

Chapter 5 Describes a scripted set of actions that a new Calculator user can walk through to learn the primary steps in defining, analyzing and managing a portfolio of energy efficiency measures.

Finally, the appendixes contain the updated CO_2 intensity results for the full EE portfolio (Appendix A) and for each of the twenty-three energy efficiency measures evaluated in previous studies (Appendix B).

Section 2: NESSIE Enhancements

The primary objectives of the 2010 NESSIE enhancements are twofold: 1) to update the model's demand growth and fuel price forecasts to better reflect current economic conditions and 2) provide a more realistic representation of the availability and economics of renewable resources, in particular, wind and biomass generation. Several important issues in the market for renewable generation motivate the work under this contract:

- *Demand Growth and Fuel Prices.* Estimates of future electric sector demand and energy have fallen substantially since the last update, which reflect short-term economic factors as well as the longer potential for increased energy efficiency. The EIA Annual Energy Outlook for 2010 provides the baseline electric demand and fuel price assumptions for this update. Prior NESSIE analyses were based on AEO 2008.
- *Wind Variability.* Although the potential for significant market penetrations of wind in the US appears to be high, generation from wind plants can be highly variable, and may not be well correlated with system loads. Systematic analysis of the hourly output and variability of wind generation is needed better understand the impact of large amounts of wind generation on system reliability. EPRI recently acquired a database containing 12 years of simulated hourly wind generation for the lower 48 US states. These data provide an opportunity to more effectively quantify the reliability effects of large-scale wind deployment.
- *Wind Geography.* Some the best wind resources in the US exist in parts of the country that are far from the largest load centers, for example, the Great Plains and the interior Northwest. To understand the economic opportunity of transferring surplus wind generation from these regions to meet demand elsewhere requires a careful understanding of the costs of transmission, line losses, and the value of the imported resource relative to native wind generation.
- *Biomass Supply.* Although biomass represents an attractive, non-emitting source of generation for the electric sector, this resource faces competing demands from the transportation sector and other climate change mitigation measures such as CO_2 sequestration, particularly under a CO_2 policy. The EPRI FASOM model provides a framework for quantifying the supply implications of these competing demands on the price and availability of biomass for the electric sector.
- *Solar Power Markets.* Previous NESSIE analyses of the future potential of renewable generation have indicated that central-station solar technologies are likely to play a limited role in the US generation mix. However, distributed solar photovoltaic generation (PV) may be significantly more competitive, given prevailing retail electricity rates. Also, opportunities for transferring solar thermal generation (from CSP) into regions with significant demand but little of no CSP resource may expand the role of sole in the future.

The objective of this project is to address each of these issues through a combination of enhancements to the NESSIE model, improved data sources to represent renewable resource potential, and application of the NESSIE model to quantify the impacts on capacity additions, generation mix, and CO_2 emissions. The following sections describe the NESSIE enhancements that address each of these issues.

Demand Growth and Fuel Prices

NESSIE uses the US Energy Information Agency's (EIA) NEMS model to provide a consistent set of demand growth, fuel price and emissions price assumptions that are inputs to NESSIE. NEMS is a general equilibrium model that simulates the entire energy/economic system of the US for 2010 to 2030. The NEMS runs incorporate EPRI's assumptions and technology cost and performance and future environmental policies, as well as EIA's assumptions about the future of the energy sector. The current version of NESSIE is based on the latest version of NEMS as reported in the Annual Energy Outlook 2010 (AEO 2010).

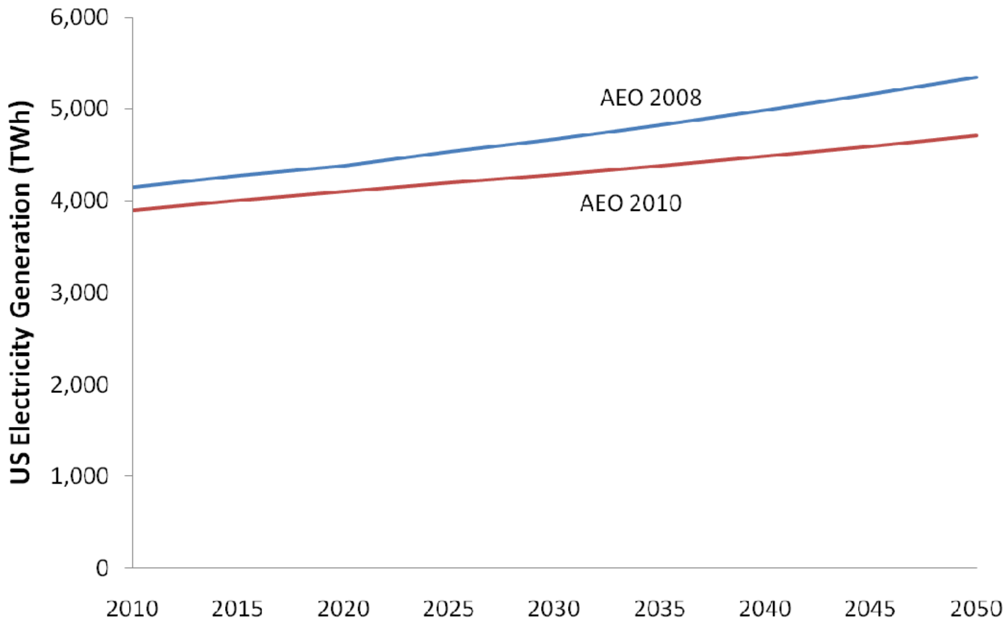


Figure 2-1
Growth in Annual Electric Generation

Figure 2-1 shows the impact of AEO 2010 demand growth assumptions, which are substantially lower than the AEO 2008 assumptions used in the last NESSIE update. This demand reduction reflects DOE's assessment that energy efficiency will play an increasing role in the future, and captures a lower starting point in 2010 due to the economic recession in the US which began at the end of 2007.

Wind Variability

In 2010 EPRI acquired access to a detailed data set for estimating the wind resource in the regions of the country. It is based on 8,760 hours of metered wind data for potential wind sites of a wide range of resource quality for the 12-year period from 1997 to 2008. This data set is being applied in a broad set of analytical activities at EPRI. For NESSIE, this data greatly improves the accuracy of the resource data, both by providing a broad set of representative wind sites, and by using the 12 years of data to provide a more statistically reliable data set than the one-year wind data samples used in prior NESSIE studies. In particular, the breadth of the data set in terms of geography, resource quality, and history provides a sound statistical basis to assess the variability or intermittency of wind output. Finally, the data set facilitates performing analyses that systematically correlate the wind power production to system loads. These analyses enable significantly more accurate calculation of the reliability impacts of this highly variable resource, in particular, the measure of capacity credit that should be assigned for wind capacity in system planning.

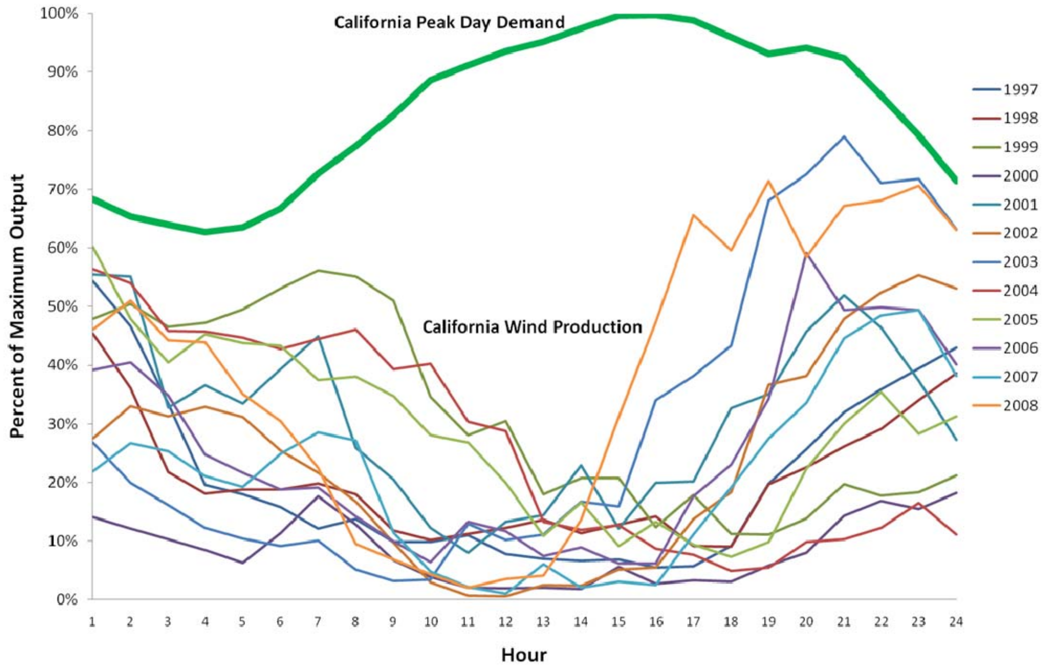


Figure 2-2
Twelve Years of Peak Day Wind Generation in California

Figure 2-2 illustrates how the greater level of wind generation detail in the new data source can provide a better understanding of the impact of wind on system reliability. The figure shows the hourly wind generation as a percent of capacity on the peak summer day in California, from native California wind sites with annual capacity factors in the 40 to 45 percent range. Twelve separate curves are plotted showing the wind output from these sites on hottest weekday of the year for each year from 1997 to 2008. Collectively the curves show a distinct pattern: during the times of day where the generation requirements of the system are highest, wind generation from otherwise high-quality wind sites provides only a small fraction (10 to 15 percent in most years) of their available generation capacity. This information ultimately gets reflected in the NESSIE production simulation by requiring additional generation resources to "back up" the wind generation to meet system reliability requirements during peak demand periods.

Wind Geography

Significant regional variations in available wind and solar resources create potential opportunities for economic transfers from regions with surplus wind resource (e.g., SPP or MAPP) to regions with limited wind resource (e.g., SERC). Such transfers may require significant investments in inter-regional transmission capacity, as well as effective integration of wind and solar generation into the importing region. In prior EPRI studies, inter-regional transfers were evaluated within NESSIE by manually shifting the amount of available wind resource from the surplus region to the limited region, and adjusting the net capacity factor of the transferred resource for transmission losses. In addition, NESSIE lacked the capability to reflect differences in the hourly load patterns of native domestic and imported wind resources, and required off-line calculations to incorporate transmission capital costs and define an optimal transfer amount.

In the 2010 NESSIE update, these offline calculations were replaced by modeling that internalized the economic decision making on wind transfers. The economic analysis recognizes both the cost of transmission to transport the wind energy between regions as well as the extra losses that occur due to the larger-than-normal transmission runs. In addition, the correlation between wind generation profiles from the exporting region and the system demand of the importing region are now captured explicitly in the evaluation of potential inter-regional transfers.

Table 2-1
Wind Transfers in the EPRI Base Case CO_2 Policy

Regional Transfer	Transmission Cost (2010 $ / MW – mile)		
	Low = $0	EPRI Base = $800	High = $1,600
MAPP to MAIN	20,000	12,668	0
MAPP to ECAR	15,000	10,681	0
MAIN to ECAR	9,820	0	0
SPP to FRCC	3,000	3,000	2,405
SPP to SERC/STV	24,000	24,000	0,290
WSCC/NWP to WSCC/RA	10,000	0	0
WSCC/NWP to WSCC/CNV	22,000	8,180	636
Total U.S. Wind Transfers	**103,820**	**58,529**	**12,331**
Total U.S. Wind Installed	**291,170**	**229,716**	**213,101**

Table 2-1 shows the economic interregional wind transfers calculated for the EPRI Base Case under three alternative transmission cost scenarios. Total inter-regional wind transfers and total US wind installations by 2050 are shown in the bottom two rows of the table. The results illustrate two important insights. First, the amount of capacity economically transferred depends critically on the transmission cost. Second, interregional transfers make up a significant fraction of the wind installed, nationally. Based on analysis of several wind integration studies in the literature, a transmission cost of $800 per MW mile was used in the base case, which is represented by the results in the middle column of the figure.

Biomass Supply

Estimating the amount of biomass fuel available for generating electricity at a particular price requires careful analysis of the economics and availability of this resource. First, there is no single fuel known as biomass. For example wood waste is different than agriculture waste, while growing switch grass has different economic characteristics than utilizing waste products. Each type of fuel must be transported to the point of use. In the case of fuels that are produced seasonally but used across the year, fuel must be inventoried for use in non-harvest months.

Previous work in NESSIE on biomass built up the supply curve of generating fuel by looking at the prices and availability these alternative types of biomass fuel for the electric sector. EPRI has more recently developed a modeling structure called FASOM that covers the agriculture and forestry sectors. This model can capture the competition for land and determine how the two sectors interact with the demands for the outputs for each sector.

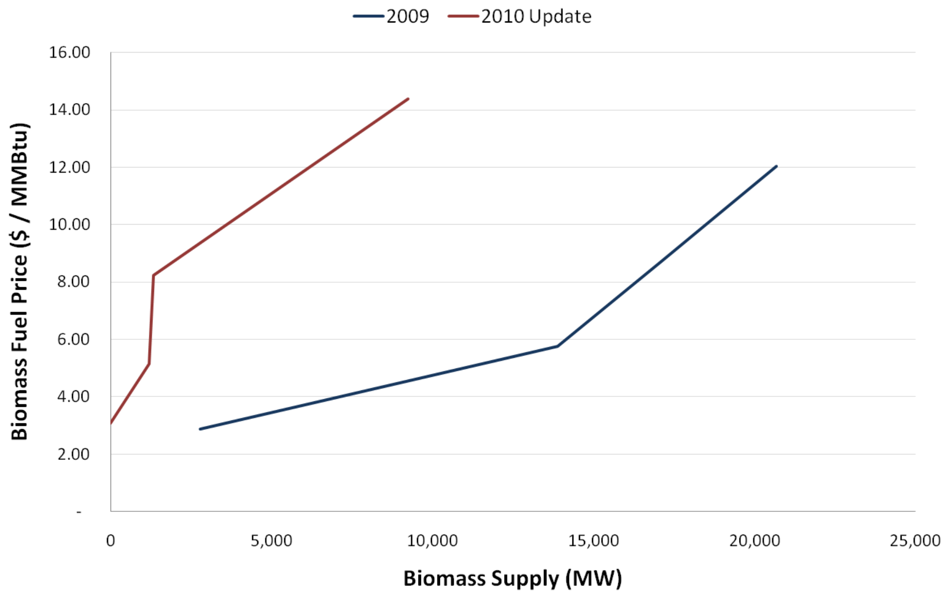


Figure 2-3
Biomass Supply Curves – 2009 and 2010 Update

The supply curves shown in Figure 2-3 reflect the costs of each of these alternative approaches to estimating biomass supply. The figure compares the supply curve produced for the 2010 NESSIE update to the curves used in the 2009 study. As the figure shows, the 2010 curve has substantially less available biomass fuel at any price point. This reduction in available supply will in turn lead to a lower utilization of biomass as a generation resource in the 2010 analysis cases.

EPRI has less experience estimating the supply economics for biomass than it does for renewable energy resources such as wind. Clearly, the assumptions for biomass supply have changed noticeably since the 2009 NESSIE update. Although EPRI has selected specific assumptions regarding biomass supply for this 2010 update, it should be noted that there is enough uncertainty in these assumptions that the 2009 and 2010 estimates should both be viewed as sensitivity cases.

Solar Power Markets

During 2010 the NESSIE team worked with solar experts from the National Renewable Energy Laboratory (NREL) to estimate the amount of impact that distributed solar photovoltaic generation (PV) could have. Their NREL model incorporated several aspects of the market for distributed solar PV that had not previously been addressed in NESSIE, which has focused primarily on the role of central-station solar technologies. First, since distributed solar PV is located on the customer site, the technology competes based on the relative economics of retail electric rates, rather than wholesale or bulk power prices. Second, relative to central-station solar, distributed solar PV has a distinct set of incentives that impact customer purchasing decisions. NREL based its market projections for distributed solar on prevailing regional retail rates, supplemented with information about the availability of specific incentives in different locations. Third, the NREL modeling leveraged detailed geographic data about the quality of solar resources across the country. The results of the model include estimates of regional distributed solar PV penetrations over time in the residential, commercial and industrial sectors.

The 2010 NESSIE update incorporated the NREL results to measure the impact of distributed solar PV on the generation requirements for each region. The impact of distributed solar is to reduce on-peak demand in 2030 by about 58 GW nationally, while reducing annual energy use by about 79 TWh. This energy and capacity was corrected to reflect that the distributed resource does not incur any transmission and distribution losses. When these T&D losses are properly accounted for, incorporating distributed solar PV into the NESSIE model has a small but significant impact on both capacity and generation requirements.

Section 3: Updated NESSIE Results

This chapter provides a snapshot of some the key results from the 2010 update of the NESSIE model. The results in this section include updated results for capacity additions by technology, generation mix over time, and the impact on CO_2 emissions from the electric sector. In addition, the results include sensitivity cases that show the importance of a CO_2 policy on each these metrics.

Base Case Results

Figure 3-1 shows the cumulative capacity additions for the EPRI Base Case from 2010 to 2050.

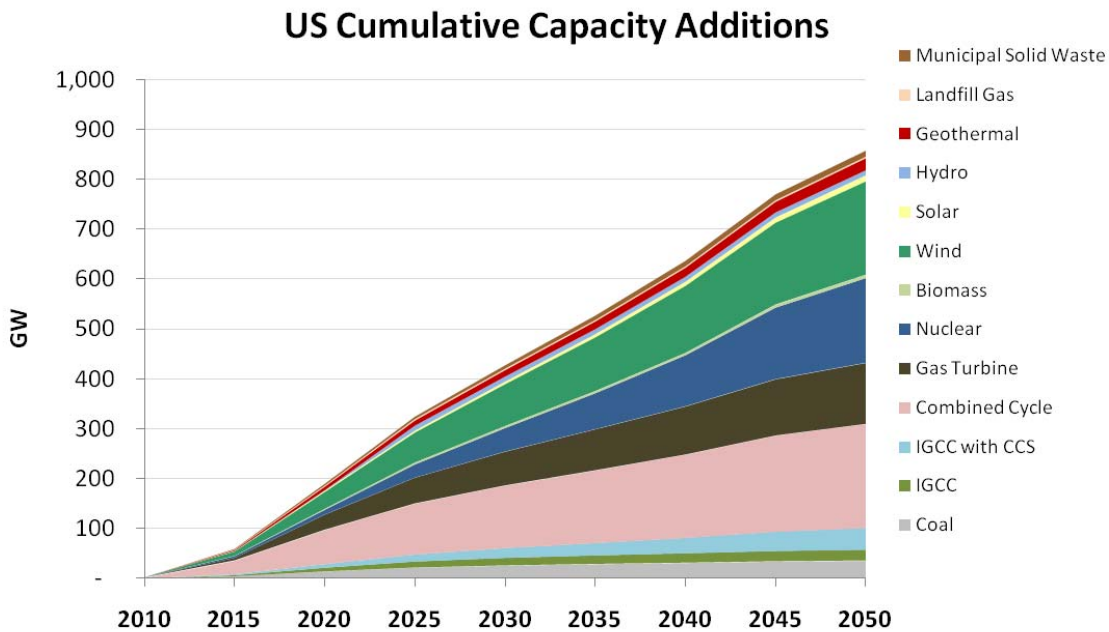


Figure 3-1
Base Case Cumulative Capacity Additions – 2010 to 2050

Base Case capacity additions show a reliance on nuclear, wind, and gas-fired generation. Nuclear and wind provide low-cost bulk power for the base-load duty cycle. The gas-fired capacity – a mix of combined-cycle plants and gas turbines – serve the intermediate and peaking duty cycles. A small amount of capacity from coal and IGCC is added, with much of the IGCC technology including Carbon Capture and Storage (CCS). Capacity from biomass, hydroelectric, geothermal, landfill gas, and municipal solid waste are limited by their resource base, providing value to the electric system but only a small contribution to the overall capacity mix. Penetrations of central-station concentrated solar power (CSP) remain low due to high capital costs across the model horizon and limited potential CSP in several regions. It should be noted that about 60,000 of distributed PV was added by 2030 at customer sites, and are not reflected in this chart.

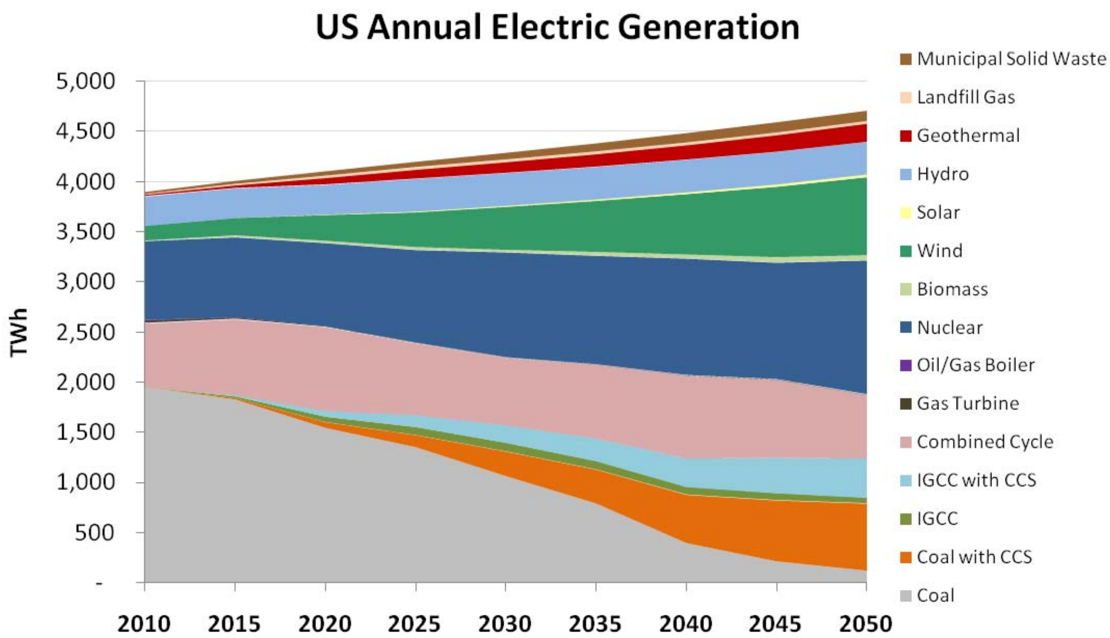


Figure 3-2
Base Case Generation Mix – 2010 to 2050

The generation by technology shown in Figure 3-2 reflects to a large extent the capacity additions shown in Figure 3-1. Coal generation is still prominent in the energy mix. However most of the generation is from plants with CCS. This occurs for two reasons. First, if a coal plant does not have CCS, its variable cost (including the cost of emitting CO_2) is high, driving it up the loading order and decreasing its capacity factor. Second, much of the existing coal capacity is either retrofitted with CCS or retired due to age and deteriorating economics. In fact, much of the non-CCS coal capacity additions shown in the previous figure are retrofitted subsequent to initial installation.

Among renewable resources, wind and geothermal generation make up the largest contribution to the overall generation mix. Nuclear and combined-cycle generation will continue to play a significant role in meeting generation requirements through 2050.

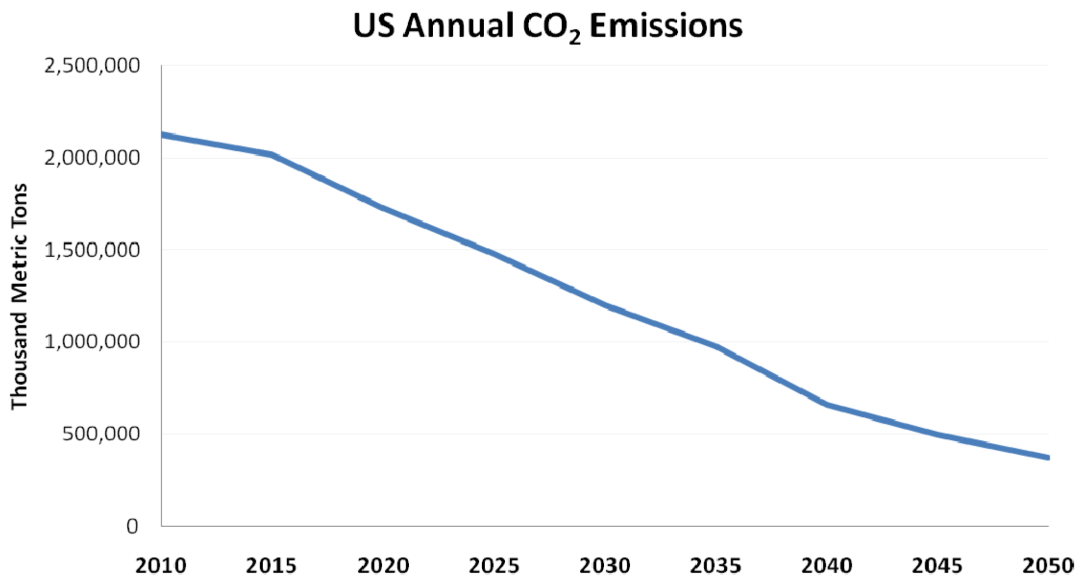


Figure 3-3
Annual CO_2 Emissions for the US Electric Sector

Figure 3-3 shows that CO_2 emissions decrease significantly over the model horizon - about 80 percent between 2010 and 2050. This decrease is the result of several significant changes in the electric system. First, about eighty percent of the 2010 emissions are produced by coal plants. NESSIE retires about half of the existing coal capacity based on declining economics that reflect the increasing cost of emitting CO_2. Most of the remaining coal capacity is retrofitted with CCS. Second, NESSIE assumes that significant amounts of new non-emitting nuclear capacity can be built in the future. Third, combined-cycle plants become more efficient over time, reducing required fuel, and therefore CO_2 emissions, per MWh of generation. Finally, the role of renewable technologies in the generation mix increases. In particular, the high penetrations of wind generation nationally provide a significant contribution to the generation mix output, with zero CO_2 emissions.

Sensitivity Analysis to CO_2 Policy

EPRI has long recognized the difficulty and uncertainty associated with understanding the CO_2 price consequences of national climate change policies. EPRI does not have an "official" forecast for the CO_2 price. Instead, EPRI performs analysis using a range of prices that represents a reasonable range of projected future prices. The insights learned from a set of sensitivity analysis cases evaluating alternative CO_2 price scenarios can be an important input for planning effective response strategies in the electric sector.

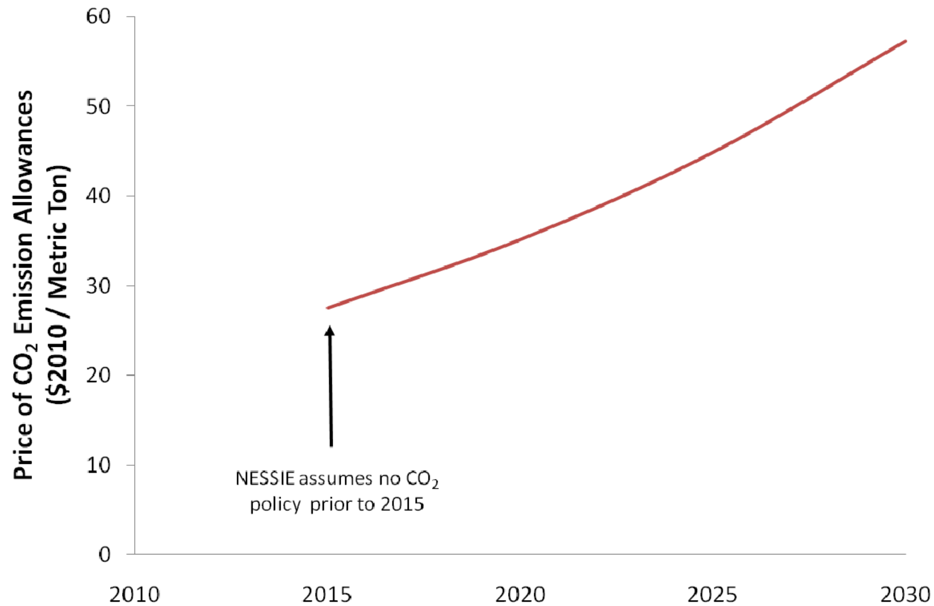


Figure 3-4
Price of CO_2 Emission Allowances in the EPRI Base Case

The sensitivity cases in this section will compare NESSIE results for the EPRI Base Case, which includes a climate policy that places a price on CO_2 emissions, to a scenario without a carbon policy. Figure 3-4 shows the price trajectory assumed in the EPRI Base Case. Both of these scenarios are available options within the EPRI CO_2 Intensity Calculator described at greater length in Chapters 4 and 5.

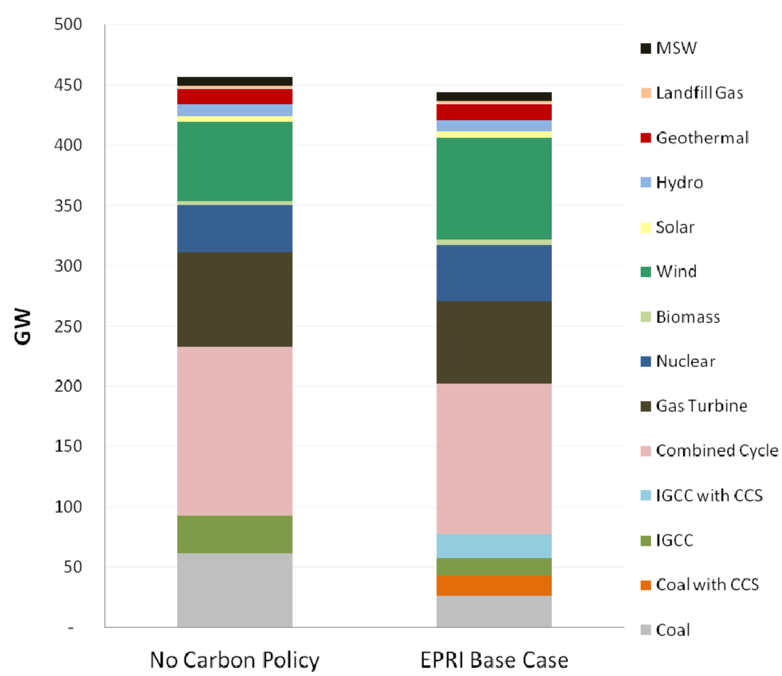


Figure 3-5
Capacity Additions by 2030 Comparing Two CO_2 Policy Scenarios

Figure 3-5 compares the cumulative capacity added through 2030 for the two different CO_2 policies. As the figure shows, the amount of low- and non-emitting generation capacity increases significantly as the CO_2 price increases. The total capacity installed is marginally lower when there is a CO_2 policy. A price on CO_2 increases wholesale market prices and drives down demand a by a small but significant amount. In addition the higher prices increase the yield of energy efficiency programs. In NESSIE we assume that Maximum Achievable Potential can be obtained with energy efficiency under a climate policy, but without a climate policy, only Realistic Achievable potential can be obtained. The impact of lower demand on capacity installations is partially offset by the additional amount of capacity that must be installed in the EPRI Base Case to back up the higher wind installations to maintain reliability. Installations of each of the other renewable generating technologies are similar across the two scenarios. The most important change from the No Carbon Policy to the EPRI Base Case is the significant decrease in new coal and IGCC capacity without CCS, and its replacement with the same technologies with CCS. Although not shown on this figure a significant amount of coal capacity without CCS is retrofitted with CCS by 2030 in response to the CO_2 prices in Figure 3-4.

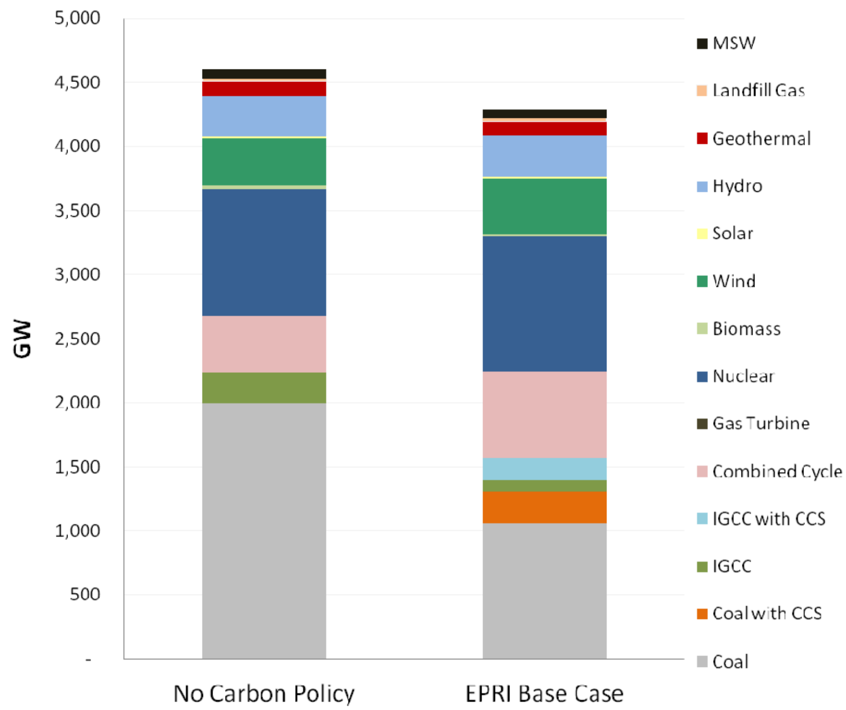


Figure 3-6
2030 Generation Mix Comparing Two CO_2 Policy Scenarios

Figure 3-6 shows the generation results for the year 2030 for the two cases. The comparison of generation mix results for the two cases is driven strongly by the different CO_2 price levels. Higher CO_2 prices depress the output of coal plants and increase the amount of coal generation from plants with CCS. As coal-fired generation is reduced, it is replaced with combined-cycle gas generation (that has a lower CO_2 emission rate), renewable generation, and to a lesser extent, nuclear. The lower amount of total energy generated represents the effects of price response and energy efficiency program effectiveness discussed above.

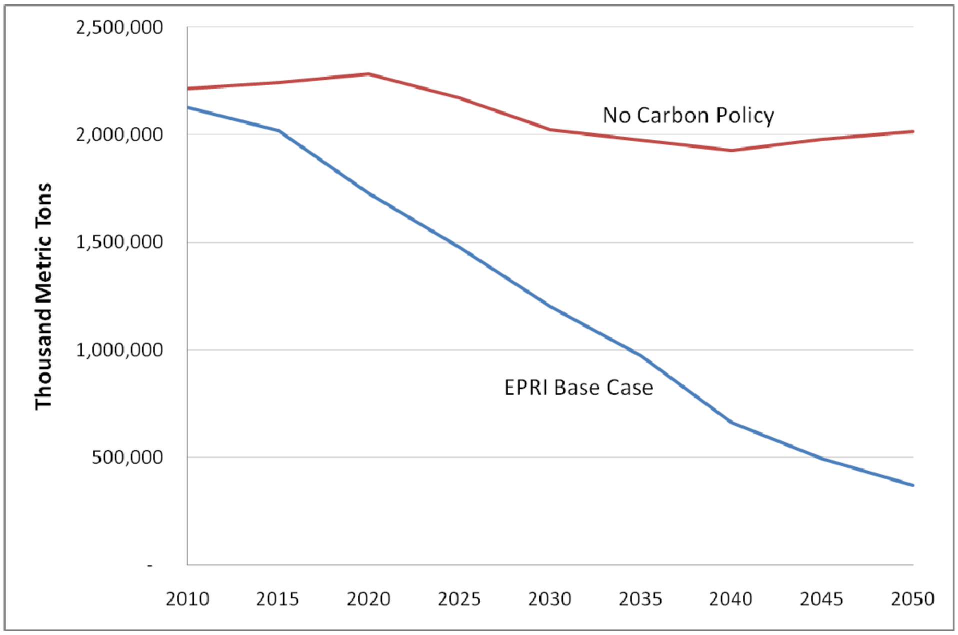


Figure 3-7
Annual CO_2 Emissions Comparing Two CO_2 Policy Scenarios

Finally, Figure 3-7 compares the change in annual CO_2 emissions over time, with and without a CO_2 policy. As the figure shows, CO_2 output from the US electric sector under the EPRI Base Case is reduced by roughly 80 percent, as compared to a scenario with No Carbon Policy.

Section 4: Users Guide to CO_2 Intensity Calculator

This chapter provides an overview of the functionality of the CO_2 Intensity Calculator that was summarized in Chapter 1. Specifically, the chapter provides a "how-to" manual for launching the application, navigating among Calculator's user screens, and performing each of the Calculator functions needed to define and evaluate energy efficiency programs.

Application Launch

The application is launched by clicking on the application file icon. As the application is launching it will be executing two important processes:

1. Establishing a connection with the database.
2. Initializing the static data in the application.

If the installation directions are followed, then these two processes will happen internally without any input needed from the user.

However, if the database has not been properly labeled or located, then the application will prompt the user to make this connection. The process for the application locating the database is as follows:

- The application will first search for the database named "EE_Calculator_DB.mdb" in the same directory where the application is located.
- If the database is not found here, then the application will attempt to open the database that was used the last time the application was used.
- If this database is not located, then a windows file dialog will be shown allowing the user to directly select the database file. At this point the user should locate the database and select it.
- If the selected file is not a valid database, then the user will be queried for a database until a valid database is located.
- If the user cannot locate a valid database, then the user can exit the application.
- Note - The application will not run properly without a valid database.

Once the database link has been established the application will proceed to load the initial static data. This will occur without requiring further input from the user. The launch process will result in the display of the Welcome Screen, described below.

Application Layout

This section will review the user interface layout of the screens of the EE Application. There are three main screens in the application:

1. **Welcome** – This screen is the opening screen of the application
2. **Program Definition Screen** - This screen contains all of the necessary controls to create, review and manage energy efficiency measures.
3. **Run Analysis Screen** – This screen is the location for analyzing the energy efficiency measures that have been created. Multiple measures can be selected and their results graphically compared.

Each of these screens has multiple controls and displays. The specifics for each control or display are described below.

Screen I - Welcome

The "Welcome" screen serves as the opening screen of the application. This screen contains information regarding the date and version of the application, as well as buttons to navigate through the other screens in the Calculator.

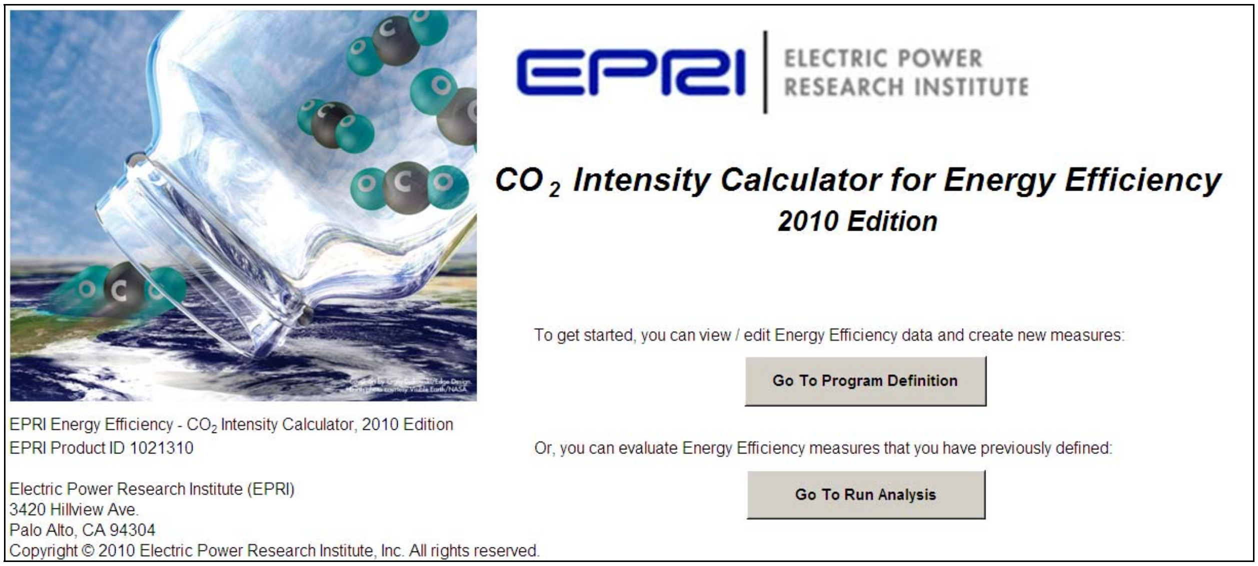


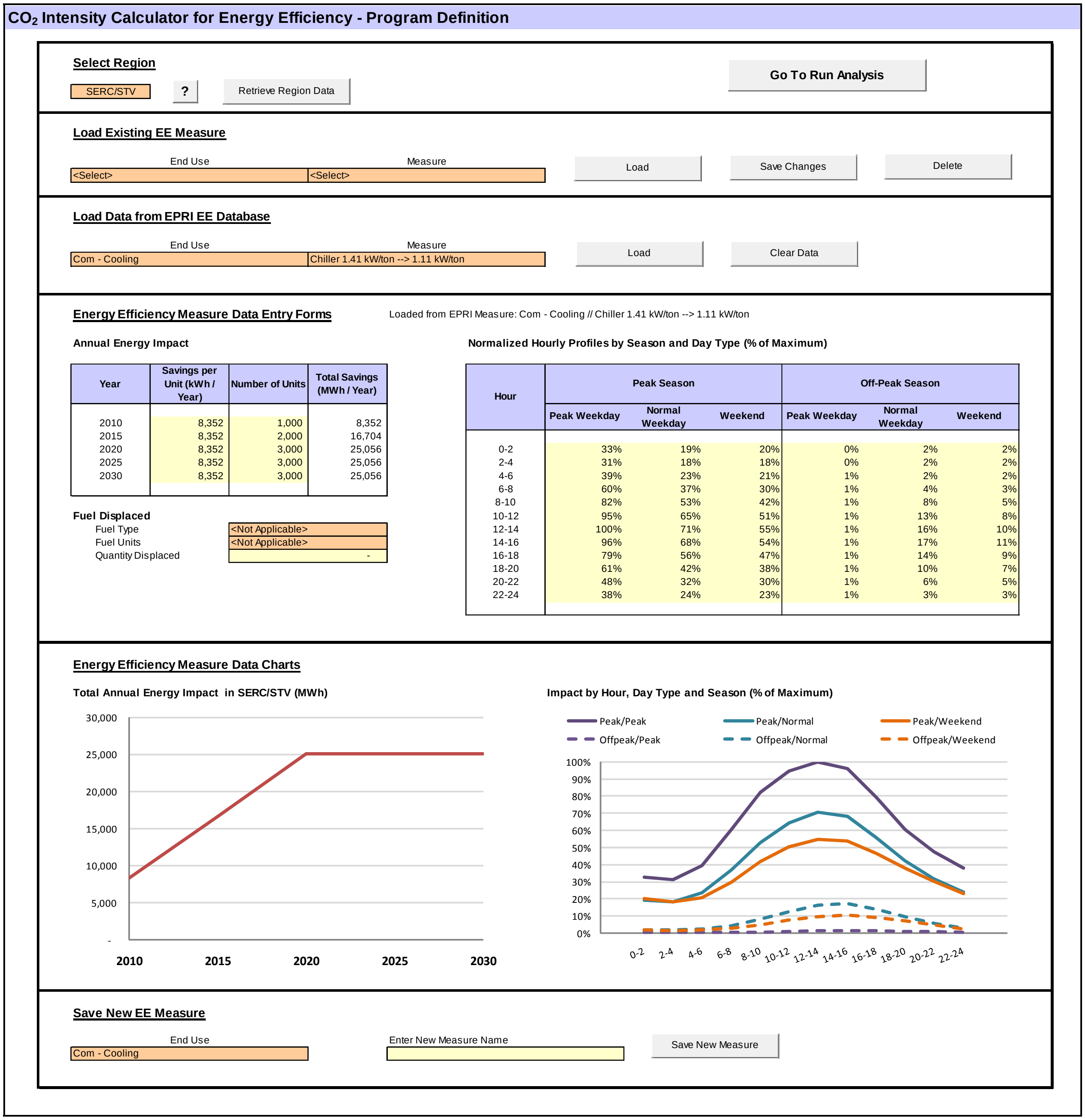
Figure 4-1
Welcome Screen

Go To Program Definition Button – Clicking this button will take you to the Program Definition Screen.

Go To Run Analysis – Clicking this button will take you to the **Run Analysis Screen**.

Screen 2 - Program Definition

This screen contains all of the controls necessary for creating and maintaining a set of energy efficiency measures. The user can retrieve an existing EPRI measure, edit the data specifics of a measure, save a new measure, save data changes to a previously created measure and delete a measure.



CO_2 Intensity Calculator for Energy Efficiency - Program Definition

Select Region

SERC/STV | ? | Retrieve Region Data | Go To Run Analysis

Load Existing EE Measure

End Use: <Select> | Measure: <Select> | Load | Save Changes | Delete

Load Data from EPRI EE Database

End Use: Com - Cooling | Measure: Chiller 1.41 kW/ton --> 1.11 kW/ton | Load | Clear Data

Energy Efficiency Measure Data Entry Forms

Loaded from EPRI Measure: Com - Cooling // Chiller 1.41 kW/ton --> 1.11 kW/ton

Annual Energy Impact

Year	Savings per Unit (kWh / Year)	Number of Units	Total Savings (MWh / Year)
2010	8,352	1,000	8,352
2015	8,352	2,000	16,704
2020	8,352	3,000	25,056
2025	8,352	3,000	25,056
2030	8,352	3,000	25,056

Fuel Displaced

Fuel Type	<Not Applicable>
Fuel Units	<Not Applicable>
Quantity Displaced	-

Normalized Hourly Profiles by Season and Day Type (% of Maximum)

Hour	Peak Season			Off-Peak Season		
	Peak Weekday	Normal Weekday	Weekend	Peak Weekday	Normal Weekday	Weekend
0-2	33%	19%	20%	0%	2%	2%
2-4	31%	18%	18%	0%	2%	2%
4-6	39%	23%	21%	1%	2%	2%
6-8	60%	37%	30%	1%	4%	3%
8-10	82%	53%	42%	1%	8%	5%
10-12	95%	65%	51%	1%	13%	8%
12-14	100%	71%	55%	1%	16%	10%
14-16	96%	68%	54%	1%	17%	11%
16-18	79%	56%	47%	1%	14%	9%
18-20	61%	42%	38%	1%	10%	7%
20-22	48%	32%	30%	1%	6%	5%
22-24	38%	24%	23%	1%	3%	3%

Energy Efficiency Measure Data Charts

Save New EE Measure

End Use: Com - Cooling | Enter New Measure Name: | Save New Measure

Figure 4-2
Program Definition Screen

The controls in this screen are divided into six sections:

1. Select Region
2. Load Existing EE Measure
3. Load Data from EPRI EE Database
4. Energy Efficiency Measure Data Entry Form
5. Energy Efficiency Measure Data Graphs
6. Save New EE Measure

The controls associated with each of these sections are described below.

Select Region

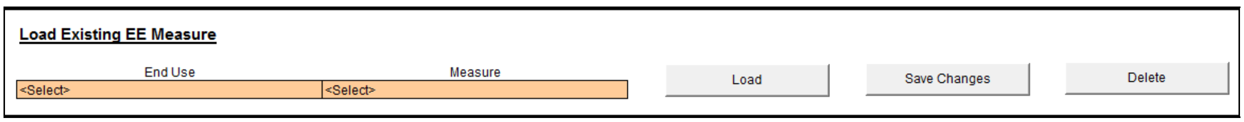
Region Selection Drop-Down – This list contains all of the NERC regions. The user selects a region and presses the **Retrieve Region Data** button to load the data into the current screen. (Note – These are the pre-2006 NERC regions, that are modeled in the most current NESSIE model analysis)

Region Help Button – Marked with a question mark **(?)**, this button brings up a window showing a map of the US with the pre-2006 NERC regions shown along with the NERC region labels.

Retrieve Region Data Button – Pressing this button will retrieve the measure data associated with NERC region shown in the **Region Selection Drop-Down**. When the data is retrieved the user will be able to manage measures for the selected region. Retrieving data for this **Program Definition Screen** will also set the region and retrieve data for the **Run Analysis Screen**.

Go To Run Analysis Button – Pressing this button will move the user to the **Run Analysis Screen**.

Load Existing EE Measure



End Use Drop-Down – The end uses for any user-created measures for the currently selected region will appear in this drop-down list. Selecting one of the end uses will cause the **Measure Drop-Down** to be populated. If no user-created measures exist for this region, then this drop-down box will be empty.

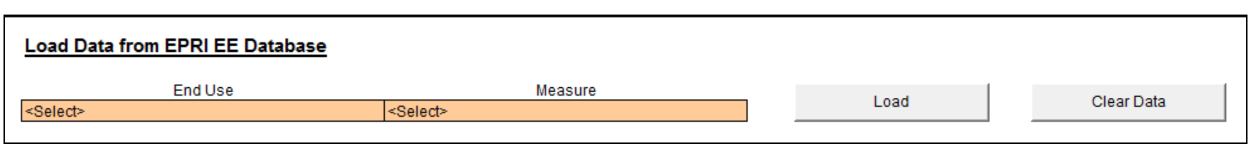
Measure Drop-Down – The user-created measures for the currently selected region and end use will appear in this drop-down. Until a region and end use are selected this list will be empty. Once a measure is selected here, the data will be loaded when the user presses the **Load Button**.

Load Button – If an end use and measure have been selected for this region, then the corresponding data for that measure will be loaded into the **Energy Efficiency Measure Data Entry Forms** by pressing this button.

Save Changes Button – If the user has changed the data for a particular measure and wants to save those changes, then this is the button to press. A valid measure has to be selected in the **Measure Drop-Down** in order to save changes. The changes are saved without verification or validation.

Delete Button – Pressing this button will result in the measure selected in the **Measure Drop-Down** being deleted. The user is asked via a pop-up window to verify that the deletion is intended. If the user clicks yes, then the measure is permanently deleted from the database.

Load Data from EPRI EE Database



End Use Drop-Down – The end uses for energy efficiency measures in the EPRI database are listed in this drop-down. When an end use is selected from the list the **Measure Drop-Down** box is populated with all measures in the EPRI database associated with the selected end use.

Measure Drop-Down – This drop-down will show all of the measures in the EPRI database associated with the end use selected in the **End Use Drop-Down**. If no end use is selected, then the **Measure Drop-Down** will be empty. The data for this measure will be loaded when the user presses the **Load Button**.

Load Button – If an end use and measure have been selected, then the corresponding data for that measure will be loaded into the **Energy Efficiency Measure Data Entry Forms** by pressing this button.

Clear Data Button – This button is used to clear the **Energy Efficiency Data Entry Forms**. Only the values in the display are cleared. The underlying data, whether corresponding to a user-created measure or an EPRI defined measure, will remain in the database. To effectively remove a user-defined measure, the **Delete Button** should be used.

Energy Efficiency Measure Data Entry Forms

This section serves as the entry area for all of the data underlying an energy efficiency measure. There are three ways in which a user can fill the data forms.

1. The user can enter all of the data manually
2. The user can load an already save user-defined measure (see section **Load Existing EE Measure** above)
3. The user can load the data from an EPRI-defined measure (see section **Load Data From EPRI EE Database** above)

For options 2 and 3 that involve loading data values from some already existing source, the end use and measure of the source will appear as a label at the top of this section along with an indication whether the origin is an EPRI or user-defined measure.

Energy Efficiency Measure Data Entry Forms

Loaded from EPRI Measure: Com - Cooling // Chiller 1.41 kW/ton --> 1.11 kW/ton

Annual Energy Impact

Year	Savings per Unit (kWh / Year)	Number of Units	Total Savings (MWh / Year)
2010	8,352	1,000	8,352
2015	8,352	2,000	16,704
2020	8,352	3,000	25,056
2025	8,352	3,000	25,056
2030	8,352	3,000	25,056

Fuel Displaced

Fuel Type	<Not Applicable>
Fuel Units	<Not Applicable>
Quantity Displaced	-

Normalized Hourly Profiles by Season and Day Type (% of Maximum)

Hour	Peak Season			Off-Peak Season		
	Peak Weekday	Normal Weekday	Weekend	Peak Weekday	Normal Weekday	Weekend
0-2	33%	19%	20%	0%	2%	2%
2-4	31%	18%	18%	0%	2%	2%
4-6	39%	23%	21%	1%	2%	2%
6-8	60%	37%	30%	1%	4%	3%
8-10	82%	53%	42%	1%	8%	5%
10-12	95%	65%	51%	1%	13%	8%
12-14	100%	71%	55%	1%	16%	10%
14-16	96%	68%	54%	1%	17%	11%
16-18	79%	56%	47%	1%	14%	9%
18-20	61%	42%	38%	1%	10%	7%
20-22	48%	32%	30%	1%	6%	5%
22-24	38%	24%	23%	1%	3%	3%

Annual Energy Impact Table / Savings per Unit – The values entered here show the amount of energy in kWh/Year that is saved by each installed unit of the measure. The **Total Savings** in energy will be calculated by multiplying this value by the number of units. There are five values in this column representing the five year intervals. A blank entry will be interpreted as zero.

Annual Energy Impact Table / Number of Units – The value represents the number of units of the measure installed. The **Total Savings** in energy will be calculated by multiplying this value by the number of units. There are five values in this column representing the five year intervals. A blank entry will be interpreted as zero.

Annual Energy Impact Table / Total Savings – The values in this column are calculated from the values for Savings per Unit and Number of Units entered by the user in the first two columns. The total savings value is show in MWh/Year.

Normalized Hourly Profiles by Season and Day Type Table – This table is used for entering the load profiles for the measure. The values will be entered as a percent of the maximum savings expected for the measure. The profile is broken into 12 two hour increments covering the 24 hours of the day. The data represents the percentage of the maximum savings expected. The data is in percentages. Decimal values will be represented as percentages as well.

The six columns represent six different profiles - the combinations of three day types and two season types:

- Peak Season, Peak Weekday
- Peak Season, Normal Weekday
- Peak Season, Weekend
- Non-Peak Season, Peak Weekday
- Non-Peak Season, Normal Weekday
- Non-Peak Season, Weekend

Fuel Displaced – The controls in this area all pertain to the case where the measure is expected reduce consumption of another fuel type. Defining the impact here will allow the calculation of the measure's impact on CO_2 consumption.

Fuel Displaced / Fuel Type – If a specific fuel type is being displaced by the energy efficiency measure, then that can be selected here. If this is not applicable to the measure being defined, then it can be left as <Not Applicable>. The fuel type options are:

- Natural Gas
- Coal
- Diesel/Fuel Oil
- Gasoline
- Average Oil
- <Not Applicable> - No fuel displacement is being analyzed

Fuel Displaced / Fuel Units – If a specific fuel is being displaced and has been selected in the **Fuel Type** control, then the user will also need to enter the units for the quantity of displaced fuel. The different choices of displaced fuel units are:

- Unit / Year - Unit depends on fuel type selection (e.g. Gallons for gasoline). **Quantity Displaced** will be multiplied by the **Number of Units** entered in **Annual Energy Impact** to determine CO_2 impact.
- MMBtu / Year - **Quantity Displaced** will be multiplied by the **Number of Units** entered in **Annual Energy Impact** to determine CO_2 impact.
- Unit / kWh - Unit depends on fuel type selection (e.g. Gallons for gasoline). **Quantity Displaced** will be multiplied by the **Total Savings** in **Annual Energy Impact** to determine CO_2 impact.
- Btu / kWh - **Quantity Displaced** will be multiplied by the **Total Savings** in **Annual Energy Impact** to determine CO_2 impact.
- <Not Applicable> - No fuel displacement is being analyzed

Fuel Displaced / Quantity Displaced – This number entry box allows the user to enter the quantity of displaced fuel. The units for the quantity entered here and how the value will be used is dependent on the choice of **Fuel Type**. The number cannot be negative. A blank entry will be interpreted as zero.

Energy Efficiency Measure Data Graphs

This section contains graphs that show a visual representation of the data entered in the **Energy Efficiency Measure Data Entry Forms** section.

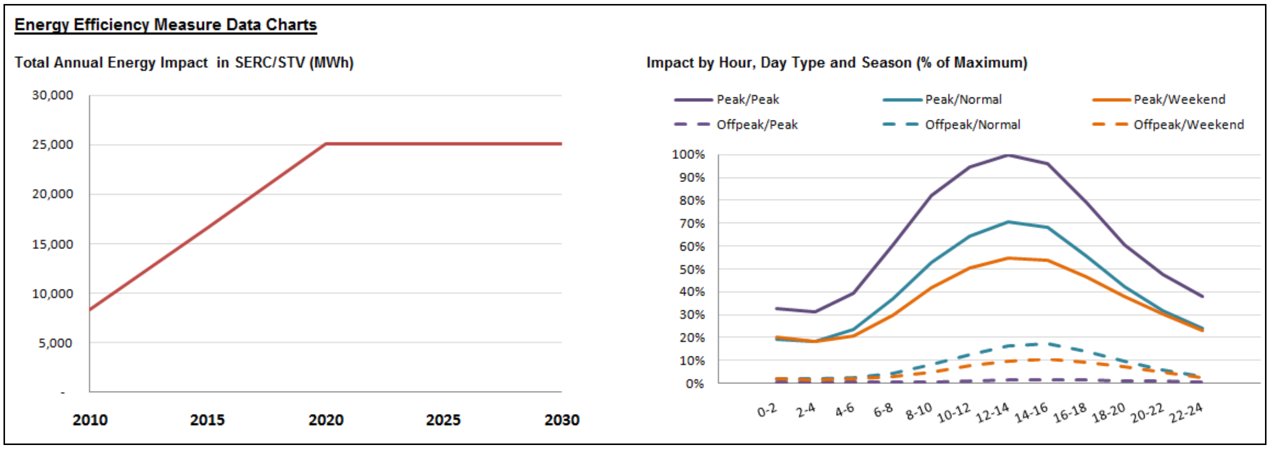


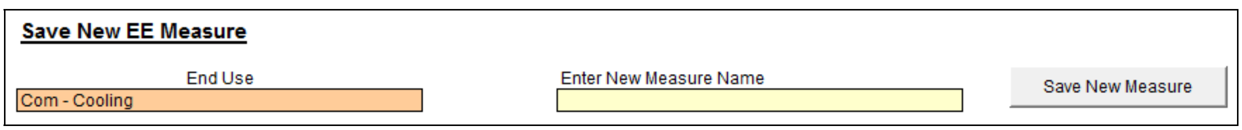
Figure 4-3
Total Annual Energy Impact (left) and Impact by Hour, Day Type and Season (right) Graphs

Total Annual Energy Impact – This graph, illustrated on the left in Figure 4-3, shows the **Total Savings** in MWh over the range of years.

Impact by Hour, Day Type and Season – This graph, illustrated on the right in Figure 4-3, shows the hourly profiles of energy saved as a percent of the maximum energy save, the six **Normalized Hourly Profiles by Season and Day Type** entered above. The solid lines indicate the peak season profiles and the dashed lines indicate the off-peak season profiles.

Save New EE Measures

This section is used to save the data entered in the **Energy Efficiency Measure Data Entry Forms** section as a new measure.



End Use Drop-Down – The end uses for energy efficiency measures in the EPRI database are listed in this drop-down. The user selects one to be associated with the new measure.

Enter New Measure Name Text Entry Box – The user types the name for the new measure in this entry box. The names are case sensitive.

Save New Measure Button – If the user has entered a **New Measure Name**, then this button press will save the data in the **Energy Efficiency Measure Data Entry Forms** as a new measure.

Screen 3 - Run Analysis

This screen contains all of the controls necessary for analyzing, comparing and graphing the measures created in the Program **Definition Screen**.

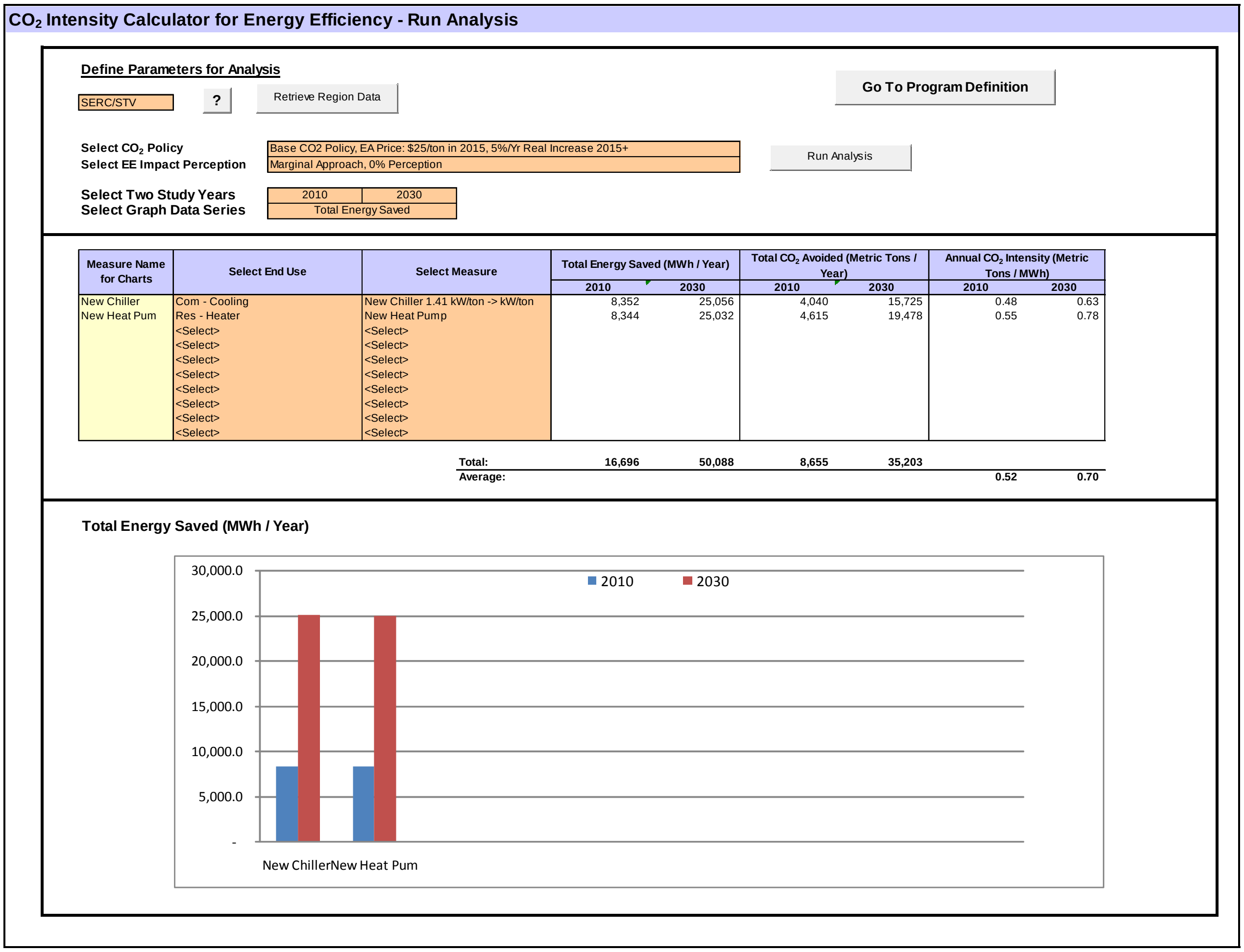
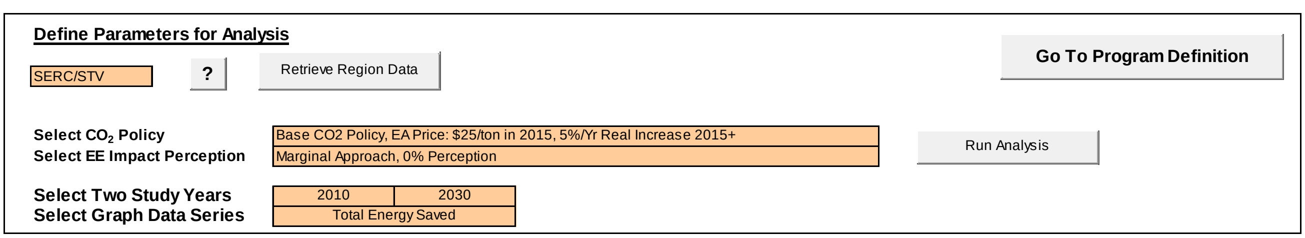


Figure 4-4
Run Analysis Screen

There are three sections on the Run Analysis screen:

1. Define Parameters for Analysis
2. Measure Definition Table
3. Graph



Define Parameters for Analysis

This section is used for defining the necessary parameters for the analysis graphs.

Region Selection Drop-Down – This list contains all of the NERC regions. The user selects a region and presses the **Retrieve Region Data** button to load the data into the current screen. (Note – These are the pre-

2006 NERC regions, that are modeled in the most current NESSIE model analysis)

Retrieve Region Data Button – Pressing this button will retrieve the measure data associated with NERC region shown in the **Region Selection Drop-Down**. When the data is retrieved the user will be able to analyze and graph measures for the selected region. The region is set only for the **Run Analysis Screen**.

Go To Program Definition Button – Pressing this button will move the user to the Program Definition Screen.

Select CO_2 Policy Drop-Down – The user can select alternative CO_2 policies for graphing. There are two options:

- Base CO_2 Policy, EA Price: $25/ton in 2015, 5%/Yr Real Increase 2015+
- No CO_2 Policy

Select EE Impact Perception Drop-Down- There are four options that describe the perception of the defined EE measure that is credited toward peak demand reduction for capacity planning.

- Marginal Approach, 0% Perception
- 0% Perception in 2010, Approaching 100% with a 10-Year Half Life
- 20% Perception in 2010, Approaching 100% with a 5-Year Half Life
- 100% Perception

Select Two Study Years Drop-Down – The user can select two years that will be compared in the graphs that are produced. There are two separate drop-down boxes for the two year choices.

Select Graph Data Series Drop-Down – The user can select the graph to be displayed. There are three different graphs to choose from, but only one can be displayed at a time. The different graphs are:

- Total Energy Saved – In MWh / Year for each year and measure selected.
- Total CO_2 Avoided – In Metric Tons / Year for each year and measure selected.
- Annual CO_2 Intensity – In Metric Tons / MWh for each year and measure selected.

Run Analysis Button – Once all of the necessary parameters have been set and the measures selected for graphing in the **Measure Definition Table**, the user can press this button to start the analysis process which finishes with the display of the selected graph. Even though only one graph is shown, the numerical results for all of them are calculated and displayed in the Results Columns of the **Measure Definition Table**.

Measure Definition Table

This section has two parts. The first part of this table is used by the user to select the measures to be analyzed. The second part displays the numerical values of the results. Up to 10 measures can be selected. There should not be any empty rows between the selected measures.

Table 4-1
Measure Definition Table

Measure Name for Charts	Select End Use	Select Measure	Total Energy Saved (MWh / Year)		Total CO_2 Avoided (Metric Tons / Year)		Annual CO_2 Intensity (Metric Tons / MWh)	
			2010	2030	2010	2030	2010	2030
New Chiller	Com - Cooling	New Chiller 1.41 kW/ton -> kW/ton	8,352	25,056	4,663	12,498	0.56	0.50
New Heat Pum	Res - Heater	New Heat Pump	8,344	25,032	6,010	16,634	0.72	0.66
	<Select>	<Select>						
	<Select>	<Select>						
	<Select>	<Select>						
	<Select>	<Select>						
	<Select>	<Select>						
	<Select>	<Select>						
	<Select>	<Select>						
	<Select>	<Select>						
		Total:	**16,696**	**50,088**	**10,672**	**29,133**		
		Average:					**0.64**	**0.58**

Measure Name for Charts – Each row contains an entry box that allows the user to enter a label for the measure that will be displayed on the graph.

Select End Use Drop-Down – In each row the end uses for any user-created measures for the currently selected region will appear in the drop-down list. Selecting one of the end uses will cause the **Select Measure Drop-**

Down to be populated. If no user-created measures exist for this region, then this drop-down box will be empty.

Select Measure Drop-Down – In each row the user-created measures for the currently selected region and end use will appear in this drop-down. Until an end use is selected this list will be empty. Once a measure is selected here then it can be part of the graph.

Result Columns – There are six remaining columns which show the numeric results of the analysis that are displayed graphically in the **Graph** section. These values are populated when the **Run Analysis Button** is pressed. There is a value for each measure for each graph and each year:

- Total Energy Saved (MWh / Year)
- Total CO_2 Avoided (Metric Tons)
- Annual CO_2 Intensity (Metric Tons / MWh)

Analysis Results Graph

The Analysis Results Graph displays the parameters set in the **Define Parameters for Analysis** section and **Measure Definition Table** once the **Run Analysis Button** is pressed. This graph is illustrated in Figure 4-5.

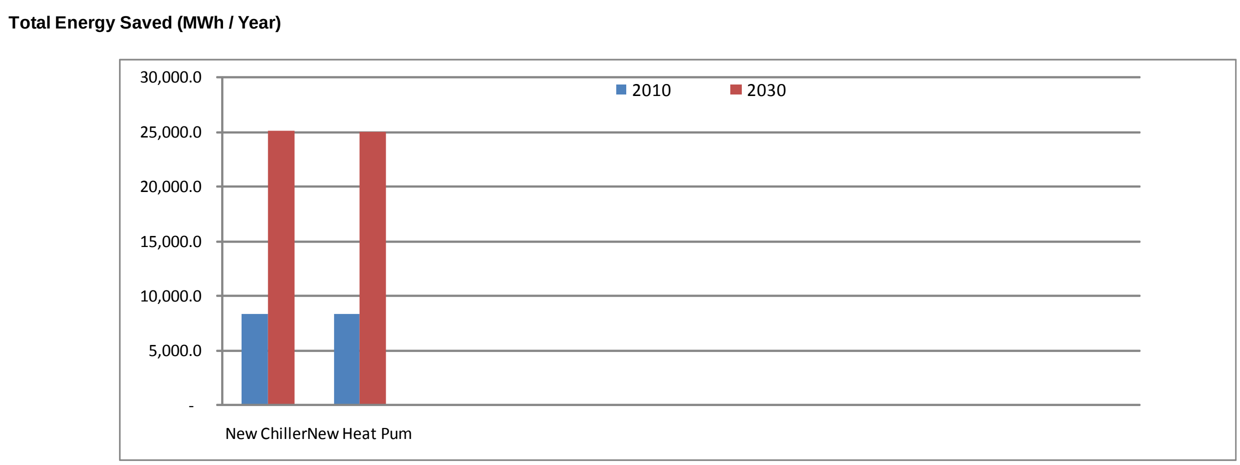


Figure 4-5
Analysis Results Graph

Section 5: A Script for Getting Started

This section provides a "hands on" tour of the Calculator, describing how to use the model's main functions to define a few example energy-efficiency measures, and evaluate their CO_2 intensity based on the data assumptions that you enter. The examples in this section are scripted, so that you can move fairly quickly through the main functionality of the Calculator.

To initiate an analysis session, open the Calculator following the instructions in the "Application Launch" section at the top of Chapter 2. It will open to the **Welcome** tab. As described in Chapter 2, the Calculator is organized around three worksheet tabs – the current **Welcome** screen, the **Program Definition Screen** where you can specify the electric energy impact of a particular energy efficiency measure that you wish to evaluate, and the **Run Analysis Screen** where you can calculate its impact on CO_2 emissions. To get started, push the **Go to Program Definition** button, which will take you to the **Program Definition** screen.

Example 1: Commercial Heat Pump Water Heat Measure Created from the EPRI Energy Efficiency Database

A valuable capability of the Calculator is to build off of the data developed in the EPRI Potential Study, which produced electric end use impacts for roughly twenty-three end-sues and roughly 70 EE measures across the Residential, Commercial and Industrial sectors. This first example lets you use these data to define a specific EE program for your own company

The first step in customizing the Calculator to your company is to set the corresponding Region, by selecting from the "Select Region" drop-down list in the upper-left corner of the screen. You can click on the question mark to see a map of the regions used in the model. As you can see, these are the pre-2006 NERC regions that are used in the EPRI NESSIE model (described in Chapter 4) that provides marginal CO_2 emissions information to the Calculator. We use this because the EIA NEMS model that provides key data inputs for NESSIE is still built around this regional structure.

After selecting your region from the drop-down, press **Retrieve Region Data** to initialize the EPRI measure database for your region. The choice of region defines two things with respect to the EPRI data:

1. the amount and hourly profile of electric savings from EE; and
2. the marginal system generation results used to calculate the amount of CO_2 emissions avoided.

The marginal emissions data were created by a series of runs with EPRI's NESSIE model for a variety of CO_2 policy and capacity expansion scenarios for each region.

A good example to get started is a Commercial Water Heating program which replaces a standard resistance electric water heater with a heat pump water heater having a COP of 3.0. To load the data for this program, as obtained from the EPRI Potential Study, go to the section called "Load Data from EPRI EE Database," then select the **Com – Water Heating** end use, then the **Heat Pump (COP 3.0)** measure. Notice that the list of measures only includes those defined for the selected end use. Then press the **Load** button.

You will see that the EPRI data for this measure includes two elements – the annual energy savings and the hourly load profile by day type. The dimensionality used in the Calculator is the same as is used in the NESSIE model. In particular, the annual data are based on five-year time steps, and the load profiles are based on six day types – peak day, normal day and weekend for both the Peak season and Off-Peak season. These profiles are normalized, so that they are all relative to the highest hour, which for the commercial water heater load occurs in the middle of the day on the peak winter weekday. You may choose to enter them as kW or any other values, as long as they are relative to each other across all day types. The model will then do the normalization for you.

The annual energy savings are specified for a single unit, which in this case would be single customer Heat Pump Water Heater installation within the region you selected. To define the total impact for this program, you need to specify the number of units in each year. Typing in the quantities **1,700, 2,500, 4,000, 5,500, 6,300** will produce a market penetration profile that looks realistic. The chart on the left displays the data for the measure in total annual MWh savings while the chart on the right displays the hourly savings profile for each of the six day types in the model.

Now that you have built a new EE measure from the EPRI database, you need to save it to the database before you can evaluate it. You do this by going to the "Save New EE Measure" section at the bottom of the screen. Notice that the drop-down list for the end use is already set to **Com – Water Heating**, so you just need to type in the name for the new measure (such as **Test Heat Pump Measure**), press **Enter,** and press the **Save New Measure** button.

Now that you have saved this measure to the database, you are ready to evaluate its impacts on CO_2 emissions. To do so, press the **Go to Run Analysis** button at the top of the page. Alternatively you can use the worksheet tabs, but it's just as easy to use the buttons. You should now be open to the **Run Analysis** screen.

The table in the middle of the screen, with the two fields entitled "Select End Use" and "Select Measure," allows you to select and evaluate any of the measures that you have created and saved to the database. As you can see, you can select up to 10 measures at a time for evaluation and side-by-side comparison, but first just focus on the Heat Pump Water Heater program that you just created. Using the drop-downs, first select the **Com – Water Heating** end use, then the **Test Heat Pump Measure** (or other name) that you created on the **Program Definition** screen. Note that the only measures contained in these lists are ones that you will create for your own company – the EPRI measures are only used as "blueprints" for building your own measures, so they don't appear on this list.

Now that you have selected the Heat Pump measure, you are ready to evaluate CO_2 emissions impacts, which you do by pressing the **Run Analysis** button. This process will normally take about three or four seconds to complete. When it finishes, you will see that there are three different quantities reported – annual electricity savings in MWh, annual CO_2 savings in metric tons, and the CO_2 intensity – tons of CO_2 saved per MWh of electricity savings. These values are reported for 2010 and 2030 – but you can select other study years by changing the selections in the field near the top of the screen entitled "Select Two Study Years" and pressing **Run Analysis** again. The column chart at the bottom of the screen is initially set to display CO_2 intensity, but this can be toggled to show total electricity savings or total CO_2 savings as well. You can try toggling among the different graph settings – it will produce the different graph views without having to re-run the analysis.

If you have changed the graph view, reset the graph to display CO_2 Intensity. In regions with a significant amount of coal-fired capacity today, the results for the Heat Pump Water Heater measure that you created are likely to show an increase in CO_2 intensity over time. This occurs because the initial results for this case assume that a carbon policy is in place, which imposes a price per ton of CO_2 emissions that increases over time. In the near term, when CO_2 prices are low or zero, coal plants are an economic source of base load generation, while gas-fired plants are less economic and tend to operate on the margin. However, as the price of CO_2 increases, coal-fired generation becomes less and less attractive as a base-load generating technology, and in fact moves up the dispatch order so that it frequently operates as the marginal unit. Because gas plants emit roughly .4 to .5 tons of CO_2 per MWh, while coal plants emit in the range of .8 – 1.0 tons / MWh, more coal operating on the margin will tend to increase the amount of CO_2 saved by EE.

You can test the impact of changing the CO_2 policy by going to the settings at the top of the screen and changing the CO_2 policy assumption from the drop-down menu in the field entitled "Select CO2 Policy." Selecting the value in the drop-down to **No CO_2 Policy** enables you to re-run the analysis without a policy that sets a price per ton of CO_2 emissions. Press **Run Analysis** to view the results under this new assumption.

As you can see, changing the CO_2 policy has a measurable impact on CO_2 emissions savings, particularly if you are in region with significant coal-fired capacity. Without a CO_2 policy, coal plants are likely to remain an economic source of base-load generation, and gas-fired capacity will continue to operate on the margin through 2030. Any decrease in CO_2 intensity over time that you observe occurs because the marginal gas plants are likely to become more efficient over time as advanced combined-cycle plants are added to the generation mix.

Example 2: Commercial Heat Pump Water Heater Measure – Defined as Total Annual MWh Savings, and Modified Load Shape

To illustrate some alternative ways we might model the impact of the Heat Pump Water Heater measure, press **Go To Program Definition** to return to the program definition screen. Suppose we have relatively good forecasts about the total energy savings from the Heat Pump program, but, because of the wide variation the size and usage patterns of commercial customers in your service territory, the savings per installation are harder to quantify. In that case, we may simply want to estimate the energy savings for the Heat Pump Water Heater as an aggregate savings across all customers in the program.

To use this approach, first clear all the data fields in the screen by pressing **Clear Data**, then re-load the Commercial Heat Pump measure from the EPRI database by pressing **Load** in the "Load Data from EPRI EE Database" section. Then, instead of using the per unit customer savings obtained from the EPRI database, first type in a **1** for the number of units in each of the five years in the "Number of Units" field, then type the total annual kWh savings from the program in the "Savings Per Unit (KWh/year)" field. Some values that will give you a realistic-looking program penetration curve are **9,000,000, 12,000,000, 18,000,000, 24,000,000, and 27,000,000** for the years 2010 through 2030, respectively. Then go down to the "Save New EE Measure" section, type in **Heat Pump 2** (or any other name that distinguishes it from the first measure you created) as the new measure name, press **Enter,** and then press **Save New Program**.

Now let's say you also realized that you recently obtained some actual monitoring data from customer sites that will provide a better representation of the Heat Pump Water Heater load shape than is available in the EPRI data. Then you can go to the data entry fields entitled "Normalized Hourly Profiles by Season and Day Type (% of Maximum)" and modify the load profile data directly. Just to get started, type in the following representative values, which will increase the water heat loads for both the peak and normal weekdays in the peak season: **16, 25, 40, 58, 74, 82, 81, 76, 67, 50, 30, 17,** for hourly percentile values in hours 1 through 12, respectively. An alternative approach would be to create the new profiles in a separate spreadsheet and copy them into these data fields, but if you do so, remember the data need to be in the identical format, with 2-hour time blocks for each of the six day types.

Now, since you're only modifying the program you just created, you can simply save the load shape changes, rather than create a completely new measure. To do that, press the **Save Changes** button. Then you can go back to the Run Analysis screen by pressing **Go To Run Analysis** and select the two water heat measures that are now in your database – the original case plus the modified version that you just created. When you are finished selecting the measures, you are ready to evaluate them side-by-side by pressing **Run Analysis.**

What you see from the results is that, even though you made substantial changes to both the annual energy and the load profiles, the annual CO_2 intensity is approximately the same in both cases. This is because the changes in load profile were not dramatic enough to shift the impact of the measure to hours where the marginal CO_2 emissions were substantially different.

Example 3: Industrial Process Heat Electrification

For a final example, we'll evaluate the impact of a program to promote switching from gas fuel to electricity for industrial process heat. To illustrate this type of program using the Calculator, go to the "Select Measure from EPRI EE Database" section, and select **Industrial Process Heat** from the "End Use" field, and **Electric Resistance** from the "Measure" field. Then press the **Load** button.

To represent a program that builds electric load, you need to represent the impact as a negative savings. For this example, assume the measure produces and annual increase in sales of 100 MWh, which you can represent as a savings of **-100,000** kWh in the "Savings per Unit (KWh/year)" field, in each of the five model years from 2010 to 2030. When you have finished entering the savings per unit, you can simply enter **1** in the "Number of Units" field, for each of the five model years.

To understand the overall impact of this fuel-switching program on CO_2 emissions, you need to consider the CO_2 savings from the fuel that gets displaced, as well as the increased CO_2 from the additional electric use. For this illustrative example, assume that the displaced fuel for process heat is natural gas. Select this fuel from the drop-down list in the "Fuel Type" field. Next, you need to specify the units of measure for the natural gas consumption that is displaced by the electrification measure. For natural gas, you can choose among **MCF / Year, MMBtu / Year, MCF / kWh,** or **Btu / kWh** from the drop-down list in the "Fuel Units" field. To keep it simple for this example, select **MMBtu / Year,** then enter **1,000** in the "Quantity Displaced" field. This quantity implies that the electric technology that gets implemented provides process heat about three times more efficiently than the existing gas technology. Obviously, improved estimates of the impact of electrification depend on the specific industrial application, and the respective gas and electric technologies involved.

Now you can go down to the "Save New EE Measure" section at the bottom of the screen and save the electrification measure that you just created. Type **Electrification** (or some other name of your choice) into the "Enter New Measure Name" field, press **Enter,** and press **Save New Measure**. Then press **Go to Run Analysis** so you can evaluate the impacts of the new electrification measure.

On the Run Analysis screen, select the electrification measure you just created from the "Select End Use" and "Select Measure" drop-down lists. Then evaluate the measure by pressing **Run Analysis.**

What you can see in this illustrative example is that replacing gas with electricity for industrial process heat may or may not pay for itself in terms of CO_2 emissions, depending on the amount of coal-fired generation in your region. In regions with significant surplus coal-fired capacity in 2010, such as ECAR, marginal emissions in may be largely from coal-fired generation.

Under a CO_2 policy, coal will continue to operate on the margin as increasing CO_2 prices make it less attractive as a base-load resource. Coal operating on the margin could result in a significant increase in CO_2 emissions under electrification, offsetting the CO_2 savings from displacing gas heating fuel.

You can also look at the results of this illustrative measure without a CO_2 policy, by changing the drop-down selection in the "Select CO_2 Policy" field to **No CO_2 Policy**, and running the model by pressing **Run Analysis.** In this case, your results are more likely to show that electrification produces a net savings in CO_2. This is because, in the absence of a CO_2 policy, coal is likely to remain an economic base-load generation option, with gas continuing to operate most of the time on the margin. The net effect is lower marginal CO_2 emissions from electrification, which are less likely to offset the CO_2 savings from the displaced gas heating fuel.

While obviously based on approximate estimates for the fuel displacement from the measure, the example illustrates how the Calculator can be used to better understand the tradeoffs faced in an electrification program similar to this one.

Section 6: Next Steps

The analysis detailed in this report describes important enhancements to EPRI's NESSIE model and development of a stand-alone CO_2 Intensity Calculator to more easily evaluate the CO_2 impact of a wide range energy efficiency measures. It represents the latest step in EPRI's continued effort to model the emissions impact of energy efficiency in a manner analytically rigorous enough to pass market or regulatory scrutiny and practical enough for utilities to implement.

Future work will focus on continued updates to NESSIE to ensure that the latest information about electricity markets and technology costs are captured, as enhancements to the CO_2 Intensity Calculator to provide greater flexibility and user customization. These steps will include:

- Import marginal emissions in utility-specific formats. Developing the capability to populating hourly marginal emissions data from utilities' own production simulation models can provide more accurate evaluation of CO2 impacts of their energy efficiency measures.
- Import energy efficiency hourly load profiles in utility-specific formats. Providing users with the ability to easily apply their own hourly load impact information can greatly improve the efficiency of the evaluation process.
- Update EPRI energy efficiency measure database. These updates should be made as needed to best reflect the most recent EPRI research into the future potential for energy efficiency in the US.
- Enhance user features. The actual experience of users during the 2010 release is likely provide the best source of input for enhancements to the functionality and usability of the Calculator.
- Conduct case studies. The work in Tasks 1 through 4 can be effectively leveraged by working with designated member utilities to implement the enhanced 2011 release of Calculator within the context of the utilities' energy efficiency planning environment.
- Update NESSIE for AEO 2011. NESSIE will be updated to incorporate the NEMS results with AEO 2011 assumptions, along with any updated EPRI cost and performance assumptions for generation technologies.

Appendix A: Aggregate Impact of Energy Efficiency on CO_2 Emissions

EPRI had developed two distinct forecasts of achievable energy efficiency potential through 2030 in its study. The Maximum Achievable Potential assumes a high level of adoption of energy efficiency measures that pass an economic screen[8]. It discounts the Economic Potential – the savings that would accrue if all customers adopted the most efficient cost-effective measures – by the imposition of a market discount factor specific to each end-use, based on the experience of exemplary programs. The Maximum Achievable potential for energy efficiency, based on the previous EPRI study, grows from 80 TWh in 2010, to 438 TWh in 2020, to 544 TWh in 2030, and is illustrated in Figure A-1.

[8] The Participant Test was applied as the economic screening metric for measures in report 1016987. For a measure to pass the Participant Test, the present value of the bill savings it affords over its useful lifetime must equal or exceed its incremental cost.

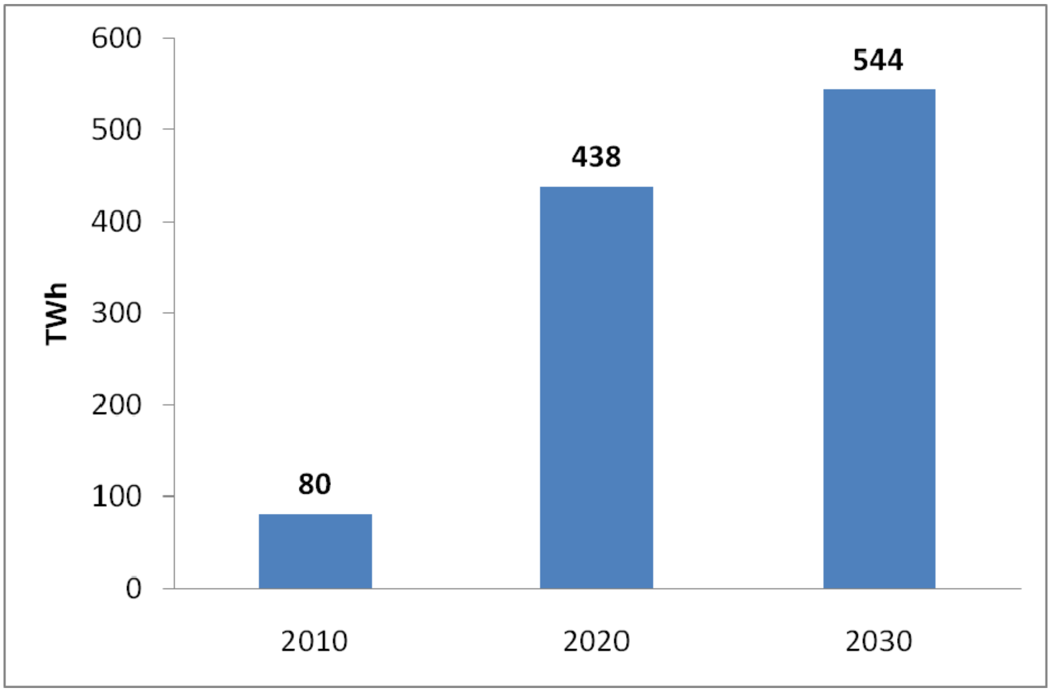


Figure A-1
Maximum Achievable Potential for Energy Efficiency

The Realistic Achievable Potential discounts the Maximum Achievable Potential by taking into account programmatic barriers specific to each end-use that will inhibit the adoption of energy-efficient measures, including learning curve impediments. The Realistic Achievable potential for energy efficiency, based on the previous EPRI study, grows from 21 TWh in 2010, to 207 TWh in 2020, to 398 TWh in 2030, and is illustrated in Figure A-2.

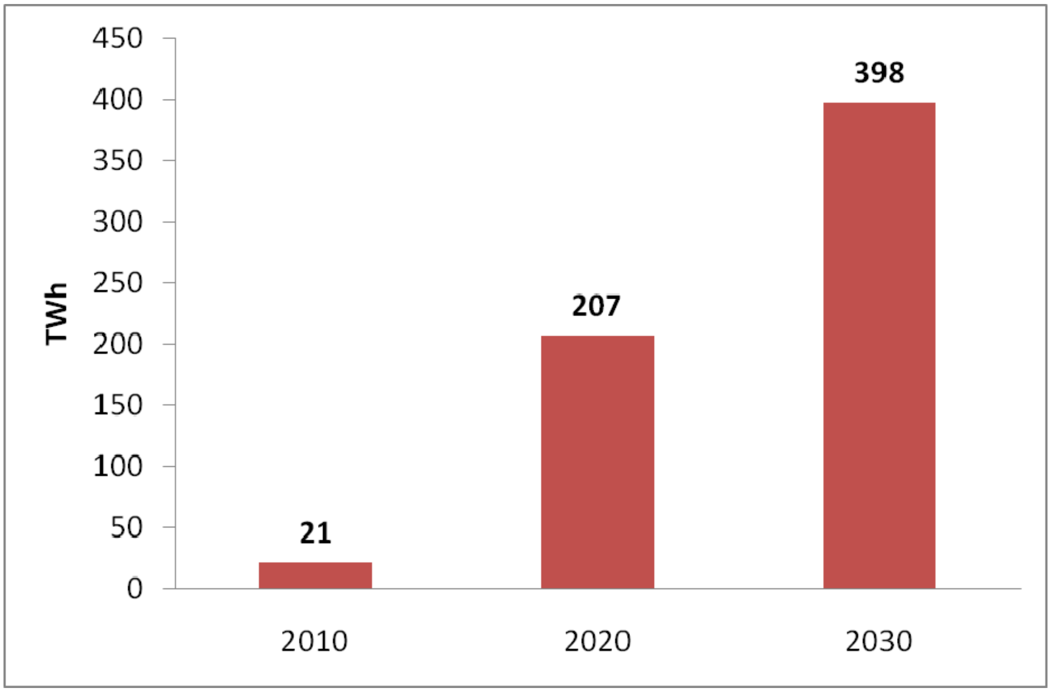


Figure A-2
Realistic Achievable Potential for Energy Efficiency

To model the impact of Maximum- and Realistic-Achievable energy efficiency on CO_2 emissions, EPRI first transformed the energy savings captured at the individual measure level for the four U.S. Census regions used for its energy efficiency potential study (Northeast, South, Midwest, and West), to the thirteen NERC regions utilized for emissions modeling in NESSIE. Secondly, each efficiency measure was attributed with a corresponding end-use load shape per NERC region.

EPRI modeled the impact of energy efficiency under scenarios with and without the presence of a CO_2 policy. The CO_2 policy was assumed to take the form of a cost-adder to electricity rates, based on EPRI's analysis of simulations of the *Waxman-Markey American Clean Energy and Security Act of 2009*. Figure A-3 illustrates the assumed forecast of CO_2 price, expressed in units of 2006 U.S. dollars per metric ton.

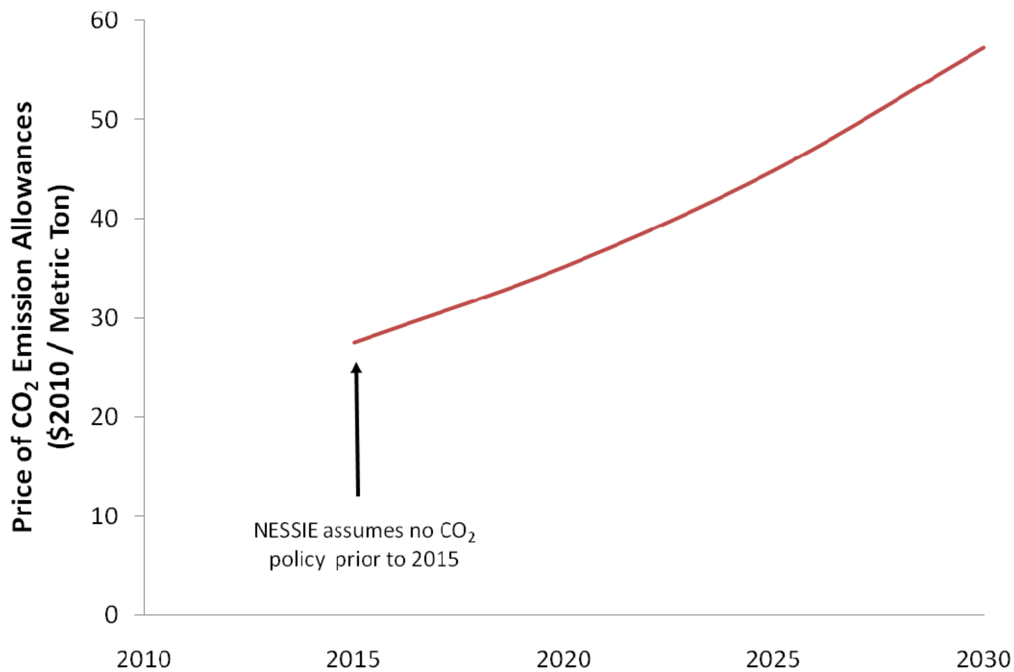


Figure A-3
Price of CO_2 Emission Allowances in the EPRI Base Case

In the case without a CO_2 policy, the NESSIE simulation of load dispatch and capacity expansion was run under the assumption of energy efficiency commensurate with the Realistic Achievable Potential.

In the case with a CO_2 policy, the NESSIE simulation of load dispatch and capacity expansion favored the more accelerated adoption of less carbon-emitting generation resources such as renewable. In addition, the CO_2 constraints imposed by CO_2 policy and monetization leads to the elevation of less carbon-intensive generation in the loading order of generation options in the NESSIE simulations. Accordingly, under the scenario with a CO_2 policy the NESSIE simulation of load dispatch and capacity expansion was run under the assumption of energy efficiency commensurate with the Maximum Achievable Potential.

Both cases – with and without CO_2 policy – were modeled based on the full Capacity Expansion method, which assumes that the forecasted impact of energy efficiency is fully integrated into the capacity planning and affects the disposition and adoption of generation assets.

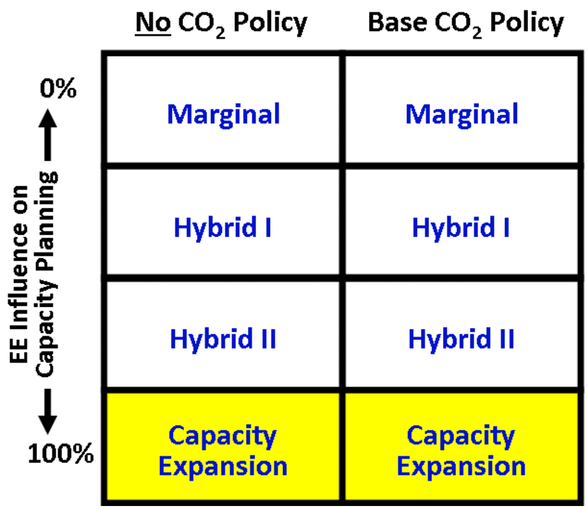


Figure A-4
Capacity Expansion Method Applied in Aggregate Energy Efficiency Impact Assessment

For both policy scenarios, the NESSIE simulation was conducted both with and without energy the associated level of energy efficiency. The difference in the simulated resultant emissions in represents the net CO_2 avoided due to the presence of energy efficiency. The results of the simulations were as follows:

No CO_2 Policy Case; Realistic Achievable Potential of Energy Efficiency

- Energy efficiency avoids 11 million metric tons CO_2 emissions in 2010
- Energy efficiency avoids 99 million metric tons CO_2 emissions in 2020
- Energy efficiency avoids 106 million metric tons CO_2 emissions in 2030

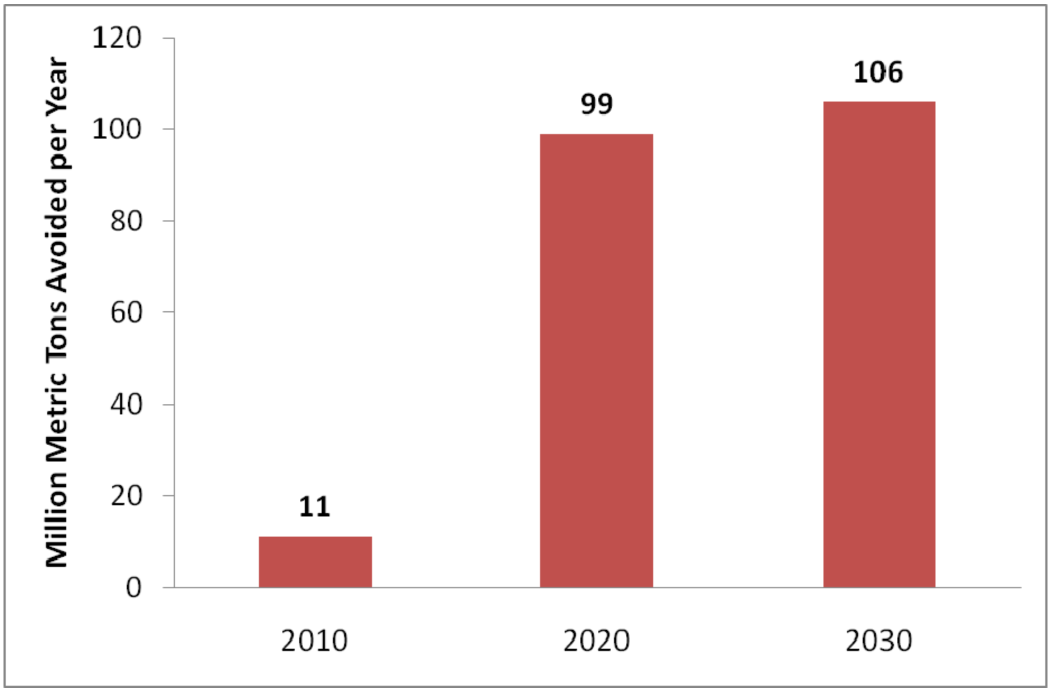


Figure A-5
Avoided U.S. CO_2 Emissions Due to Energy Efficiency (No CO_2 Policy Assumed)

CO_2 Policy Case; Maximum Achievable Potential of Energy Efficiency

- Energy efficiency avoids 29 million metric tons CO_2 emissions in 2010
- Energy efficiency avoids 20 million metric tons CO_2 emissions in 2020
- Energy efficiency avoids 104 million metric tons CO_2 emissions in 2030

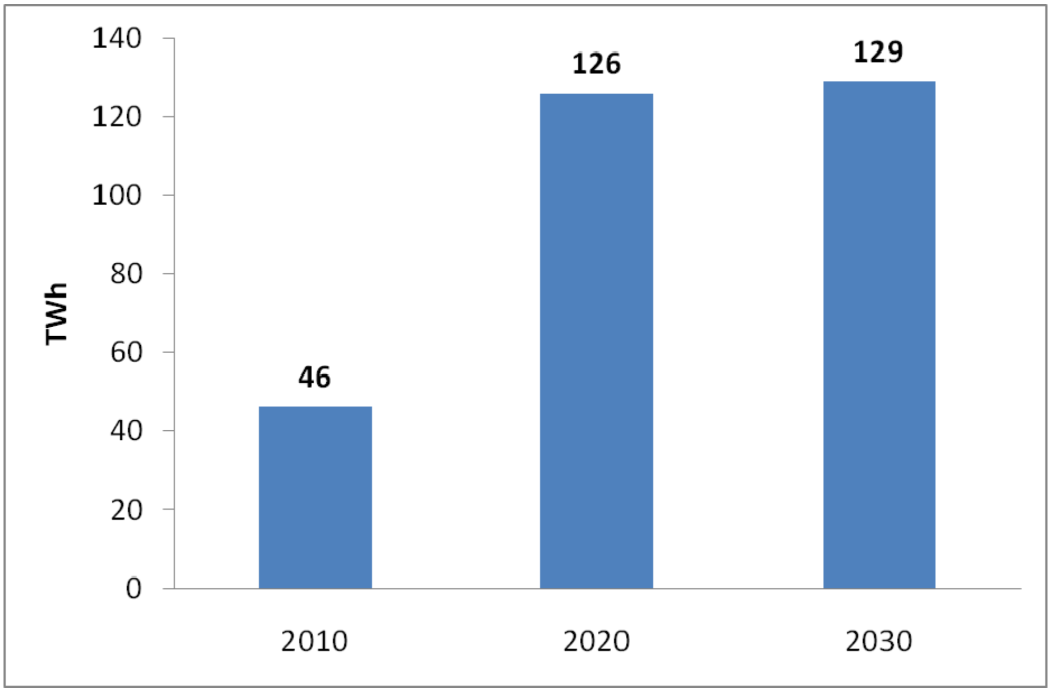


Figure A-6
Avoided U.S. CO_2 Emissions Due to Energy Efficiency (CO_2 Policy Assumed)

CO_2 policy compels a faster rate of adoption of newer less carbon-intensive generation and retirement of existing carbon-intensive generation in order to meet emissions compliance requirements. Therefore, applying as we did the assumption that impacts of energy efficiency are perfectly predicted, energy efficiency can forestall less carbon-intensive generation from coming online and extend the operation of existing carbon-intensive assets that would otherwise be retired. This explains why the avoided CO_2 attributable to energy efficiency only slightly more in the case with a CO_2 policy than the case without a CO_2 policy (27 percent higher in 2020), despite the fact that the kilowatt-hours reduced by energy efficiency under the CO_2 policy is substantially greater (111 percent higher in 2020) than that reduced without the CO_2 policy (i.e. the kilowatt-hour savings of the Maximum Achievable energy efficiency potential in the CO_2 policy case is greater than the kilowatt-hour savings of the Realistic Achievable energy efficiency potential in the case without a CO_2 policy).

Appendix B: Marginal Avoided CO_2 Intensities

Energy efficiency programs are typically conducted on annual program cycles and their estimated impacts cannot be predicted today with sufficient precision and confidence to significantly affect capacity expansion planning over a longer time horizon. Therefore, the base methodology employed in this study, the Marginal Method, considers the emissions impact of generation avoided at the margin by an energy efficiency measure corresponding to a given end use without assuming that energy efficiency materially affects capacity expansion. In this regard, the electricity and demand savings from energy efficiency programs in a given year does not affect the composition of built plants but rather their economic dispatch.

This approach was applied to all twenty four end-uses in all thirteen NESSIE regions for the years 2010, 2015, 2020, 2025, and 2030. The marginal CO_2 intensity results shown in this appendix were calculated using key inputs stored in the database for the CO_2 Intensity Calculator database:

1. Regional generation results, including marginal CO_2 emissions, produced by a series of NESSIE simulation runs, and
2. EE electric load impacts for the twenty-three energy efficiency measures developed in the 2009 study.

The NESSIE model was run under scenarios both with and without the presence of the CO_2 policy described in earlier chapters. The production simulation runs EPRI Base Case CO_2 policy and the No carbon Case were run assuming Maximum Achievable Potential and Realistic Achievable Potential energy efficiency levels, respectively.

The results of these simulations are distilled into tables of CO_2 intensities specific to a given:

- **end-use**, based on its unique load shape
- **region**, based on its current and anticipated generation mix
- **year,** based on changing carbon-intensity of generation over time

The level of disaggregation of these marginal CO_2 intensities is commensurate with how savings from energy efficiency programs are typically accounted for – at the sector and end-use level over time. In other words, most energy efficiency savings are documented at the level of "residential lighting" or "commercial water heating", since they correspond to the common programs of *residential CFL rebate program* or *commercial water heater tune-up/retrofit program*. Accordingly, energy efficiency impacts, defined by the metric of avoided kilowatt-hours, are measured and documented. The marginal CO_2 intensity corresponding to the program (end use) based on an implementer's region can therefore be applied as coefficient multiplier to electricity savings to provide a convenient conversion of kilowatt-hour reductions to avoided tons of CO_2 emissions.

For example, in the ECAR region for the year 2010 in the case without any CO_2 policy, the marginal CO_2 intensity of Residential Lighting is 0.78 metric tons of CO_2 avoided per MWh saved; by contrast, the marginal CO_2 intensity in the same region and year corresponding to Commercial Water Heating is 0.81 metric tons of CO_2 avoided per MWh saved. Consider a utility whose energy efficiency programs in residential lighting result in savings in 2010 of 1,000 MWh, and whose commercial water heater efficiency programs result in savings of 1,000 MWh that same year. Instead of the typical method used today of applying the average ratio of CO_2 emissions per unit of electricity generated, whether at the national, state or utility level – a method which is generally regarded as not sufficiently rigorous for broader acceptance in emissions reduction markets – the utility can simply apply the marginal intensities as multipliers to obtain emissions impacts:

- Residential Lighting
  1,000 MWh x 0.78 metric tons CO_2 /MWh = 780 metric tons CO_2
- Commercial Water Heating
  1,000 MWh x 0.81 metric tons CO_2 /MWh = 810 metric tons CO_2

In this way, these marginal emissions factors represent an analytically rigorous approach to quantifying the marginal emissions impacts of energy efficiency that is also practicable for a utility or other type of program implementer to apply.

The following ten tables in this chapter summarize the marginal CO_2 intensities based on the Marginal Method, for the scenarios both with and without the presence of a CO_2 policy, for the years 2010, 2015, 2020, 2025, and 2030.

Marginal Method Emissions Intensities, No CO_2 Policy

Table B-1
Marginal Method, No CO_2 Policy (2010)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.58	0.74	0.51	0.53	0.83	0.79	0.60	0.46	0.52	0.52	0.59	0.46	0.45	0.60
Heating	0.63	0.85	0.49	0.60	0.95	0.90	0.52	0.44	0.43	0.66	0.82	0.52	0.60	0.48
Water Heating	0.60	0.81	0.48	0.56	0.93	0.85	0.56	0.44	0.46	0.59	0.70	0.49	0.51	0.54
Lighting. Interior	0.60	0.79	0.48	0.55	0.91	0.85	0.56	0.45	0.47	0.57	0.68	0.49	0.50	0.55
Lighting, Exterior	0.66	0.91	0.50	0.68	0.93	0.93	0.51	0.44	0.45	0.69	0.79	0.61	0.65	0.50
Office Equipment	0.62	0.82	0.48	0.58	0.92	0.86	0.55	0.44	0.47	0.60	0.71	0.51	0.53	0.54
Refrigeration	0.62	0.84	0.49	0.60	0.92	0.88	0.54	0.44	0.47	0.62	0.72	0.53	0.54	0.53
Ventilation	0.63	0.85	0.49	0.60	0.92	0.88	0.54	0.44	0.47	0.63	0.73	0.53	0.55	0.53
RESIDENTIAL														
Central AC	0.58	0.73	0.53	0.53	0.81	0.78	0.60	0.48	0.54	0.51	0.55	0.48	0.46	0.60
Room AC	0.58	0.73	0.53	0.53	0.81	0.79	0.60	0.49	0.54	0.50	0.54	0.48	0.45	0.60
Space Heating	0.65	0.87	0.48	0.62	0.95	0.91	0.52	0.44	0.43	0.68	0.81	0.53	0.60	0.50
Water Heating	0.61	0.83	0.47	0.56	0.94	0.88	0.55	0.44	0.46	0.60	0.72	0.48	0.51	0.53
Lighting	0.61	0.78	0.48	0.56	0.91	0.84	0.56	0.45	0.47	0.57	0.68	0.50	0.52	0.55
Refrigerator	0.63	0.85	0.49	0.60	0.92	0.88	0.54	0.44	0.47	0.62	0.72	0.53	0.55	0.53
Dishwasher	0.60	0.81	0.47	0.52	0.93	0.86	0.56	0.45	0.47	0.57	0.67	0.46	0.48	0.55
Clothes Washer	0.60	0.80	0.47	0.52	0.92	0.85	0.57	0.45	0.47	0.56	0.67	0.45	0.45	0.56
Clothes Dryer	0.60	0.80	0.47	0.51	0.93	0.85	0.57	0.45	0.47	0.57	0.67	0.45	0.46	0.55
Television	0.62	0.81	0.48	0.58	0.91	0.86	0.55	0.45	0.47	0.59	0.71	0.52	0.54	0.54
Personal Computers	0.62	0.81	0.48	0.58	0.91	0.86	0.55	0.45	0.47	0.59	0.71	0.52	0.54	0.54
INDUSTRIAL														
Process Heating	0.62	0.82	0.48	0.58	0.92	0.86	0.55	0.45	0.47	0.60	0.71	0.52	0.54	0.54
Machine Drive	0.62	0.82	0.48	0.59	0.92	0.86	0.55	0.44	0.47	0.61	0.71	0.52	0.54	0.54
HVAC (facility)	0.61	0.81	0.48	0.58	0.91	0.86	0.55	0.45	0.47	0.59	0.70	0.51	0.53	0.54
Lighting (facility)	0.61	0.81	0.48	0.58	0.91	0.86	0.55	0.45	0.47	0.59	0.70	0.51	0.53	0.54
Other Process Use	0.62	0.81	0.48	0.57	0.91	0.86	0.55	0.45	0.47	0.59	0.70	0.51	0.53	0.54

Table B-2
Marginal Method, No CO_2 Policy (2015)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.52	0.64	0.47	0.53	0.68	0.66	0.45	0.45	0.52	0.48	0.54	0.42	0.45	0.44
Heating	0.57	0.76	0.52	0.61	0.84	0.76	0.42	0.43	0.43	0.57	0.70	0.50	0.54	0.40
Water Heating	0.53	0.69	0.47	0.56	0.77	0.68	0.43	0.44	0.46	0.51	0.59	0.45	0.48	0.42
Lighting. Interior	0.53	0.66	0.47	0.55	0.75	0.68	0.43	0.44	0.47	0.51	0.59	0.45	0.47	0.42
Lighting, Exterior	0.61	0.85	0.52	0.70	0.85	0.84	0.42	0.43	0.45	0.60	0.70	0.59	0.57	0.40
Office Equipment	0.55	0.71	0.48	0.59	0.77	0.72	0.43	0.44	0.47	0.53	0.61	0.48	0.50	0.42
Refrigeration	0.56	0.74	0.48	0.61	0.79	0.74	0.43	0.43	0.47	0.54	0.63	0.50	0.50	0.42
Ventilation	0.56	0.75	0.48	0.62	0.80	0.75	0.43	0.43	0.46	0.54	0.64	0.50	0.51	0.41
RESIDENTIAL														
Central AC	0.52	0.63	0.48	0.52	0.67	0.67	0.46	0.46	0.54	0.47	0.52	0.45	0.45	0.44
Room AC	0.52	0.63	0.48	0.53	0.67	0.67	0.47	0.47	0.54	0.47	0.52	0.45	0.46	0.44
Space Heating	0.59	0.78	0.51	0.64	0.85	0.78	0.42	0.43	0.43	0.59	0.70	0.51	0.55	0.41
Water Heating	0.55	0.72	0.46	0.57	0.80	0.73	0.43	0.43	0.46	0.52	0.62	0.45	0.48	0.42
Lighting	0.53	0.65	0.48	0.56	0.74	0.68	0.43	0.44	0.47	0.50	0.58	0.47	0.48	0.42
Refrigerator	0.56	0.75	0.48	0.61	0.79	0.75	0.43	0.43	0.47	0.54	0.63	0.50	0.50	0.42
Dishwasher	0.53	0.69	0.46	0.53	0.77	0.70	0.43	0.44	0.47	0.50	0.59	0.43	0.46	0.42
Clothes Washer	0.52	0.68	0.45	0.53	0.76	0.68	0.44	0.44	0.47	0.49	0.58	0.41	0.44	0.43
Clothes Dryer	0.53	0.68	0.45	0.53	0.77	0.69	0.43	0.44	0.47	0.50	0.58	0.41	0.45	0.43
Television	0.55	0.70	0.48	0.59	0.77	0.71	0.43	0.44	0.47	0.52	0.61	0.49	0.50	0.42
Personal Computers	0.55	0.70	0.48	0.59	0.77	0.71	0.43	0.44	0.47	0.52	0.61	0.49	0.50	0.42
INDUSTRIAL														
Process Heating	0.55	0.71	0.48	0.59	0.77	0.72	0.43	0.44	0.47	0.52	0.61	0.49	0.50	0.42
Machine Drive	0.55	0.71	0.48	0.60	0.78	0.72	0.43	0.44	0.47	0.53	0.62	0.49	0.50	0.42
HVAC (facility)	0.54	0.69	0.48	0.58	0.76	0.71	0.43	0.44	0.47	0.52	0.61	0.48	0.49	0.42
Lighting (facility)	0.54	0.69	0.48	0.58	0.77	0.71	0.43	0.44	0.47	0.52	0.61	0.48	0.49	0.42
Other Process Use	0.54	0.69	0.48	0.58	0.77	0.71	0.43	0.44	0.47	0.52	0.60	0.48	0.49	0.42

Table B-1
Marginal Method, No CO_2 Policy (2020)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSC
COMMERCIAL														
Cooling	0.50	0.54	0.45	0.51	0.62	0.60	0.42	0.43	0.46	0.47	0.55	0.67	0.46	0.40
Heating	0.60	0.68	0.66	0.65	0.79	0.73	0.43	0.43	0.43	0.57	0.74	0.76	0.60	0.38
Water Heating	0.54	0.60	0.50	0.57	0.71	0.65	0.41	0.43	0.44	0.50	0.62	0.73	0.51	0.38
Lighting. Interior	0.53	0.57	0.49	0.55	0.69	0.64	0.41	0.43	0.44	0.50	0.61	0.72	0.50	0.38
Lighting, Exterior	0.63	0.77	0.62	0.73	0.82	0.80	0.45	0.44	0.43	0.61	0.73	0.82	0.62	0.39
Office Equipment	0.56	0.62	0.52	0.60	0.72	0.68	0.42	0.43	0.44	0.52	0.64	0.74	0.53	0.38
Refrigeration	0.57	0.65	0.53	0.62	0.74	0.70	0.42	0.43	0.44	0.53	0.65	0.76	0.54	0.38
Ventilation	0.58	0.66	0.54	0.63	0.75	0.71	0.42	0.43	0.44	0.54	0.67	0.76	0.55	0.38
RESIDENTIAL														
Central AC	0.50	0.53	0.45	0.50	0.61	0.61	0.42	0.44	0.46	0.47	0.53	0.67	0.46	0.41
Room AC	0.50	0.53	0.45	0.51	0.62	0.61	0.42	0.44	0.46	0.47	0.52	0.65	0.46	0.41
Space Heating	0.63	0.71	0.61	0.67	0.80	0.75	0.44	0.43	0.43	0.58	0.73	0.77	0.60	0.38
Water Heating	0.56	0.62	0.52	0.59	0.74	0.69	0.41	0.42	0.43	0.51	0.65	0.74	0.52	0.37
Lighting	0.53	0.57	0.50	0.56	0.68	0.64	0.41	0.42	0.44	0.50	0.61	0.73	0.51	0.38
Refrigerator	0.57	0.66	0.53	0.63	0.74	0.71	0.42	0.43	0.44	0.54	0.66	0.76	0.54	0.38
Dishwasher	0.54	0.59	0.49	0.55	0.71	0.67	0.40	0.42	0.44	0.49	0.61	0.72	0.49	0.38
Clothes Washer	0.52	0.58	0.47	0.54	0.69	0.64	0.39	0.42	0.44	0.47	0.60	0.71	0.48	0.38
Clothes Dryer	0.53	0.58	0.48	0.54	0.70	0.65	0.39	0.42	0.44	0.48	0.61	0.72	0.49	0.37
Television	0.55	0.61	0.52	0.59	0.71	0.68	0.41	0.42	0.43	0.52	0.63	0.75	0.53	0.38
Personal Computers	0.55	0.61	0.52	0.59	0.71	0.68	0.41	0.42	0.43	0.52	0.63	0.75	0.53	0.38
INDUSTRIAL														
Process Heating	0.56	0.62	0.52	0.60	0.72	0.68	0.42	0.43	0.44	0.52	0.64	0.75	0.53	0.38
Machine Drive	0.56	0.62	0.53	0.60	0.72	0.68	0.42	0.43	0.44	0.52	0.64	0.75	0.54	0.38
HVAC (facility)	0.55	0.60	0.52	0.59	0.71	0.67	0.42	0.43	0.44	0.52	0.63	0.74	0.52	0.38
Lighting (facility)	0.55	0.60	0.52	0.59	0.71	0.67	0.42	0.43	0.44	0.52	0.63	0.74	0.53	0.38
Other Process Use	0.55	0.60	0.51	0.58	0.71	0.67	0.41	0.42	0.44	0.51	0.63	0.74	0.53	0.38

Table B-2
Marginal Method, No CO_2 Policy (2025)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.51	0.52	0.50	0.49	0.61	0.60	0.40	0.43	0.43	0.48	0.61	0.73	0.47	0.36
Heating	0.64	0.67	0.78	0.65	0.81	0.74	0.46	0.46	0.48	0.64	0.84	0.74	0.72	0.42
Water Heating	0.57	0.58	0.60	0.56	0.73	0.65	0.42	0.44	0.44	0.53	0.73	0.73	0.58	0.37
Lighting. Interior	0.56	0.56	0.59	0.54	0.70	0.65	0.41	0.44	0.44	0.52	0.72	0.73	0.56	0.37
Lighting, Exterior	0.67	0.75	0.71	0.72	0.83	0.79	0.50	0.50	0.49	0.70	0.81	0.83	0.70	0.41
Office Equipment	0.58	0.60	0.62	0.59	0.73	0.68	0.44	0.46	0.45	0.56	0.74	0.75	0.60	0.38
Refrigeration	0.60	0.63	0.62	0.61	0.75	0.70	0.44	0.46	0.45	0.58	0.74	0.77	0.61	0.38
Ventilation	0.61	0.64	0.64	0.62	0.76	0.71	0.45	0.46	0.46	0.59	0.76	0.77	0.63	0.38
RESIDENTIAL														
Central AC	0.50	0.50	0.49	0.48	0.61	0.60	0.40	0.44	0.43	0.47	0.56	0.74	0.47	0.37
Room AC	0.50	0.51	0.48	0.49	0.61	0.60	0.40	0.44	0.43	0.47	0.56	0.71	0.45	0.37
Space Heating	0.66	0.69	0.73	0.67	0.82	0.76	0.48	0.47	0.49	0.65	0.84	0.75	0.71	0.41
Water Heating	0.58	0.61	0.63	0.59	0.76	0.70	0.41	0.43	0.44	0.55	0.75	0.74	0.60	0.37
Lighting	0.56	0.55	0.59	0.55	0.70	0.65	0.42	0.44	0.45	0.53	0.72	0.74	0.57	0.37
Refrigerator	0.60	0.64	0.63	0.62	0.76	0.71	0.45	0.46	0.45	0.59	0.75	0.77	0.62	0.38
Dishwasher	0.56	0.57	0.58	0.55	0.73	0.67	0.39	0.42	0.43	0.52	0.72	0.73	0.55	0.36
Clothes Washer	0.54	0.55	0.57	0.54	0.71	0.64	0.38	0.41	0.42	0.50	0.70	0.72	0.55	0.36
Clothes Dryer	0.55	0.56	0.58	0.54	0.72	0.66	0.38	0.41	0.42	0.51	0.71	0.72	0.55	0.36
Television	0.58	0.60	0.62	0.58	0.73	0.68	0.44	0.45	0.45	0.56	0.74	0.76	0.60	0.37
Personal Computers	0.58	0.60	0.62	0.58	0.73	0.68	0.44	0.45	0.45	0.56	0.74	0.76	0.60	0.37
INDUSTRIAL														
Process Heating	0.59	0.60	0.62	0.59	0.74	0.68	0.44	0.45	0.45	0.56	0.74	0.76	0.60	0.38
Machine Drive	0.59	0.61	0.63	0.59	0.74	0.69	0.44	0.45	0.45	0.57	0.74	0.76	0.60	0.38
HVAC (facility)	0.58	0.59	0.62	0.58	0.73	0.67	0.43	0.45	0.45	0.56	0.74	0.75	0.59	0.37
Lighting (facility)	0.58	0.59	0.62	0.58	0.73	0.68	0.43	0.45	0.45	0.56	0.74	0.75	0.59	0.37
Other Process Use	0.58	0.59	0.61	0.57	0.73	0.67	0.43	0.45	0.45	0.55	0.74	0.75	0.59	0.37

Table B-3
Marginal Method, No CO_2 Policy (2030)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.52	0.51	0.52	0.48	0.61	0.61	0.40	0.43	0.42	0.47	0.61	0.81	0.54	0.36
Heating	0.66	0.66	0.80	0.64	0.81	0.74	0.46	0.47	0.48	0.62	0.84	0.89	0.80	0.44
Water Heating	0.59	0.58	0.63	0.55	0.73	0.66	0.41	0.44	0.44	0.52	0.74	0.87	0.67	0.38
Lighting. Interior	0.57	0.55	0.62	0.53	0.71	0.66	0.41	0.44	0.43	0.51	0.72	0.87	0.65	0.37
Lighting, Exterior	0.69	0.74	0.72	0.71	0.83	0.79	0.50	0.51	0.51	0.69	0.82	0.89	0.76	0.41
Office Equipment	0.60	0.59	0.64	0.58	0.73	0.69	0.43	0.45	0.45	0.55	0.74	0.87	0.68	0.39
Refrigeration	0.61	0.62	0.65	0.60	0.75	0.71	0.44	0.46	0.45	0.57	0.74	0.88	0.69	0.39
Ventilation	0.62	0.63	0.67	0.62	0.76	0.72	0.45	0.46	0.46	0.58	0.76	0.88	0.71	0.39
RESIDENTIAL														
Central AC	0.50	0.50	0.50	0.47	0.61	0.61	0.40	0.43	0.43	0.46	0.56	0.78	0.51	0.36
Room AC	0.50	0.50	0.49	0.48	0.61	0.61	0.40	0.43	0.43	0.46	0.56	0.75	0.50	0.36
Space Heating	0.69	0.68	0.75	0.66	0.82	0.76	0.47	0.48	0.51	0.64	0.84	0.89	0.78	0.43
Water Heating	0.60	0.60	0.66	0.59	0.76	0.70	0.41	0.43	0.43	0.54	0.75	0.89	0.69	0.38
Lighting	0.58	0.55	0.62	0.54	0.70	0.66	0.42	0.44	0.45	0.52	0.72	0.87	0.65	0.38
Refrigerator	0.62	0.63	0.65	0.61	0.76	0.72	0.44	0.46	0.45	0.58	0.75	0.88	0.69	0.39
Dishwasher	0.57	0.57	0.61	0.54	0.74	0.68	0.39	0.41	0.42	0.50	0.72	0.89	0.64	0.37
Clothes Washer	0.56	0.55	0.60	0.53	0.71	0.66	0.38	0.40	0.40	0.47	0.70	0.88	0.64	0.37
Clothes Dryer	0.57	0.56	0.61	0.53	0.73	0.67	0.38	0.41	0.41	0.49	0.71	0.88	0.64	0.37
Television	0.60	0.59	0.64	0.58	0.73	0.69	0.43	0.45	0.46	0.55	0.74	0.87	0.68	0.38
Personal Computers	0.60	0.59	0.64	0.58	0.73	0.69	0.43	0.45	0.46	0.55	0.74	0.87	0.68	0.38
INDUSTRIAL														
Process Heating	0.60	0.60	0.65	0.58	0.74	0.69	0.43	0.45	0.45	0.56	0.75	0.87	0.68	0.38
Machine Drive	0.61	0.60	0.65	0.59	0.74	0.69	0.44	0.46	0.46	0.56	0.75	0.87	0.69	0.39
HVAC (facility)	0.60	0.58	0.64	0.57	0.73	0.68	0.43	0.45	0.45	0.55	0.74	0.87	0.67	0.38
Lighting (facility)	0.60	0.58	0.64	0.57	0.73	0.68	0.43	0.45	0.45	0.55	0.74	0.87	0.68	0.38
Other Process Use	0.60	0.58	0.64	0.56	0.73	0.68	0.43	0.45	0.45	0.55	0.74	0.87	0.68	0.38

Marginal Method Emissions Intensities with CO2 Policy

Table B-4
Marginal Method with CO_2 Policy (2010)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.58	0.80	0.49	0.50	0.86	0.96	0.58	0.46	0.51	0.45	0.58	0.40	0.46	0.60
Heating	0.62	0.93	0.52	0.52	0.96	1.02	0.51	0.44	0.43	0.51	0.81	0.35	0.60	0.49
Water Heating	0.60	0.89	0.48	0.50	0.94	1.00	0.55	0.45	0.46	0.47	0.69	0.35	0.51	0.55
Lighting. Interior	0.60	0.87	0.48	0.50	0.93	1.00	0.55	0.45	0.47	0.47	0.68	0.36	0.50	0.56
Lighting, Exterior	0.64	0.94	0.52	0.59	0.94	1.01	0.50	0.44	0.45	0.53	0.78	0.52	0.65	0.50
Office Equipment	0.61	0.89	0.49	0.52	0.93	1.00	0.54	0.45	0.46	0.48	0.71	0.40	0.54	0.54
Refrigeration	0.62	0.90	0.49	0.53	0.93	1.00	0.53	0.44	0.47	0.49	0.71	0.42	0.55	0.54
Ventilation	0.62	0.91	0.49	0.53	0.94	1.00	0.53	0.44	0.46	0.49	0.73	0.41	0.56	0.53
RESIDENTIAL														
Central AC	0.58	0.78	0.51	0.51	0.84	0.94	0.59	0.48	0.53	0.45	0.55	0.48	0.47	0.61
Room AC	0.59	0.77	0.51	0.51	0.84	0.94	0.59	0.49	0.54	0.45	0.54	0.48	0.46	0.61
Space Heating	0.63	0.94	0.50	0.53	0.96	1.02	0.51	0.44	0.43	0.52	0.81	0.36	0.60	0.50
Water Heating	0.60	0.90	0.47	0.49	0.95	1.01	0.54	0.44	0.46	0.47	0.71	0.34	0.51	0.54
Lighting	0.60	0.86	0.49	0.50	0.92	1.00	0.55	0.45	0.47	0.47	0.68	0.38	0.53	0.56
Refrigerator	0.62	0.91	0.49	0.53	0.93	1.00	0.53	0.44	0.47	0.49	0.72	0.42	0.55	0.54
Dishwasher	0.59	0.88	0.47	0.47	0.94	1.00	0.55	0.45	0.47	0.46	0.66	0.32	0.48	0.56
Clothes Washer	0.59	0.88	0.46	0.46	0.94	1.00	0.55	0.45	0.47	0.45	0.66	0.31	0.46	0.56
Clothes Dryer	0.59	0.88	0.46	0.46	0.95	1.00	0.55	0.45	0.47	0.46	0.66	0.30	0.46	0.56
Television	0.61	0.88	0.49	0.52	0.93	1.00	0.54	0.45	0.46	0.48	0.70	0.41	0.55	0.54
Personal Computers	0.61	0.88	0.49	0.52	0.93	1.00	0.54	0.45	0.46	0.48	0.70	0.41	0.55	0.54
INDUSTRIAL														
Process Heating	0.61	0.89	0.49	0.52	0.93	1.00	0.54	0.45	0.46	0.48	0.71	0.40	0.55	0.55
Machine Drive	0.61	0.89	0.49	0.52	0.93	1.00	0.54	0.45	0.46	0.48	0.71	0.40	0.55	0.54
HVAC (facility)	0.61	0.88	0.49	0.52	0.93	1.00	0.54	0.45	0.47	0.48	0.70	0.39	0.54	0.55
Lighting (facility)	0.61	0.88	0.49	0.52	0.93	1.00	0.54	0.45	0.47	0.48	0.70	0.40	0.54	0.55
Other Process Use	0.61	0.88	0.49	0.51	0.93	1.00	0.54	0.45	0.47	0.48	0.70	0.40	0.54	0.55

Table B-5
Marginal Method with CO_2 Policy (2015)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.52	0.59	0.48	0.49	0.69	0.90	0.48	0.43	0.51	0.46	0.50	0.46	0.45	0.44
Heating	0.57	0.71	0.54	0.50	0.85	1.00	0.43	0.43	0.43	0.44	0.64	0.51	0.58	0.42
Water Heating	0.54	0.64	0.48	0.49	0.78	0.97	0.45	0.42	0.46	0.44	0.54	0.48	0.49	0.43
Lighting. Interior	0.54	0.62	0.48	0.48	0.76	0.96	0.45	0.42	0.47	0.44	0.54	0.48	0.49	0.43
Lighting, Exterior	0.60	0.79	0.52	0.58	0.86	1.00	0.43	0.44	0.45	0.45	0.66	0.58	0.61	0.42
Office Equipment	0.55	0.66	0.49	0.51	0.79	0.97	0.44	0.43	0.46	0.44	0.56	0.50	0.52	0.43
Refrigeration	0.56	0.69	0.49	0.52	0.80	0.97	0.44	0.43	0.46	0.44	0.58	0.51	0.52	0.43
Ventilation	0.56	0.70	0.49	0.52	0.81	0.98	0.44	0.43	0.46	0.44	0.59	0.51	0.53	0.43
RESIDENTIAL														
Central AC	0.53	0.57	0.49	0.49	0.68	0.89	0.48	0.44	0.53	0.46	0.50	0.48	0.45	0.45
Room AC	0.53	0.58	0.49	0.49	0.68	0.88	0.49	0.45	0.53	0.46	0.50	0.48	0.44	0.45
Space Heating	0.60	0.74	0.52	0.52	0.86	1.01	0.43	0.43	0.43	0.44	0.64	0.51	0.58	0.42
Water Heating	0.55	0.66	0.47	0.48	0.81	0.98	0.44	0.42	0.46	0.44	0.55	0.47	0.49	0.43
Lighting	0.54	0.61	0.48	0.49	0.75	0.96	0.45	0.42	0.47	0.44	0.54	0.49	0.50	0.43
Refrigerator	0.56	0.69	0.49	0.52	0.81	0.98	0.44	0.43	0.46	0.44	0.58	0.51	0.52	0.43
Dishwasher	0.54	0.63	0.46	0.46	0.79	0.98	0.45	0.42	0.46	0.44	0.52	0.46	0.47	0.43
Clothes Washer	0.53	0.62	0.46	0.45	0.77	0.97	0.45	0.42	0.47	0.44	0.50	0.45	0.45	0.43
Clothes Dryer	0.53	0.62	0.46	0.45	0.78	0.97	0.45	0.42	0.46	0.44	0.51	0.45	0.46	0.43
Television	0.55	0.65	0.49	0.50	0.78	0.97	0.45	0.42	0.46	0.44	0.57	0.50	0.52	0.43
Personal Computers	0.55	0.65	0.49	0.50	0.78	0.97	0.45	0.42	0.46	0.44	0.57	0.50	0.52	0.43
INDUSTRIAL														
Process Heating	0.55	0.66	0.49	0.51	0.78	0.97	0.45	0.43	0.46	0.44	0.57	0.50	0.52	0.43
Machine Drive	0.55	0.66	0.49	0.51	0.79	0.97	0.44	0.43	0.46	0.44	0.57	0.50	0.52	0.43
HVAC (facility)	0.55	0.64	0.49	0.50	0.78	0.97	0.45	0.42	0.46	0.44	0.56	0.50	0.51	0.43
Lighting (facility)	0.55	0.64	0.49	0.50	0.78	0.97	0.45	0.42	0.46	0.44	0.56	0.50	0.51	0.43
Other Process Use	0.55	0.64	0.49	0.50	0.78	0.97	0.45	0.42	0.46	0.44	0.56	0.50	0.51	0.43

Table B-6
Marginal Method with CO_2 Policy (2020)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.54	0.70	0.52	0.61	0.69	0.81	0.45	0.43	0.46	0.53	0.50	0.43	0.44	0.43
Heating	0.58	0.78	0.64	0.58	0.79	0.92	0.44	0.44	0.53	0.45	0.69	0.51	0.53	0.41
Water Heating	0.56	0.77	0.59	0.62	0.76	0.87	0.44	0.44	0.49	0.47	0.56	0.46	0.47	0.41
Lighting. Interior	0.56	0.75	0.58	0.62	0.74	0.86	0.44	0.43	0.48	0.48	0.55	0.46	0.47	0.42
Lighting, Exterior	0.60	0.77	0.61	0.59	0.81	0.94	0.44	0.43	0.55	0.47	0.69	0.60	0.56	0.41
Office Equipment	0.57	0.75	0.59	0.61	0.76	0.88	0.44	0.43	0.50	0.48	0.59	0.49	0.49	0.41
Refrigeration	0.57	0.76	0.59	0.60	0.76	0.89	0.44	0.43	0.50	0.48	0.60	0.50	0.49	0.41
Ventilation	0.58	0.76	0.60	0.60	0.77	0.90	0.44	0.43	0.50	0.47	0.61	0.51	0.50	0.41
RESIDENTIAL														
Central AC	0.54	0.70	0.51	0.62	0.68	0.81	0.45	0.44	0.47	0.55	0.49	0.45	0.44	0.43
Room AC	0.54	0.70	0.50	0.61	0.68	0.80	0.46	0.44	0.47	0.55	0.49	0.45	0.44	0.43
Space Heating	0.60	0.78	0.63	0.58	0.80	0.92	0.44	0.44	0.55	0.45	0.68	0.52	0.54	0.41
Water Heating	0.57	0.79	0.60	0.60	0.76	0.90	0.45	0.44	0.48	0.47	0.58	0.46	0.47	0.41
Lighting	0.56	0.75	0.58	0.61	0.74	0.86	0.44	0.43	0.50	0.49	0.56	0.48	0.47	0.41
Refrigerator	0.58	0.76	0.59	0.60	0.76	0.90	0.44	0.43	0.50	0.48	0.60	0.51	0.49	0.41
Dishwasher	0.56	0.79	0.58	0.62	0.74	0.89	0.45	0.44	0.46	0.47	0.55	0.43	0.46	0.41
Clothes Washer	0.55	0.79	0.58	0.61	0.74	0.88	0.45	0.44	0.45	0.48	0.53	0.41	0.44	0.41
Clothes Dryer	0.56	0.79	0.58	0.62	0.74	0.88	0.45	0.44	0.46	0.47	0.53	0.42	0.45	0.41
Television	0.57	0.76	0.59	0.60	0.76	0.88	0.44	0.43	0.51	0.48	0.59	0.50	0.49	0.41
Personal Computers	0.57	0.76	0.59	0.60	0.76	0.88	0.44	0.43	0.51	0.48	0.59	0.50	0.49	0.41
INDUSTRIAL														
Process Heating	0.57	0.76	0.59	0.61	0.76	0.88	0.44	0.43	0.50	0.48	0.59	0.49	0.49	0.41
Machine Drive	0.57	0.76	0.59	0.61	0.76	0.88	0.44	0.43	0.50	0.48	0.59	0.50	0.49	0.41
HVAC (facility)	0.57	0.76	0.59	0.61	0.75	0.87	0.44	0.43	0.50	0.48	0.58	0.49	0.48	0.41
Lighting (facility)	0.57	0.76	0.59	0.61	0.75	0.87	0.44	0.43	0.50	0.48	0.58	0.49	0.48	0.41
Other Process Use	0.57	0.76	0.59	0.61	0.75	0.87	0.44	0.43	0.50	0.48	0.58	0.49	0.48	0.41

Table B-7
Marginal Method with CO_2 Policy (2025)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.56	0.72	0.49	0.49	0.65	0.79	0.48	0.44	0.48	0.52	0.62	0.72	0.49	0.39
Heating	0.61	0.70	0.64	0.49	0.75	0.92	0.44	0.45	0.49	0.61	0.69	0.73	0.70	0.42
Water Heating	0.58	0.74	0.54	0.47	0.69	0.89	0.46	0.45	0.48	0.54	0.67	0.74	0.58	0.39
Lighting. Interior	0.58	0.75	0.53	0.47	0.68	0.88	0.46	0.45	0.47	0.54	0.66	0.74	0.56	0.39
Lighting, Exterior	0.62	0.64	0.60	0.55	0.79	0.91	0.47	0.47	0.48	0.66	0.69	0.75	0.68	0.42
Office Equipment	0.59	0.72	0.55	0.49	0.70	0.88	0.46	0.45	0.48	0.56	0.67	0.74	0.60	0.40
Refrigeration	0.60	0.70	0.55	0.50	0.72	0.89	0.46	0.45	0.48	0.58	0.66	0.74	0.61	0.40
Ventilation	0.60	0.70	0.56	0.50	0.73	0.90	0.46	0.45	0.48	0.58	0.66	0.74	0.62	0.40
RESIDENTIAL														
Central AC	0.55	0.72	0.48	0.49	0.64	0.79	0.48	0.44	0.47	0.52	0.61	0.70	0.48	0.41
Room AC	0.55	0.72	0.48	0.49	0.64	0.78	0.49	0.44	0.47	0.52	0.61	0.68	0.47	0.41
Space Heating	0.64	0.68	0.62	0.50	0.76	0.93	0.45	0.46	0.48	0.62	0.70	0.74	0.69	0.41
Water Heating	0.59	0.73	0.54	0.46	0.71	0.90	0.44	0.44	0.48	0.55	0.65	0.74	0.60	0.39
Lighting	0.59	0.74	0.54	0.48	0.68	0.87	0.46	0.44	0.48	0.55	0.67	0.73	0.57	0.40
Refrigerator	0.60	0.70	0.55	0.50	0.72	0.89	0.46	0.45	0.48	0.58	0.66	0.74	0.61	0.40
Dishwasher	0.58	0.75	0.52	0.44	0.68	0.90	0.44	0.44	0.47	0.53	0.65	0.74	0.56	0.39
Clothes Washer	0.57	0.76	0.51	0.43	0.67	0.89	0.44	0.44	0.48	0.51	0.64	0.74	0.56	0.38
Clothes Dryer	0.57	0.76	0.52	0.43	0.67	0.90	0.44	0.44	0.47	0.52	0.65	0.74	0.56	0.38
Television	0.59	0.72	0.55	0.49	0.70	0.88	0.46	0.44	0.48	0.57	0.67	0.74	0.60	0.40
Personal Computers	0.59	0.72	0.55	0.49	0.70	0.88	0.46	0.44	0.48	0.57	0.67	0.74	0.60	0.40
INDUSTRIAL														
Process Heating	0.59	0.72	0.55	0.49	0.70	0.88	0.46	0.44	0.48	0.57	0.67	0.74	0.60	0.40
Machine Drive	0.59	0.72	0.55	0.49	0.71	0.88	0.46	0.45	0.48	0.57	0.67	0.74	0.60	0.40
HVAC (facility)	0.59	0.73	0.55	0.49	0.70	0.88	0.46	0.44	0.48	0.56	0.67	0.74	0.59	0.40
Lighting (facility)	0.59	0.73	0.55	0.49	0.70	0.88	0.46	0.44	0.48	0.56	0.67	0.74	0.59	0.40
Other Process Use	0.59	0.73	0.55	0.49	0.70	0.88	0.46	0.44	0.48	0.56	0.67	0.74	0.59	0.40

Table B-8
Marginal Method with CO_2 Policy (2030)

Annual CO2 Intensity (Metric Tons Avoided / MWh Saved)

End Use	Total US	ECAR	ERCOT	MAAC	MAIN	MAPP	NPCC/NY	NPCC/NE	SERC/FL	SERC/STV	SPP	WSCC/NWP	WSCC/RA	WSCC/CNV
COMMERCIAL														
Cooling	0.55	0.65	0.48	0.44	0.58	0.57	0.42	0.46	0.50	0.59	0.59	0.93	0.60	0.37
Heating	0.58	0.57	0.56	0.47	0.69	0.60	0.41	0.47	0.52	0.74	0.67	0.88	0.68	0.40
Water Heating	0.57	0.61	0.50	0.44	0.64	0.56	0.40	0.47	0.53	0.66	0.59	0.93	0.67	0.38
Lighting. Interior	0.57	0.63	0.50	0.44	0.62	0.56	0.40	0.47	0.52	0.65	0.59	0.93	0.67	0.37
Lighting, Exterior	0.59	0.56	0.54	0.54	0.70	0.64	0.44	0.45	0.49	0.77	0.68	0.82	0.63	0.39
Office Equipment	0.57	0.61	0.51	0.47	0.64	0.58	0.41	0.47	0.52	0.67	0.61	0.90	0.66	0.38
Refrigeration	0.58	0.60	0.51	0.48	0.65	0.59	0.42	0.47	0.51	0.69	0.62	0.89	0.66	0.38
Ventilation	0.58	0.60	0.52	0.48	0.66	0.60	0.42	0.47	0.51	0.70	0.63	0.89	0.66	0.38
RESIDENTIAL														
Central AC	0.53	0.63	0.47	0.44	0.57	0.57	0.43	0.46	0.48	0.57	0.59	0.88	0.55	0.37
Room AC	0.52	0.63	0.47	0.44	0.58	0.57	0.43	0.46	0.48	0.56	0.59	0.84	0.54	0.37
Space Heating	0.61	0.57	0.54	0.49	0.69	0.61	0.42	0.47	0.51	0.75	0.67	0.88	0.66	0.40
Water Heating	0.57	0.58	0.52	0.43	0.66	0.58	0.40	0.48	0.53	0.69	0.60	0.93	0.67	0.38
Lighting	0.56	0.62	0.49	0.45	0.63	0.58	0.41	0.46	0.51	0.65	0.60	0.90	0.65	0.38
Refrigerator	0.58	0.60	0.51	0.48	0.66	0.59	0.41	0.47	0.51	0.69	0.63	0.89	0.65	0.38
Dishwasher	0.56	0.59	0.50	0.40	0.64	0.56	0.38	0.49	0.53	0.66	0.59	0.95	0.65	0.37
Clothes Washer	0.56	0.60	0.50	0.40	0.63	0.55	0.38	0.49	0.54	0.64	0.57	0.96	0.67	0.37
Clothes Dryer	0.56	0.60	0.50	0.39	0.64	0.55	0.38	0.49	0.54	0.65	0.58	0.96	0.66	0.37
Television	0.57	0.60	0.51	0.47	0.65	0.59	0.41	0.45	0.50	0.68	0.61	0.89	0.66	0.38
Personal Computers	0.57	0.60	0.51	0.47	0.65	0.59	0.41	0.45	0.50	0.68	0.61	0.89	0.66	0.38
INDUSTRIAL														
Process Heating	0.57	0.61	0.51	0.47	0.65	0.59	0.41	0.46	0.51	0.68	0.62	0.90	0.66	0.38
Machine Drive	0.57	0.61	0.51	0.47	0.65	0.59	0.41	0.46	0.51	0.68	0.62	0.90	0.66	0.38
HVAC (facility)	0.57	0.61	0.51	0.46	0.64	0.58	0.41	0.46	0.51	0.67	0.61	0.90	0.66	0.38
Lighting (facility)	0.57	0.61	0.51	0.46	0.65	0.58	0.41	0.46	0.51	0.67	0.61	0.90	0.66	0.38
Other Process Use	0.57	0.61	0.50	0.46	0.65	0.58	0.41	0.46	0.51	0.67	0.61	0.90	0.66	0.38

This modeling approach provides convenient look-up tables of marginal emissions multipliers for utilities to apply to the electricity savings from their energy efficiency programs to yield marginal CO_2 emissions reduction values. The choice of whether to apply the values for the case with or without CO_2 policy is subjective and will depend on the context in which the analysis is being conducted.

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Electric Power Research Institute
3420 Hillview Avenue, Palo Alto, California 94304-1338 • PO Box 10412, Palo Alto, California 94303-0813 USA
800.313.3774 • 650.855.2121 • askepri@epri.com • www.epri.com