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A New Approach for Modeling the Peak Utility Impacts from a Proposed CUAC Standard

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Office of Building Technologies
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U.S. Department of Energy

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Acronyms, Abbreviations, and Symbols

AEO	Annual Energy Outlook
BLAST	Building Loads and System Thermodynamics
BT	DOE's Building and Technologies program
CBECS	Commercial Buildings Energy Consumption Survey
CLF	conservation load factor
CUAC	commercial unitary air conditioner
DOE	U.S. Department of Energy
EIA	Energy Information Administration
EMM	Electricity Market Module of NEMS
GW	10^9 (giga)watt
kW	10^3 (kilo)watt
LCC	life cycle cost
LDC	load duration curve
LDSM	Load and Demand Side Management NEMS sub-module
MEF	marginal emissions factor
NEMS	National Energy Modeling System
NERC	North American Reliability Council
NES	National Energy Savings model
PNNL	Pacific Northwest National Laboratory
RCAC	residential central air conditioning
RMS	root mean square
SEER	seasonal energy efficiency ratio
TSL	trial standard level (e.g. TSL 4)
TMY	typical meteorological year
TWh	10^{12} (tera)watt hour
Δ	mathematical symbol for "change in"

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Abstract

This report describes a new Berkeley Lab approach for modeling the likely peak electricity load reductions from proposed energy efficiency programs in the National Energy Modeling System (NEMS). This method is presented in the context of the commercial unitary air conditioning (CUAC) energy efficiency standards. A previous report investigating the residential central air conditioning (RCAC) load shapes in NEMS revealed that the peak reduction results were lower than expected. This effect was believed to be due in part to the presence of the *squelch*, a program algorithm designed to ensure changes in the system load over time are consistent with the input historic trend. The squelch applies a system load-scaling factor that scales any differences between the end-use bottom-up and system loads to maintain consistency with historic trends. To obtain more accurate peak reduction estimates, a new approach for modeling the impact of peaky end uses in NEMS-BT has been developed. The new approach decrements the system load directly, reducing the impact of the squelch on the final results. This report also discusses a number of additional factors, in particular non-coincidence between end-use loads and system loads as represented within NEMS, and their impacts on the peak reductions calculated by NEMS.

Using Berkeley Lab's new *double-decrement* approach reduces the conservation load factor (CLF) on an input load decrement from 25% down to 19% for a SEER 13 CUAC trial standard level, as seen in NEMS-BT output. About 4 GW more in peak capacity reduction results from this new approach as compared to Berkeley Lab's traditional end-use decrement approach, which relied solely on lowering end use energy consumption. The new method has been fully implemented and tested in the Annual Energy Outlook 2003 (AEO2003) version of NEMS and will routinely be applied to future versions. This capability is now available for use in future end-use efficiency or other policy analysis that requires accurate representation of time varying load reductions

1. Introduction

Berkeley Lab has developed a new approach for modeling the peak utility impacts from a peak coincident end use using the National Energy Modeling System (NEMS). The impetus for developing this new approach stems from Berkeley Lab's prior difficulties with adequately representing efficiency improvements to a peaky end use in NEMS.

Developed and maintained by the Energy Information Administration (EIA), NEMS is a mid-range energy forecast model that has been used for the utility analysis and environmental assessment portions of various appliance energy efficiency standards' rulemakings for nearly a decade. NEMS relies upon a set of assumptions, which are fairly transparent due to the exposure and scrutiny each Annual Energy Outlook (AEO) receives. The Annual Energy Outlook is the annual forecast prepared by the Energy Information Administration (EIA) using NEMS. NEMS also offers a sophisticated picture of the effect of appliance standards because its scale allows it to measure the interactions between the various energy supply and demand sectors and the economy as a whole. Berkeley Lab calls the version of NEMS used to model proposed energy-efficiency standards NEMS-BT because this work is conducted under the auspices of the Department of Energy (DOE) Building and Technologies (BT) program. EIA requires that any modified version of NEMS be named differently, to distinguish them from EIA's Annual Energy Outlook (AEO) Reference Case version. Throughout this memo, NEMS-BT is used to refer to the appliance standards' modified version used at Berkeley Lab. The AEO version of the model is referred to as simply NEMS.

A previous effort investigated how the residential central air conditioning (RCAC) load shape is represented in NEMS-BT, and presented some alternative approaches to modeling this end use to achieve more accurate peak effects. Analysis of the RCAC end use was the first rulemaking analysis Berkeley Lab has performed using NEMS-BT for a highly peak-load-coincident end use. Also, the California electricity market problems of 2000 and the northeast blackout of 2003 dramatically heightened policy interest in peak effects. The RCAC analysis first alerted Berkeley Lab to the stunted peak impacts resulting from input energy savings. This work discovered the presence of the squelch, which was believed to be masking the peak impacts. The current work will show that a number of factors affect the peak reduction calculations, that in this case the squelch does not significantly impact the results, and that a more important factor is the degree of coincidence between this peaky end use and the system load. A new method for producing accurate peak effects could not be developed in time to meet the aggressive schedule of the RCAC rulemaking, but this experience led Berkeley Lab to immediately begin working on developing a new approach to be used in the CUAC and other upcoming analyses.

The new Berkeley Lab approach decrements the hourly system load directly instead of simply lowering energy use by the end use. This report explains the new approach and presents preliminary results. Extensive analysis of the CUAC end use and system load shapes are also presented to validate that the load shapes used are credible. The focus of this report is the current CUAC rulemaking, although this approach was designed for other end uses, notably utility distribution transformers.

The structure of this work is:

- **Section 2** provides background information and summarizes what Berkeley Lab has learned about the behavior of load shapes in NEMS from our previous work. This section includes a description of the conservation load factor (CLF), which is a helpful indicator of how well NEMS translates energy savings from a peaky end use to peak load reductions.
- **Section 3** presents a comparison of the end use and system load shapes in NEMS with those from an externally produced source. This section also reports some statistical measurements that seek any consistent trends in the differences.
- **Section 4** details Berkeley Lab's new double decrement approach.
- **Section 5** presents some preliminary results using the new double decrement approach, including some sensitivity analysis runs.
- **Section 6** discusses some of the tools Berkeley Lab uses to interpret results.
- **Section 7** summarizes the findings and conclusions from this work.

2. Background

This work builds upon a previous report that sought to explore how the RCAC load shapes were treated in NEMS (LaCommare et al. 2002). This section summarizes previous work. Subsection 2.1 revisits earlier findings, while subsection 2.2 provides an overview of the traditional energy decrement only approach Berkeley Lab established to model the utility impacts from proposed energy efficiency standards. Subsection 2.3 discusses a measure used in this work to evaluate how well NEMS-BT is capturing the peak impacts from a proposed CUAC energy efficiency standard. Results using the traditional approach are presented in subsection 2.4.

2.1 Key Findings from Previous Work

Berkeley Lab's analysis of the treatment of RCAC load shapes in NEMS-BT uncovered some problems that help explain the puzzling small peak impacts found in analysis of proposed RCAC standards.

Our key findings were:

- **NEMS was using an inappropriate load shape to represent residential space cooling.** Berkeley Lab found that the residential space-cooling end use was represented in the AEO2001 (or earlier) version of NEMS by an October-peaking load profile, rather than a more credible one like the RSFCAO67 load shape that was included in inputs but not activated. The CLF dropped from 35% to 23% for proposed RCAC Trial Standard Level (TSL) 4 when the autumn-peaking load shape was replaced with the summer-peaking RSFCAO67. A TSL is a certain feasible combination of technical energy efficiency improvements to an appliance. Within NEMS, this corresponds to a specified percent reduction in the amount of energy consumed for that end-use. Subsequent to this finding, EIA responded by updating a number of end-use load shapes, including the residential space cooling load shape, rectifying this problem.
- **NEMS uses a squelch factor to scale down system load so that it coincides with the historical data used to initialize the model.** Removing this squelch has a dramatic effect on forecast peak growth, e.g. a 3.5% increase in the AEO2001 Reference Case installed capacity in 2020. Note that the squelch lowers all NEMS peak load growth forecasts. Although conclusions from the RCAC analysis pointed to the squelch as the primary culprit for the limited peak impacts, in the present analysis of the CUAC standard, we find that the degree of coincidence between the end-use and the system loads is the most important factor. Please refer to Appendices A and D for more detail on how loads are modeled, and how the squelch is implemented, and to Appendix F for an example analysis of case runs with and without the squelch.
- **NEMS updated AEO2002 load shapes with the traditional end-use energy only decrement approach was used for the RCAC rulemaking analysis.** This chosen combination decreased the CLF in the AEO2001 analysis from 45% to 33%.

The discovery of both the inappropriate space-cooling load shape in the 2001 version of NEMS-BT and the squelch factor helped to explain the troublesome results. However, as previously

mentioned, recent work has revealed that the squelch actually has little to do with our lower-than-expected peak utility impacts. Instead, as will be discussed in Section 5.4.3, non-coincidence appears to account for the majority of the difference between the input and output CLF. Appendix F presents a detailed explanation of how the squelch does little to impact the peak load.

EIA responded in a timely manner to Berkeley Lab's request to refine the NEMS load shapes. Prior literature indicated that a reasonable CLF for the RCAC end use might be 10-15%. Although improving the load shapes lowered the CLF (from 45% to 33% for trial standard level (TSL) 4), the results still appear to be much higher than expected. Berkeley Lab continued investigating this problem and has developed a new approach for future analyses that can clearly track the effects from a proposed energy efficiency standard.

2.2 Traditional Approach

The traditional approach to analyzing a proposed energy efficiency appliance standard is to simply reduce the end-use energy consumption of the appliance for each modeled year and by regional census divisions. This subtracted value is calculated exogenously to NEMS-BT and is referred to as the *energy decrement*. This approach worked well for most end uses recently studied (e.g. residential clothes washers, water heaters, and commercial fluorescent ballasts); however, the RCAC rulemaking being conducted during California's winter of discontent, 2000-2001, raised concerns because NEMS-BT did not appear to be accurately reflecting the amount of installed generating capacity potentially saved.

Because the relative size of appliance energy efficiency standard savings implemented in NEMS-BT is so small compared to the fluctuations in energy use by the whole energy sector, multiple NEMS-BT runs must be performed using larger decrements that are simple multiples of the proposed energy savings. Interpolated values for the NEMS-BT savings are derived from this series of larger-decrement simulations; the savings in each of the runs are based on an appliance energy efficiency TSL, which represents a certain combination of energy efficiency improvements to the appliance that are considered technically feasible by Berkeley Lab engineers.

The electricity generation and capacity output by fuel type for each of the NEMS-BT runs, e.g. 4, 6, and 8 times the TSL energy savings, are then regressed, and the actual forecast of the impact of the standard is interpolated back to the origin, i.e. to the Reference Case. The linear regression is forced through the origin because a zero change will result if no standard is enacted.

The NEMS-BT analysis reports changes resulting from an appliance standard; these include changes in installed generating capacity and the corresponding equivalent number of power plants avoided, electric generation saved by the power sector, and carbon and NOx emissions saved at electricity generators.

The method described above was recently used for the utility and environmental analysis related to the federal rulemakings for residential clothes washers, water heaters, and commercial fluorescent ballasts. However, unlike these other end uses, the RCAC and CUAC end uses are

peaky, that is they have a low load factor and their use coincides with system peaks. The CLF is a convenient indicator of the peakiness of the likely energy savings of any end use.

2.3 What is the Conservation Load Factor?

Analysis of non-peaky end uses on the power-sector are simpler because their use is not strongly coincident with peak demand times, i.e. the impact of a standard on new power plant construction is limited. The CLF measures how peaky an end use is and, in general, how peaky the load decrement might be resulting from improved efficiency in this end use. Any capacity factor relates actual output to maximum possible output. By, definition the CLF is expressed as follows:

$$\text{CLF} = \frac{\text{Average Energy Savings (GWh)}}{\text{Peak Load Savings (GW) * 8760 (h)}}$$

For an end use like refrigerators, whose load shape is fairly flat, a CLF value of approximately 60 to 70% is typical. This value indicates that average load of the end use is 60 to 70% of its peak load, yielding a flatter (baseload) profile. However, for a peaky end use like RCAC and CUAC, the CLF is typically in the range of 10-20% (Koomey et al. 1990; Treidler and Modera 1994). The high-demand episodes are largely on hot, summer days when air conditioning use is high.

This report uses more than one CLF to help understand the results from a proposed CUAC standard. The one used most often in this and the previous work is called the National Proxy CLF_{out}, which is based on NEMS output. This metric is the ratio of the average year-round energy savings to the peak capacity savings as shown below:

$$\text{National Proxy CLF}_{\text{out}} = \frac{\text{Average Energy Load Savings (GWh)}}{\text{Peak Capacity Savings (GW) * 8760 (h)}}$$

The National Proxy CLF_{out} is calculated for the U.S. from the NEMS-BT output due to limitations in the parameters NEMS outputs and is referred to in this report herein as the National CLF_{out}. NEMS-BT does not calculate a national value for load so installed capacity is therefore used as a proxy and regional CLF's are used to accommodate the regional load data provided in the model.

Because CUAC and RCAC are peak-coincident end uses, the energy efficiency standard will usually result in large peak demand savings relative to the energy saved. For example, using the established end-use decrement or traditional approach, the proposed CUAC TSL 4 (roughly equivalent to a seasonal energy efficiency ratio, or SEER, of 13), which saves an estimated 31.9 TWh of site energy in 2020, results in a reduction of only 14.5 GW of installed generating capacity, translating to a National CLF_{out} of roughly 25%. That is, the peak reduction result from AEO2001 is at least 10 to 20 GW lower than expected and the corresponding National CLF_{out} is substantially higher, i.e. capacity reduction would be closer to 25 GW with a typical National CLF_{out} of 15%. Because the CUAC rulemaking is still in its early stages, all CUAC runs use the

energy savings from the RCAC rulemaking as a general approximation for the energy savings from this end use.

Table 1 below briefly describes each metric used in this analysis. The LF_{in} refers to the load factor estimated from the input end use load shape, which is important because the degree of coincidence between the system load and end-use load shape has a significant influence on the National CLF_{out} , which reflects capacity savings. In order to relate LF_{in} , which is an input to the model and estimated by region, to the National CLF_{out} , which is based on changes to installed capacity and only easily estimated for the U.S., we found an intermediate estimate of the CLF, called the Regional CLF_{out} , which is based on the hourly load output and can be calculated by region, to help us compare how the load factor evolves through NEMS-BT. The Regional CLF_{out} is somewhat different than the definition for the National CLF_{out} in that the regional calculation uses load data while the national estimate uses capacity as a proxy for load. The Regional CLF_{out} is explained in more detail in Section 6.

Table 1. Description of CLF Metrics

Name	Description of Metric	Formula
LF_{in}	Implicit load factor by EMM region based on fraction of peak load to total annual demand that characterizes the end use or system load shape	$\frac{\text{Average End-Use or System Load}}{\text{Peak End-Use or System Load}}$
CLF_{in}	The CLF of the load decrement by EMM region and equal to the LF_{in} if the decrement is proportional across all regions	$\frac{\text{Average End-Use Load Savings}}{\text{Peak End-Use Load Savings}}$
Regional CLF_{out}	The CLF of the decrement to the system load by EMM region	$\frac{\text{Average System Load}}{\text{Peak System Load}}$
National (Proxy) CLF_{out}	The national result based on electricity generation and peak only.	$\frac{\text{Average Energy Savings}}{\text{Peak Capacity Savings}}$

Berkeley Lab relies heavily on the CLF to gauge how well NEMS-BT represents the CUAC end use and to compare how modifications to the approach represent the CUAC peak coincidence.

2.4 Results Using Traditional Approach

A summary of the results using the traditional approach described in the previous section is presented in Table 2 below. Results are reported for year 2020 using the AEO2003 version of NEMS-BT. The results only cover CUAC energy savings and ignore savings from ventilation or heat pumps, which are currently not included as part of the CUAC standard. Note that our previous report showed results from both RCAC and heat pumps, which are not directly comparable.

Table 2. CUAC Cooling-Only Results in Year 2020 Using the Traditional Approach in the 2003 Version of NEMS-BT

Trial Standard Level	Energy Sales Change (TWh)	Peak Capacity Change (GW)	National CLF _{out} (%)
TSL 1	-12.7	-4.5	32%
TSL 2	-21.3	-9.7	25%
TSL 3	-24.7	-11.2	25%
TSL 4	-31.9	-14.5	25%
TSL 5	-62.3	-24.6	29%

As will be discussed further in subsection 6.4, varying the multipliers can influence the range in magnitude of the National CLF_{out} in this table. In general, the higher the multipliers that are chosen, the higher the National CLF_{out} tends to be. Table 3 shows the sets of multipliers used for each of the CUAC TSLs. For the traditional approach results, TSLs 1 and 5 use higher sets of multipliers, resulting in higher National CLF_{out} values as seen in Table 2. For this reason, the results in this report, with the exception of the Table 2 results, use the lower set of multipliers presented in Table 3. In general, the use of lower multipliers lowers the CLF roughly 2-5%. Table 4 shows the results for CUAC TSL 4 using both the higher and lower multipliers to perform our analysis. The effect of the multipliers is discussed further in Section 6.3.2.

Table 3. Comparison of Multipliers used for each CUAC TSL

Trial Standard Level	Higher Multipliers	Lower Multipliers
TSL 1	12,24,36	5,8,10
TSL 2	6,8,10	3,4,5
TSL 3	6,8,10	3,4,5
TSL 4	4,6,8	2,3,4
TSL 5	2,4,6	1,1.5,2

Table 4. Impact of Results for CUAC TSL 4 Due to Multipliers

	Peak Capacity Change (GW)	National CLF _{out}
Higher Multipliers	14.5	25%
Lower Multipliers	16.5	22%

3. Validating the Load Shapes in NEMS

This section compares NEMS commercial space cooling end-use and system load shapes to those from an external simulation. Also, NEMS system loads are compared to historic system load data. The purpose is to ensure that the load shapes in NEMS are credible and to identify any significant differences. Section 3.1 presents the end use space cooling and ventilation load shapes. Section 3.2 compares those NEMS end-use load shapes to ones developed exogenously by building simulations. Section 3.3 makes a similar comparison for the system loads among three sources – NEMS, historic 1999 data, and TMY weather normalized data. Finally, section 3.4 compares the end-use space cooling load shape in NEMS to the system load shape in NEMS to gauge the degree of peak coincidence or non-coincidence.

Throughout this section, comparisons of the various load shapes are illustrated by focusing on the ECAR (East Central Area Reliability) EMM region. All regions were similarly analyzed but this region should provide enough representative information to satisfy the reader. ECAR amounts to roughly 15 % of the total U.S. load so is a significant contributor to the overall impact from a proposed CUAC standard. Figure 1 shows a map of the 13 EMM regions and Table 5 shows the shorthand used in this report for each of these regions.

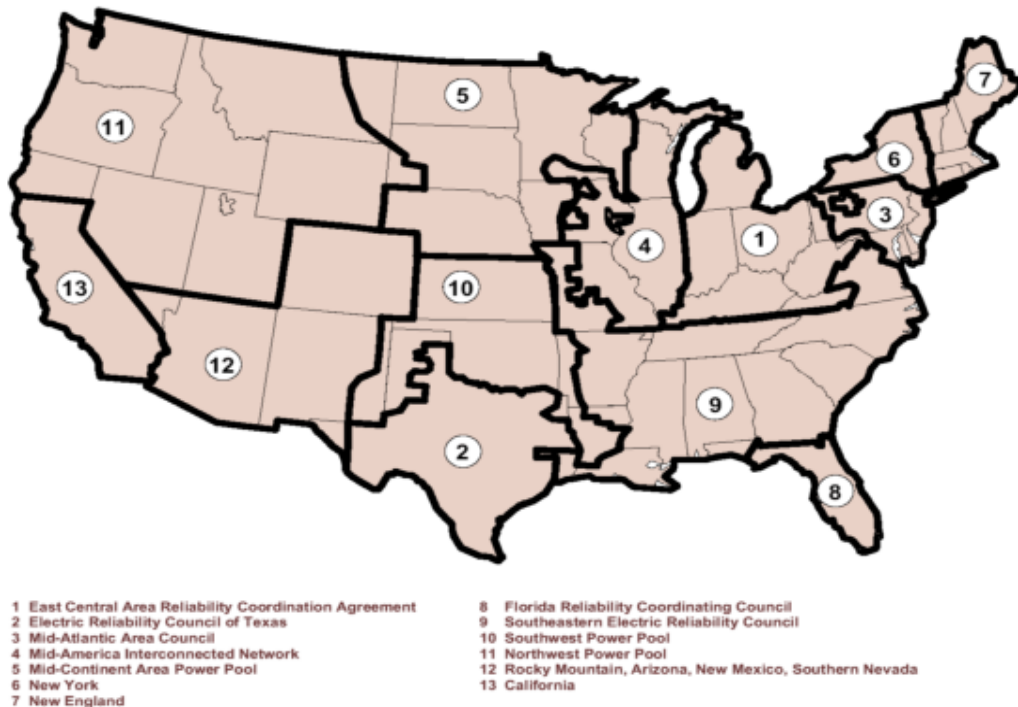


Figure 1. Map of EMM Regions

Table 5. Definition of EMM Regions

#	EMM Region	Definition
1	ECAR	East Central Area Reliability Coordination Agreement
2	ERCOT	Electric Reliability Council of Texas
3	MAAC	Mid-Atlantic Area Council
4	MAIN	Mid-America Interconnected Network
5	MAPP	Mid-Continent Area Power Pool
6	NY	New York
7	NE	New England
8	FL	Florida Reliability Coordinating Council
9	STV	Southeastern Electric Reliability Council
10	SPP	Southwest Power Pool
11	NWP	Northwest Power Pool
12	RA	Rocky Mountains, Arizona, New Mexico and southern Nevada
13	CNV	California

3.1 End-Use Space Cooling and Ventilation Load Shapes in NEMS

Although still in the early stages of the rulemaking analysis, it is estimated that over 55% of the energy savings estimated from this standard will come from commercial space cooling, which is highly peak coincident, with the remaining 45% derived from ventilation savings. The space cooling load shape is more peak coincident than the ventilation load shape so it is important that it be accurately represented in this CUAC analysis. For more detailed illustration of the space cooling load profiles for the months of January, April, July and October for four EMM regions – ECAR, NE, SERC, and CNV please see Appendix C. This appendix of figures also includes hourly profiles from simulated loads that will be discussed in more detail in the next section. The commercial space cooling end use is represented by 13 different load shapes, one for each of the 13 EMM regions. Table 6 below shows the LF_{in} and peak hour of the input commercial space cooling load shapes for each region. With the exception of EMM region 13, the load shape peaks at 3pm in July.

Table 6. Commercial Space Cooling LF_{in} and Peak Hour from Input Load Shape of AEO2003 Version

EMM Region	LF_{in} (%)	Month and Hour of Peak
1	10%	July 3pm
2	15%	July 3pm
3	11%	July 3pm
4	10%	July 3pm
5	10%	July 3pm
6	9%	July 3pm
7	8%	July 3pm
8	16%	July 3pm
9	15%	July 3pm
10	12%	July 3pm
11	12%	July 3pm
12	12%	July 3pm
13	12%	August 3pm

Figure 2 illustrates the commercial space cooling load profile for ECAR. This figure shows the normalized hourly load for three day types - weekday, weekend and the peak day for the month of July assuming an annual energy demand of 1000 kWh. All load curves are expressed as fractions of annual energy use, making them very readily compared by applying a consistent annual consumption value. In Figure 2, the ECAR space cooling load profile shows a clear apex on the peak day at 3pm, consistent with Table 6. This strong peak is characteristic of the demand from this end use in regions with warmer, drier climates in the summer. For most other regions, this shape is similar during the month of July, although varying in the magnitude of the hourly load. The commercial space cooling load profile is essentially zero during the winter months from November through March.

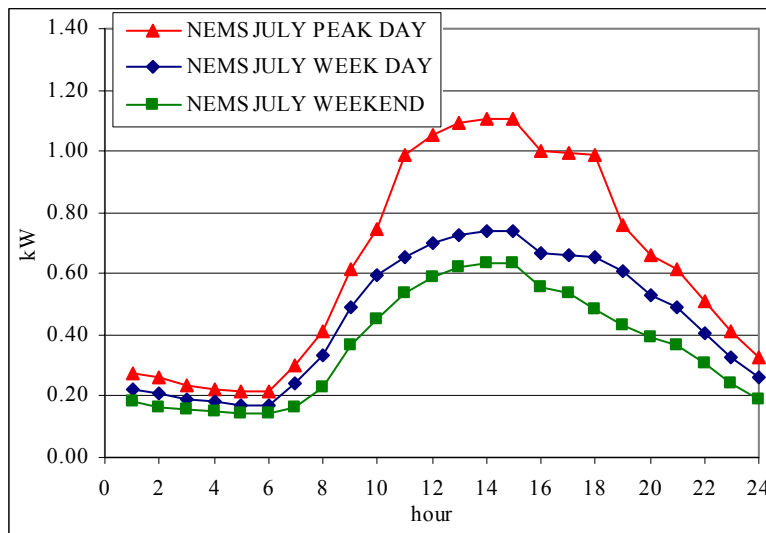


Figure 2. NEMS July Space Cooling Load Shapes for ECAR

Figure 3 shows the commercial ventilation load profile for ECAR for the month of July. Unlike the commercial space cooling load profile, the ventilation shape in NEMS is characteristically

flat throughout both the day and the year. Note that ventilation is in use during all seasons irrespective of the need for heating or cooling. The CUAC rulemaking covers energy savings from this end use, where savings are largely during the non-peak hours of the day.

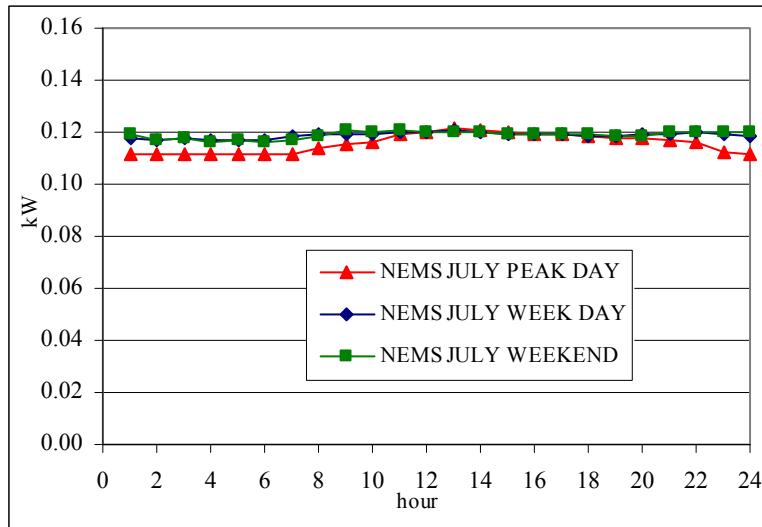


Figure 3. NEMS July Ventilation Load Shapes for ECAR

In general, the space cooling and ventilation load shapes in NEMS cover a broader range of technology types than under consideration for the CUAC rulemaking. The NEMS end uses that are covered under the proposed CUAC energy efficiency standard roughly cover only commercial sector space cooling and ventilation. The space cooling end use in NEMS covers a variety of cooling technology types, including heat pumps, chillers, and rooftop, residential-style and window unit air conditioners. The CUAC rulemaking, however, only considers a subset of these: air-cooled single package and split system unitary air conditioners with cooling capacities of $\geq 69,000$ kJ/h (65,000 Btu/h) to $< 250,000$ kJ/h (240,000 Btu/h). This is roughly equivalent to 20-70 kW sized units. The ventilation load shape in NEMS covers the circulation of air through a building to provide fresh air to the occupants and to deliver heating and cooling to the occupied spaces. Again, this is a broader spectrum than is considered in the rulemaking.

Heat pumps are not currently included under the CUAC rulemaking.

3.2 Comparison of End-Use Load Shapes with Simulations

Berkeley Lab compared the NEMS end use space cooling and ventilation load shapes to simulated CUAC and ventilation load shapes developed by Pacific Northwest National Laboratory (PNNL). Section 3.2.1 provides detailed information about the simulated load shapes. Section 3.2.2 then presents the comparison of the NEMS space cooling and simulated AC load shapes to the PNNL simulated shapes, hereafter called typical meteorological year (TMY) CUAC load shapes.

3.2.1 Simulation of Load Shapes

PNNL used commercial building simulations to generate TMY CUAC load shapes. The simulations consider how CUAC energy-use varies according to efficiency level and a number of factors including climate, building-type, building occupancy and function. The simulations yield hourly estimates of the buildings' electric loads, including CUAC and ventilation. These are subsequently used in the Life Cycle Cost (LCC) analysis portion of the CUAC rulemaking process to assess the operating cost-savings that the CUAC equipment provides at each of the efficiency levels analyzed.

The simulations produced results for a variety of building types in different climate locations to represent the diversity of use and performance of unitary air conditioning equipment. The 1995 Commercial Buildings Energy Consumption Survey (CBECS 95) was the primary source of data used to develop a data set consisting of 1033 buildings. Only buildings that are air conditioned over 70% of their floor space with unitary air conditioning equipment were included. Six building types were considered: assembly, education, food service, office, retail, and warehouse. These six building types account for 73% of the annual cooling energy use and 67% of the floor space of commercial buildings that reported having unitary air-conditioning equipment. The meteorological data is represented by TMY data to represent each of the 1,033 buildings represented in the simulation analysis. Using TMY data removes the influence of abnormal weather phenomena and therefore removes any association to a specific year.

Each building in the set was modeled using the Building Loads and System Thermodynamics (BLAST) software and the simulations were performed using a generic building model. The prototype building is a three-story 4,500 m² (48,000 ft²) building situated in 15 separate climate zones. The result is an estimated hourly end-use energy profile for CUAC equipment.¹

3.2.2 Comparison of NEMS Commercial Space Cooling Load Shape with Simulated TMY CUAC Load Shape

NEMS defines only 13 different commercial space-cooling load shapes, one for each of the 13 EMM regions, making no distinction among the various commercial building types. For purposes of making direct comparisons between the load shapes in NEMS and those that were simulated, a single representative simulated load shape was determined for each EMM region. This was accomplished by assigning each of the 1,033 buildings to an EMM region, and then aggregating building CUAC loads to a single load shape using CBECS based weighting.

Similar to Figure 2, Figure 4 illustrates the NEMS ECAR July hourly load profile for commercial space cooling, this time in conjunction with the corresponding TMY simulated load for the CUAC end use. Both shapes are normalized to an annual energy use of 1,000 kWh. The purpose of this comparison is to illustrate what, if any, differences exist between these two data sources. The ECAR EMM region is shown for illustrative purposes as generally representative of the variation between the NEMS space cooling and simulated TMY CUAC load shapes seen in other EMM regions and day types. For the most part, the NEMS and simulated load profiles both

¹ For more detailed information on the commercial building end use load characterizations, a PowerPoint presentation is available at the following website: http://www.eere.energy.gov/buildings/appliance_standards/commercial/ac_hp.html

capture the shape of the peak for this region’s July cooling load. The simulated TMY CUAC load profile peaks around 4 pm, while the NEMS cooling shape peaks at 3 pm. In general, the simulated TMY load shape is smaller than the NEMS shape with the TMY peak roughly 30 % lower than the NEMS peak. This is similar to what is seen in other regions, with the shape of the profile well captured, yet somewhat significant differences in the magnitude of the peak. During the summer months, NEMS is generally higher than the TMY simulated peak, although in winter the TMY shows more use than the NEMS profile.

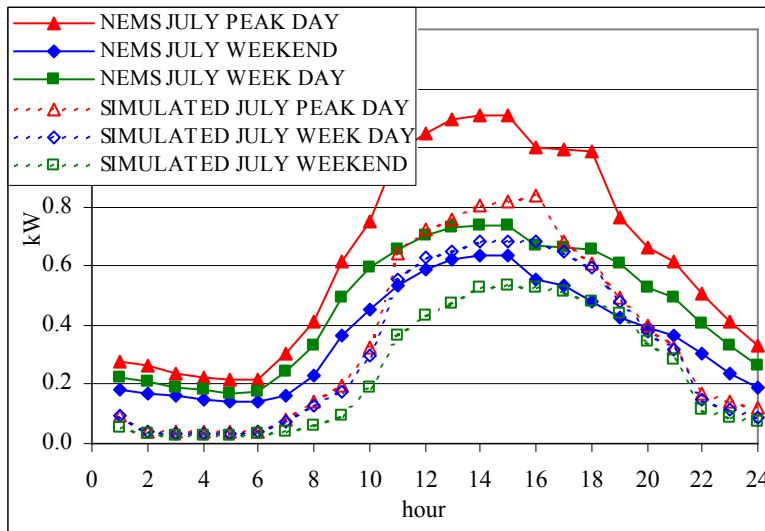


Figure 4. Comparison of NEMS Space Cooling and Simulated TMY CUAC Load Shapes

The NEMS space cooling load shape that was updated in the AEO2001 version and that is still used in the AEO2003 version is based on a large database of end use load shapes called the RELOAD database. This database is a large collection of 1,486 load profiles compiled by EPRI with the original development of the load shapes performed by ICF Resources, Inc. Unfortunately not much is known about the specifics regarding the RELOAD database, as EPRI no longer maintains this file nor possesses any detailed documentation for it (Holte 2001b).

The updated space cooling load shape is a composite of space cooling end use load shapes from different building types taken from the RELOAD database. Table 7 shows the commercial space cooling end use load shape composition. Interestingly, the commercial space cooling load shape is based entirely on air conditioning load shapes for the city of Chicago, with over one-third coming from a load shape for a commercial large retail building.

Table 7. Composition of Commercial Space Cooling Load Shape in NEMS

Share of Load Shape	Commercial Building Type in Chicago
35.0%	Large office
15.9%	Shopping center
11.6%	Large retail
14.6%	School
6.4%	Restaurant
6.4%	Fast Food
3.1%	Grocery
3.1%	Hospital
4.0%	Warehouse

Source: OnLocation, Inc., *Alternative Sectoral Load Shapes for NEMS*, August 2001.

However, this was only done for the weekday and weekend load shapes. The space cooling peak day load shape from the RELOAD database was not deemed acceptable so was constructed from the weekday load shape using *reasonable assumptions*. OnLocation, Inc. assumed that the peak day load shape was 50% higher than the weekday load shape for 12 hours out of the peak day and 25% higher than the weekday load shape for the remaining 12 non-peak hours. Therefore the peak hours are essentially the highest hours of the weekday load shape (Holte 2001a).

Regional load shapes were constructed using weather information by Census Division region. Monthly normal temperature data from the Short Term Energy Outlook was used to calculate the cooling degree days, which were then applied to each region's space cooling load shape. The percentage of cooling degree days in each month were used to adjust the monthly loads to reflect the regional influence of climate.

Figure 5 shows a comparison of the implicit LF_{in} based on the load profile from the NEMS input space cooling load shape and the simulated TMY CUAC load shape. In general, the simulated TMY CLF is higher, i.e. the NEMS space cooling load shape is peakier. The PNNL TMY CUAC load shape is based on simulations of more than 1,033 commercial buildings and is adjusted to be weather-neutral.

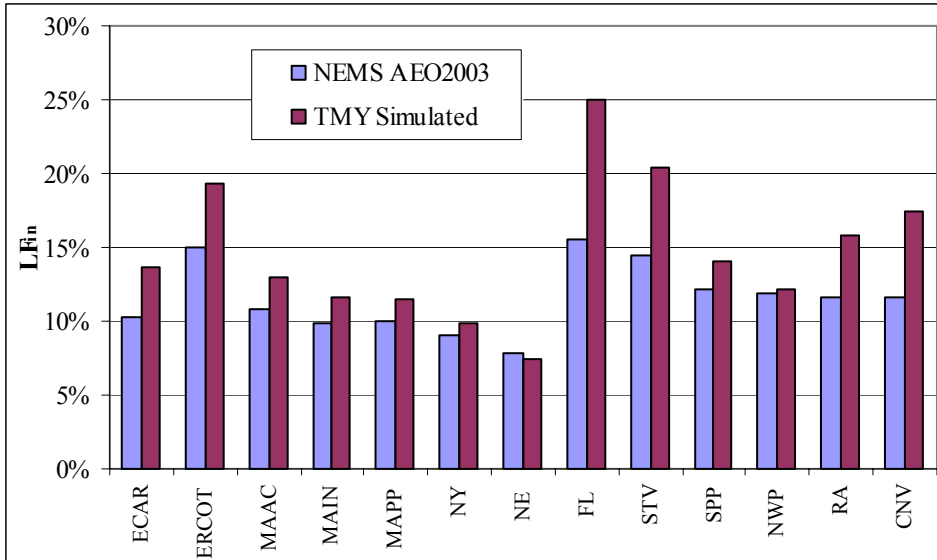


Figure 5. Comparison of NEMS and TMY Simulated Cooling Load Shape L_{Fin}

Figure 6 shows a similar comparison except this time for ventilation, and noticeable differences exist between the NEMS and TMY load shapes. The NEMS load profile is simply flat throughout the day, whereas the simulated load shape indicates a higher-level usage from 10am to 6pm compared to the nighttime hours. The flat shape in the NEMS ventilation load shape is likely due to an oversimplified use assumption that does not account for typical commercial building operating schedules. The building simulations show lower usage at night and high flat usage during the day. Because real buildings are often not ventilated when the building is unoccupied, the PNNL shapes appear prima facie more credible.

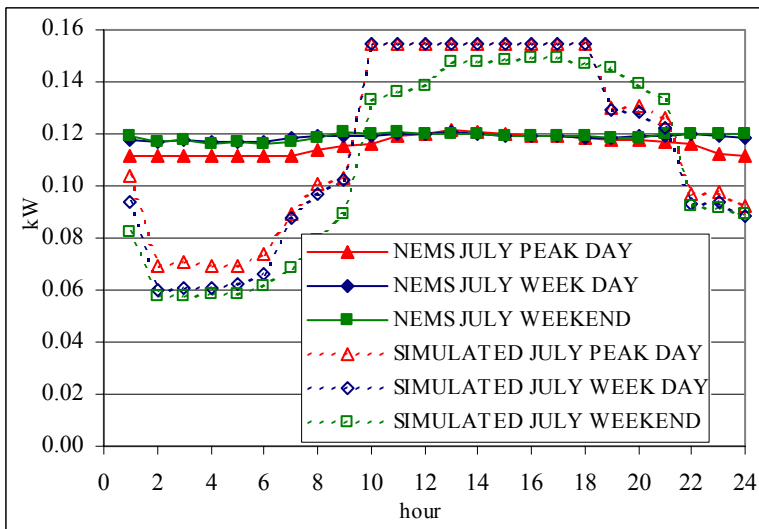


Figure 6. Comparison of NEMS Ventilation and Simulated TMY Ventilation Load Shapes

A more complete display of the comparisons appears in Appendix C, showing the hourly profiles for four months, January, April, July, and October, and four EMM regions, ECAR, NE, STV, and CNV.

3.3 Comparison of NEMS System Load Shape with Historical Data and TMY System Load

This section compares NEMS system load shapes to historical 1999 data and to weather normalized load data. Because coincidence of end use load decrements with system load is a major determinant of the National CLF_{out} , it is important to validate the NEMS system load shapes as well as to improve on its end use load shapes.

The historical data on hourly system loads was taken from the U.S. Federal Energy Regulatory Commission (FERC) Form 714 filings. Every utility in the country with an annual peak load above 200 MW for its planning area must report a time series of hourly load each year. The analysis used market data from year 1999 for California, and from 2000 for New York, PJM, and New England.

The TMY system load shapes were developed at Berkeley Lab based on historical 1999 system load data and collected TMY temperature data. For each EMM region and for every hour, including an index for day/night, and day type, a least-squares third-order-polynomial fit is used to express load as a function of TMY temperature. Experimentation with different models showed the best fit was from a third-order polynomial. This polynomial is used to compute the TMY loads as a function of TMY temperature. A correction is then made to the TMY loads to represent fluctuations around the mean value computed with a polynomial fit. This variation is calculated as the difference between the historical load and the predicted load to develop a frequency distribution that is then used to generate a set of random corrections to the TMY predicted loads. The values of the fluctuations range from -15% to $+20\%$ and are randomly applied to the predicted loads in order to account for the degree of random fluctuation around the fitted value predicted by the model.²

Figure 7 illustrates a comparison of the ECAR June to September system load shapes from NEMS with the TMY system loads. All three profiles are normalized to an annual demand of 1,000 kWh. Because the TMY system load shape is derived based on the historical 1999 data, it makes sense that both the TMY and historical system loads would have similar characteristic shapes. The main difference between these two shapes is the influence of extreme weather, which is removed from the TMY load profile. As was seen in Figure 4 with the NEMS space cooling and TMY CUAC load shape comparison, the NEMS system load is slightly higher in magnitude compared to the simulation or historical 1999 system loads. However, this is not evident in most other regions. Overall, the shape of the peak day system load is comparable across all three sources.

² For more information on how the TMY system loads were developed, please see *Appendix N: Modeling TMY Prices of the CUAC Rulemaking TSD*.

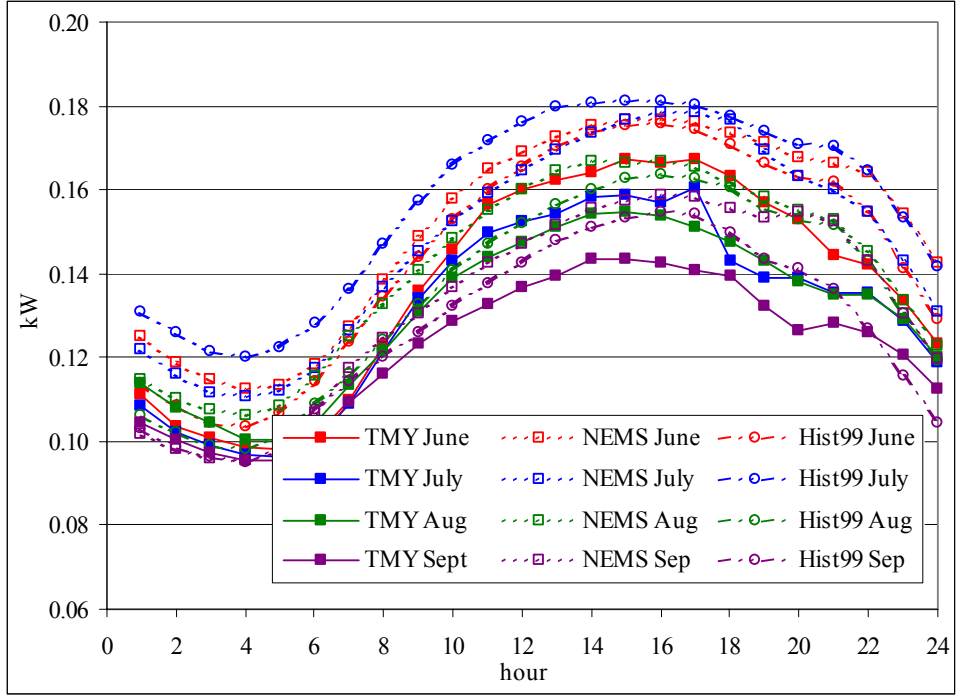


Figure 7. Comparison of System Load Peak Day in ECAR from NEMS, TMY, and Historical 1999 Data

Berkeley Lab also calculated the root mean square (RMS) difference to identify the degree of variability among the NEMS, TMY, and historical 1999 system load shapes. The RMS difference is expressed as follows,

$$RMSDifference = \sqrt{\frac{\sum_{n=1}^{24} (X_{NEMS} - X_{TMY})^2}{n - 1}}$$

where X_{NEMS} and X_{TMY} are the energy demanded for a given hour of each day type, month and region and n is the number of hours in the day. The differences are calculated for each day type and each month for all 13 EMM regions.

Figure 8 illustrates the RMS difference for each day type and month of the year for the ECAR region. Both the difference between the NEMS and TMY system load and between the historical 1999 and TMY system loads are shown. Although there is some noticeable variability in the difference, there is no consistent trend error that would suggest a discrepancy between these data sources. The same is true of the remaining EMM regions with the exception of the MAPP region, where the NEMS system load is significantly higher than the other two sources. Berkeley Lab has yet to conclude why this one EMM region appears to be behaving anomalously.

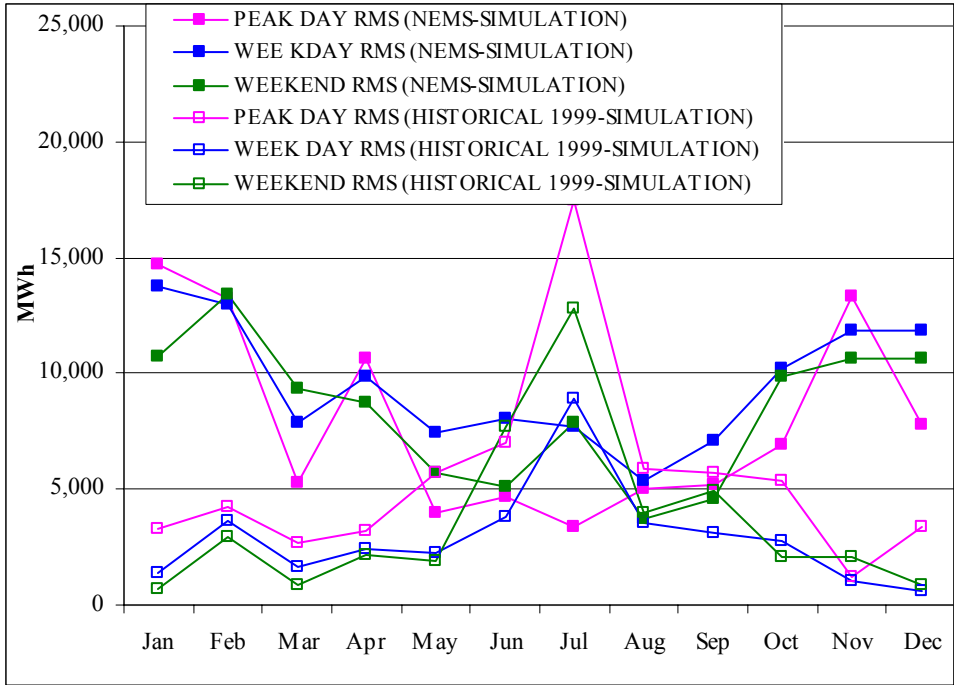


Figure 8. Root Mean Square Difference of ECAR System Load

Expressed as a percentage of the average daily demand in Figure 9, the RMS difference represents less than 1% of the daily energy demanded. The difference in the peak day is higher than for the weekday or weekend day types, and again, this is true of the other EMM regions. However, compared to the total usage for the day, the overall impact is small, indicating that the differences in the system loads do not exhibit a systematic bias. This is not to say that the system load shapes are not different, just that the differences don't look systematic. For more information on an exercise performed by Berkeley Lab of what it takes to restore the substituted TMY system load shape in NEMS-BT back to the Reference Case, please see Appendix G.

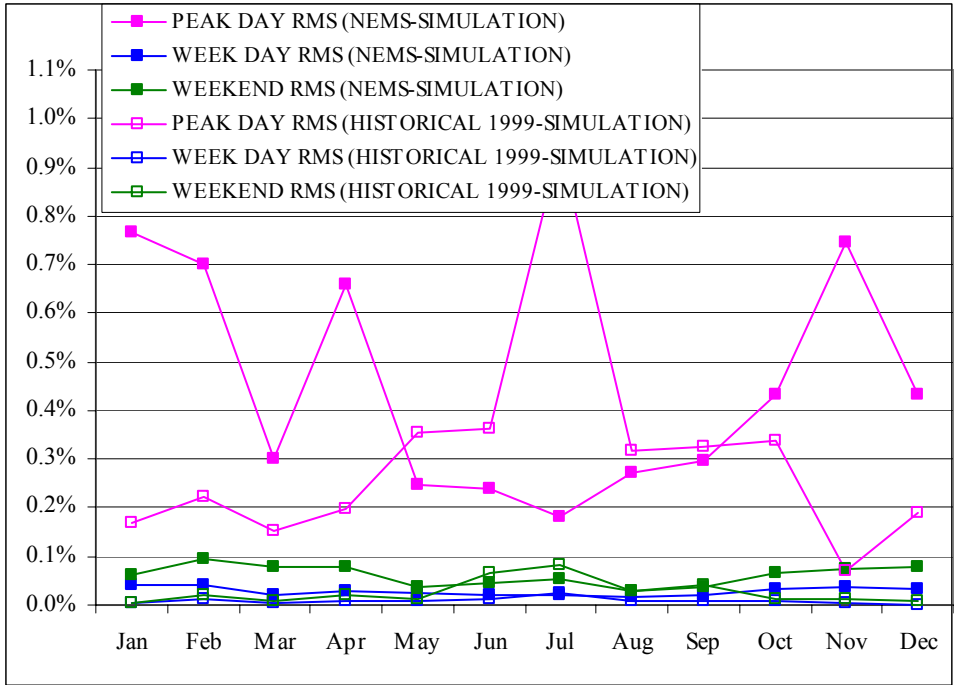


Figure 9. Root Mean Square Difference of System Load for ECAR as Percentage of Daily Load

Additionally, Berkeley Lab also plotted a series of scatter plots that compare the peak hour from the NEMS, TMY, and historical 1999 data sources. Figure 10 compares the TMY and NEMS system loads when the total annual energy is set equal for both sources. With the total energy equal in both cases, the peak load is plotted as a percentage of each month and region’s total energy demand. The diagonal line represents equivalent peak hours. Figure 11 shows a similar plot for NEMS and historical 1999 system loads. In both cases, the scatter of points is evenly distributed around the diagonal, with no indication of a bias by month or region. That is, the 13 points for any month of the year (representing each of the 13 EMM regions) do not appear to be systematically skewed to one side of the 45-degree line. This test shows that the relative size of the peak to total energy is consistent across the three data sources.

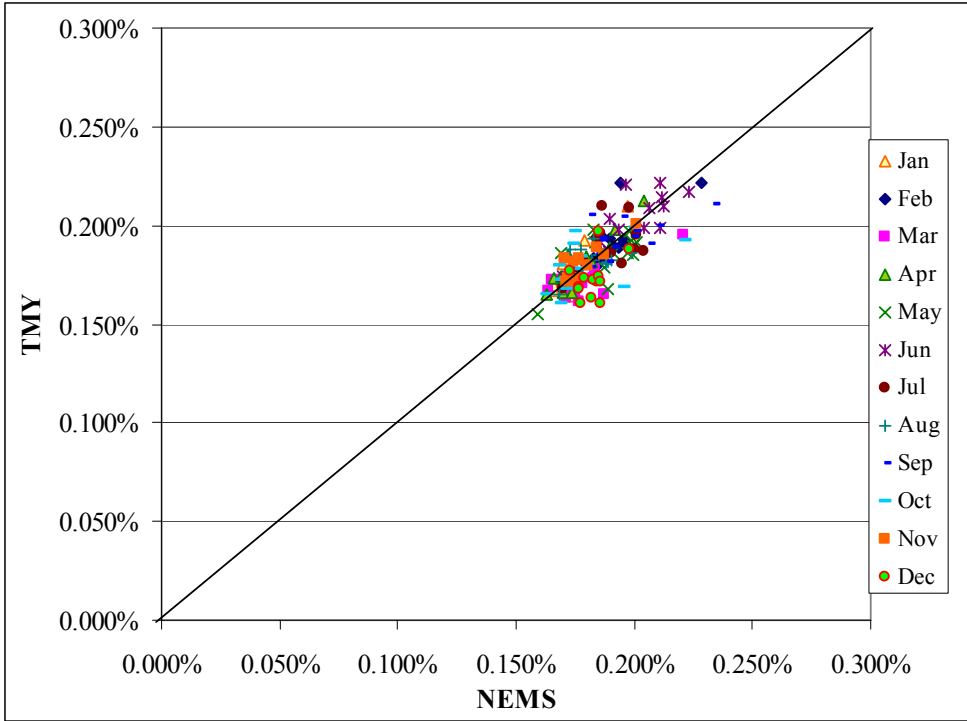


Figure 10. Peak Hour Energy as a Percentage of Total Demand by Month and EMM Region: NEMS vs. TMY System Loads

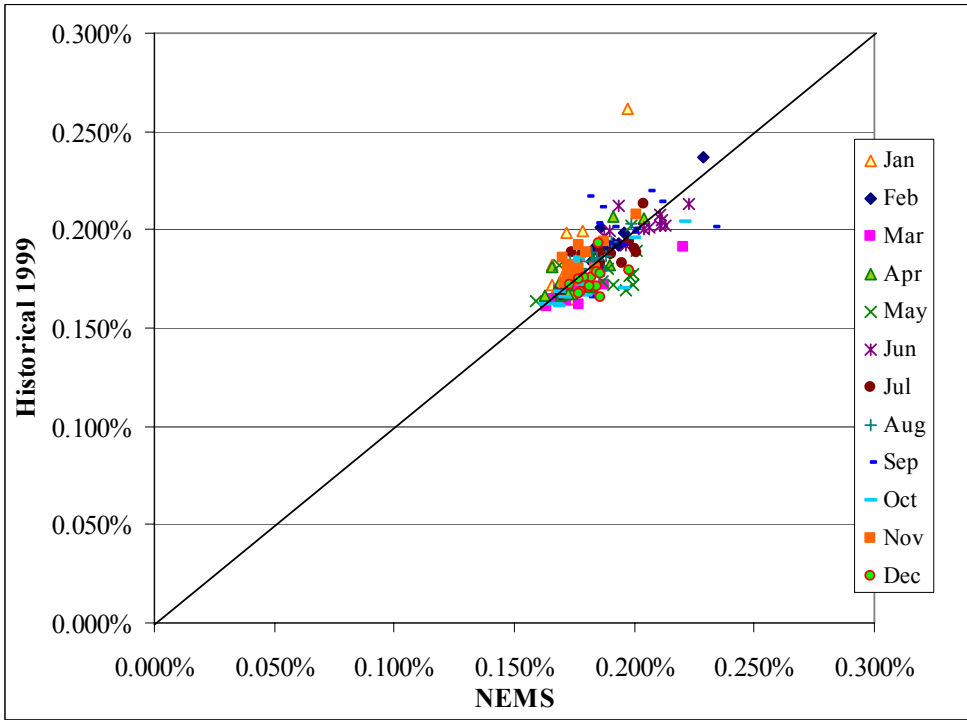


Figure 11. Peak Hour Energy as a Percentage of Total Demand by Month and EMM Region: NEMS vs. Historical 1999 System Loads

A comparison of the total energy when the peak hours are set equal was also performed. In this exercise each hour's demand is transformed relative to the peak hour such that the share of the peak hour is maintained, but the magnitude of the demand changes. Figure 12 shows the scatter plot of the total energy in GWh for each month and region compared between the NEMS and TMY system loads. Figure 13 shows a similar figure comparing the NEMS and historical 1999 data sets. In both figures, the scatter of points is evenly distributed around the diagonal. Again, no bias for time of year is detectable in these figures.

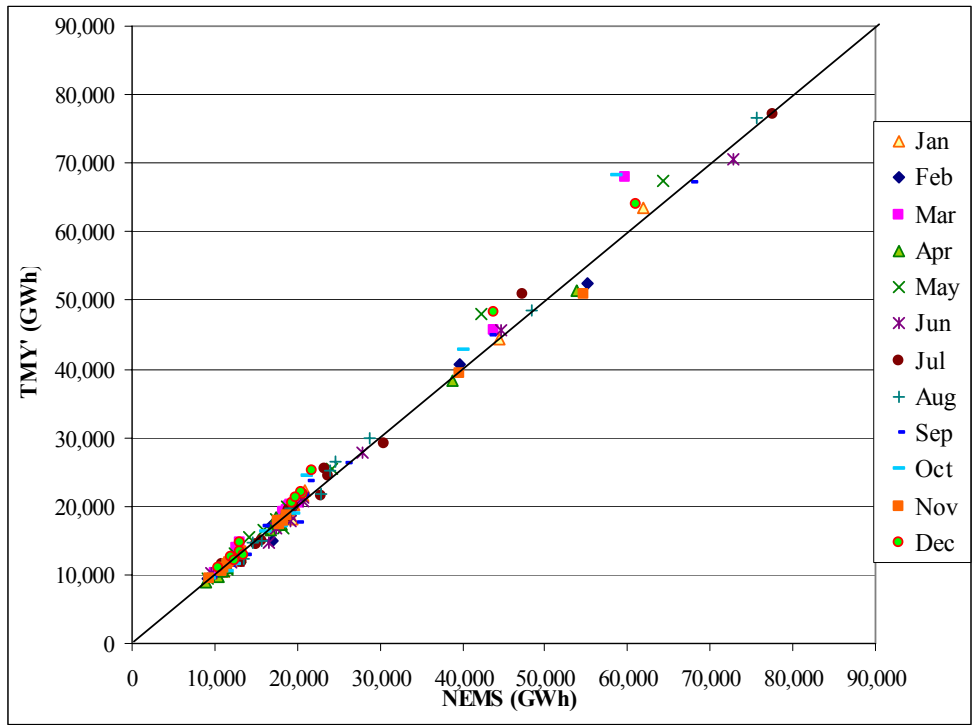


Figure 12. Total Energy by Month and EMM Region: NEMS vs. TMY System Loads

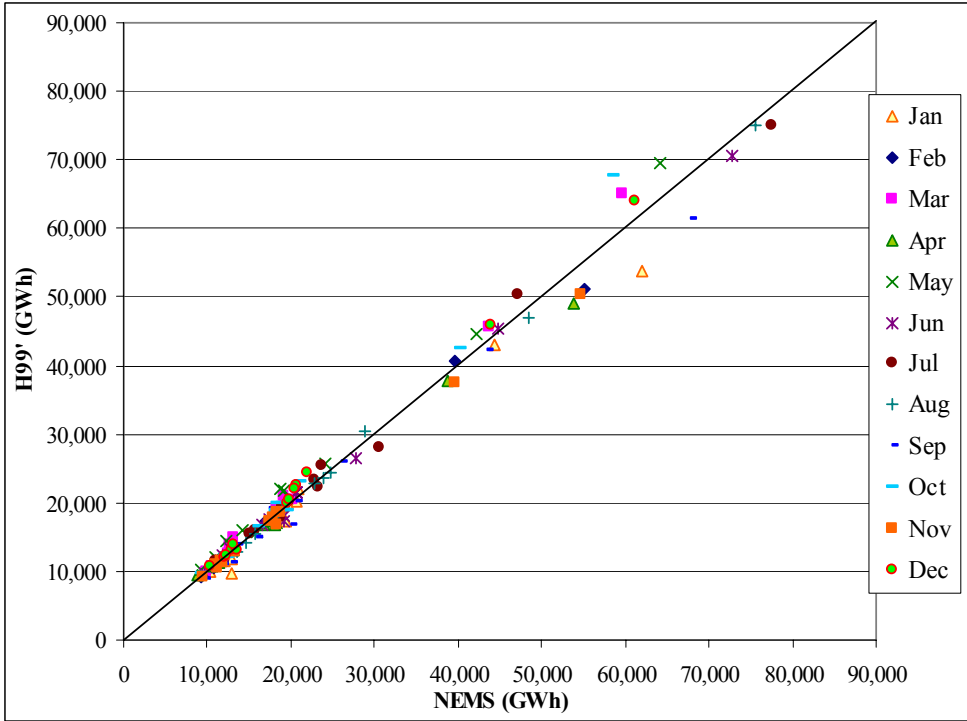


Figure 13. Total Energy by Month and EMM Region: NEMS vs. Historical 1999 System Loads

3.4 Comparison of Space Cooling Load Shape with System Load Shape in NEMS

This section compares the end-use space cooling and CUAC load shapes with the NEMS system load shape to illustrate the degree of non-coincidence inherent between these two loads. Berkeley Lab’s new approach models the effects from a CUAC standard by modifying the system load so it is important to understand any differences between them.

Figure 14 below illustrates the comparison of the NEMS July 2000 ECAR system load with the simulated AC load. The y-axis shows the load normalized to an annual demand of 1000 kWh for ease of comparison. As expected the system load shape is more flat than the AC load shape. Again, we see the AC load shape peaking around 4pm while the system peak for this month is flat during the afternoon.

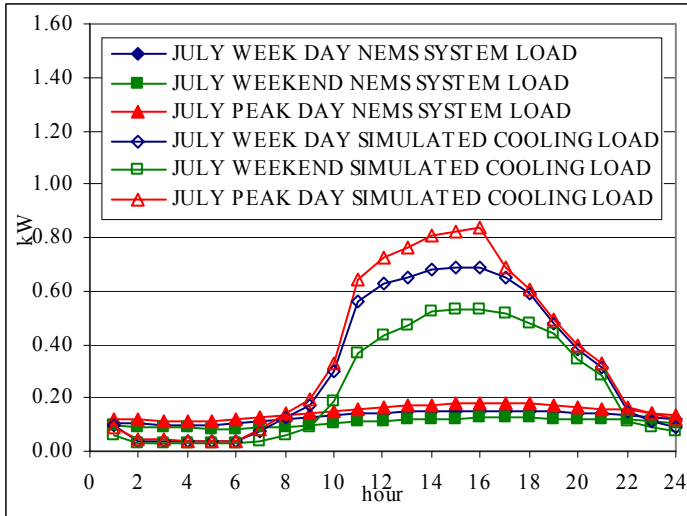


Figure 14. July NEMS System Load with Simulated AC Load Shape in ECAR

Figure 15 shows a similar illustration, except this time displaying the NEMS space cooling load shape instead of the simulated one. Here we see slightly less coincidence between the end-use space-cooling load (which peaks at 3pm) and the NEMS system load, illustrating the difference in the timing of the energy demanded. Again, both load profiles are normalized to an annual demand of 1,000 kWh. When focusing on the peak hour of the day, Figures 14 and 15 illustrate a slight difference in the coincidence of the NEMS space cooling load and the NEMS system load versus the TMY CUAC load with the NEMS system load. Although this section focuses on the ECAR region and the month of July, the comparisons are largely consistent with other EMM regions during the summer months.

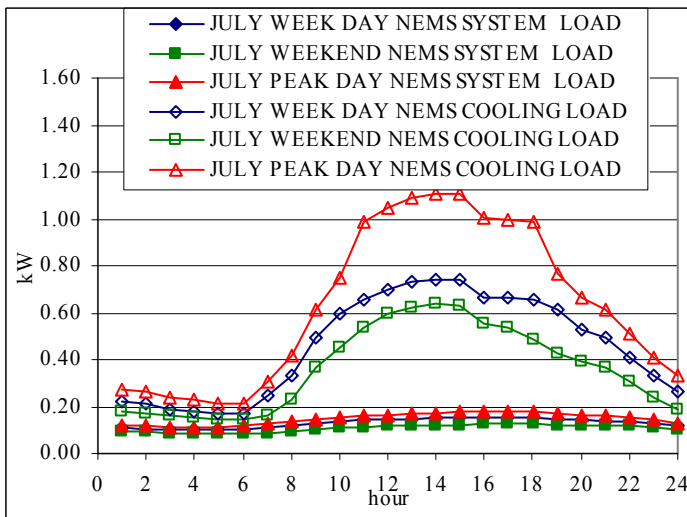


Figure 15. July NEMS System Load with NEMS Space Cooling Load Shape in ECAR

The issue of non-coincidence is an important one and will be discussed in more detail later in this report. Table 8 below shows the peak hour of the system load and the space-cooling loads for each EMM region. For the NEMS system and space cooling load shapes, the peaks are based

on the year 2000. The simulated TMY CUAC load shape is weather-adjusted so does not correspond to any particular year.

In the ECAR region, the NEMS system load peaks at 5 pm in July, while the NEMS space cooling and the simulated TMY CUAC loads peak at 3pm and 4pm in July, respectively. The ECAR TMY system load peaks at 5pm in June. But not all EMM regions follow a similar pattern. For example, in ERCOT, both the NEMS space cooling and simulated TMY CUAC loads peak at 3pm in July, while the NEMS system load peaks in August at 4pm and the TMY system load peaks in July at 4pm. The NWP region depicts the greatest amount of non-coincidence between the cooling and system load shapes. For the NWP region, the NEMS space cooling and simulated TMY CUAC loads peak at 3 and 4pm in July, respectively, while both the NEMS and TMY system loads are winter peaking.

Table 8. Month and Time of Peak Hour from End Use and System Loads

EMM #	EMM Region	NEMS Commercial Space Cooling	Simulated TMY CUAC	NEMS System Load	TMY System Load
1	ECAR	July 3pm	July 4pm	July 5pm	June 5pm
2	ERCOT	July 3pm	July 3pm	August 4pm	July 4pm
3	MAAC	July 3pm	June 4pm	July 5pm	July 3pm
4	MAIN	July 3pm	July 12pm	July 2pm	July 1pm
5	MAPP	July 3pm	July 3pm	July 3pm	July 4pm
6	NY	July 3pm	July 4pm	June 3pm	July 4pm
7	NE	July 3pm	August 2pm	July 5pm	July 2pm
8	FL	July 3pm	August 12pm	June 5pm	June 3pm
9	STV	July 3pm	July 3pm	July 3pm	July 2pm
10	SPP	July 3pm	August 3pm	July 5pm	June 4pm
11	NWP	July 3pm	July 4pm	December 7pm	January 6pm
12	RA	July 3pm	June 4pm	July 4pm	June 3pm
13	CNV	August 3pm	July 3pm	September 4pm	September 12pm

3.5 Summary of Load Shape Comparisons

A comparison of the system load shapes in NEMS with those developed for TMY data and with historical data show that differences exist, although these differences do not seem to be overly concerning. The end use space cooling and TMY CUAC load shapes appear to be highly coincident overall. Although the NEMS ventilation load shape appears flat compared with the TMY simulated ventilation load shape, the amount of savings during these off peak hours is small and therefore not likely to significantly impact the results. The system loads appear similar among the three data sources and further examination using the RMS difference does not indicate any consistent trend in the differences. All differences are less than one percent of the energy demanded. Normalizing the system loads of these three sources by setting the peak hour equivalent and then total energy equivalent to identify potential inconsistencies also showed no persistent identifiable differences. A comparison of the end use NEMS space cooling load shapes with the NEMS system load shows a contrast in the peak hour, providing a first indication of the degree of non-coincidence apparent between the cooling and system load profiles.

4. The New Double Decrement Approach

This section details the approach that Berkeley Lab has developed to model the utility impacts associated with a proposed appliance standard. The method is demonstrated using the CUAC energy efficiency standard. Previous experience with modeling a peaky end use using NEMS-BT resulted in inaccurate peak impacts, raising the need to model peak-coincident end uses using an alternative method. Despite the fact that NEMS-BT does represent the commercial space cooling end use, this approach decrements the hourly system load directly from the system load. However, to ensure that the energy balance is correct throughout NEMS, equivalent amounts of energy must be decremented from the end use and system load shape sides. Hence, this method has been called the double decrement approach.

The approach is summarized into three different parts, each run sequentially in a single NEMS-BT run:

Part 1 – End-Use Consumption Decrement

The energy savings are decremented from the NEMS-BT space cooling end use to model the effect on the demand-side of NEMS-BT.

Part 2 – Restoration of the System Load

Coding changes are then made to restore the effect that decrementing the end use demand has on the supply side. This ensures that the hourly decrement to the system load is not duplicating the effects from changes made to the demand side.

Part 3 – Decrement Hourly System Load

The hourly system load is decremented to match the savings decremented on the demand side, ensuring the peak reductions are properly modeled.

Figure 16 illustrates how all three parts are performed as one NEMS-BT run. Part 1 essentially describes the traditional approach explained in section 2.2 where the energy savings estimated from a proposed CUAC standard are decremented from the commercial module space cooling end use. This change reduces the annual end-use consumption for commercial sector space cooling in the *comm.f* commercial demand module. Modifications are also made to read in a created *savings.dat* input file that decrements the “EndUseConsump” parameter and weights the savings by Census Division based on the share of consumption in each region. This decrement is made in the “COMConsumption” sub-module of the commercial sector demand module.

For each forecast year in NEMS-BT, the “Restoration” restores any changes that may have affected the system load as a result of changes made by performing the traditional end-use decrement approach on the demand side. Because this approach modifies both the demand and supply sides, a restoration is required to isolate the impacts between the commercial sector and Electricity Market Module (EMM). A code change restores the system load back to its Reference Case value in the “DSMNWS” subroutine of the Load Demand Side Management module. The estimated restoration is applied to the end of each forecast year after the decrement to the demand side occurs, facilitating the need for only one run to implement this approach.

Finally, the hourly system load is decremented according to the energy savings dictated by the proposed standard level. The hourly decrement is made to each region to each of the three day types – weekday, weekend, and peak day, each of the 24 hours in a day type, and to each of the

12 months. The savings are decremented in this way for every year that the standard applies, beginning in 2007 and ending in 2025, the final year of the forecast, and by EMM region. The 864 hours are decremented in energy units based on estimates of the annual energy savings and on the simulated TMY CUAC load shapes. In this way, the annual energy savings are proportional to the characteristic shape of this end use. The code changes are made in the “DSMHLM” subroutine of the Load and Demand Side Management (LDSM) sub-module with the decrement made to the “SYLOAD” hourly system load parameter.

For a more detailed mathematical description of the code modifications made in this approach, please see Appendix B.

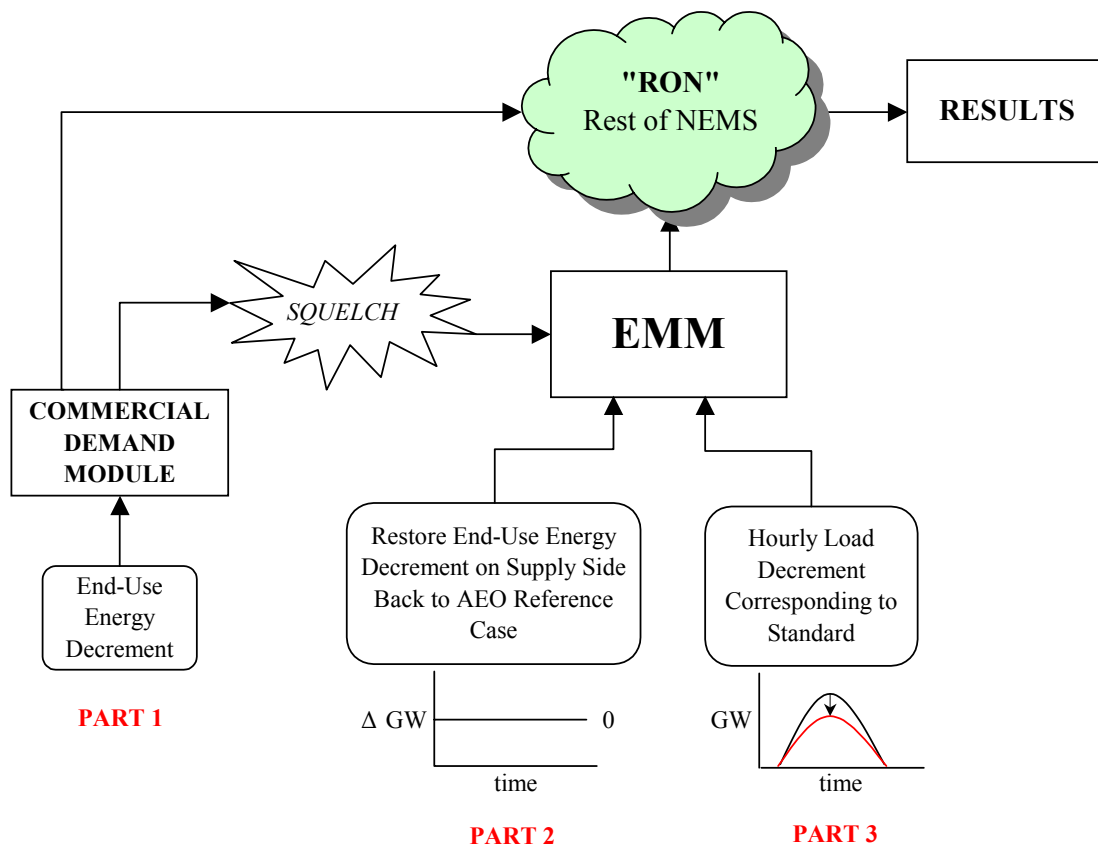


Figure 16. Flowchart of Double Decrement Approach in NEMS-BT

Because the size of the energy savings is small compared to the magnitude of the electricity sector, higher decrement runs are required, consistent with the traditional approach. A series of multipliers are chosen based on experience to inflate the energy savings enough to see a clear effect. Typically three multipliers are used per TSL and the impacts from these three runs are interpolated and linearly regressed to determine the impact from the actual standard. This technique has worked well in the past using the traditional approach. However, one concern that has arisen from the current work is the chance of changes to the shape of the load duration curve (LDC) when the decremented savings are too high. This phenomenon is understandable as

larger decrements lead to greater impacts to the LDC. Subsection 2.4 briefly addressed this concern of using higher multipliers and subsection 6.3.2 illustrates how significant an effect higher multipliers can have on the peak impacts.

5. Results Using Double Decrement Approach

This section presents results from implementing the new double decrement approach. Section 5.1 provides some preliminary results from experimenting with the hourly decrement as a way of validating how peak end uses behave. Section 5.2 then presents the results using the double decrement approach to model a proposed CUAC standard using energy savings from the prior RCAC rulemaking. Section 5.3 then discusses an experiment Berkeley Lab conducted to switch out the system load shape with a TMY normalized one. Section 5.4 then summarizes our results. All results are presented using the AEO2003 version of NEMS.

Throughout this work, the analysis uses the RCAC forecasted energy savings because the CUAC rulemaking is still in the early stages of analysis and no quantitative results are yet available. According to the current state of the CUAC rulemaking, heat pumps are not included, unlike the RCAC rulemaking where they were included; therefore, the results in this section only reflect effects from the cooling energy savings.

The double decrement approach allows the energy savings to be modeled consistently with the CUAC energy savings development; that is, the savings are modeled hourly by decrementing the system load for all three-day types (weekday, weekend and peak day), and all 12 months.

5.1 Early Stage Runs

Initially, a series of experimental runs were performed to better understand peak load behavior, including decrementing the LDC during the top 500 peak hours of the year or just during the peak summer hours. The results are assessed using the CLF of the resulting effects from these sensitivity runs.

5.1.1 Decrementing the Top 500 Hours

This exercise sought to understand how NEMS-BT responds to reductions that are almost perfectly coincident with the system peak to ensure that NEMS-BT properly handles modifications to the peak load. The top 500 hours of the annual LDC were identified and a load decrement equal to the energy savings from the proposed CUAC standard was dispersed across the top 500 hours.³ This experimental run used a 3x TSL 4 level of forecasted energy savings and the implicit CLF_{in} is an estimated 6% in 2025. The code changes were made in the LDSM sub-module of NEMS-BT (*uldsm.f*).

The results from this sensitivity run are promising. Decrementing the top 500 hours in the year results in a very peak coincident National CLF_{out} of 7% in 2025. The closeness of the CLF_{in} to the National CLF_{out} indicates the nearly perfect coincidence between the input savings and resulting decrement. Total installed generating capacity is reduced 129.6 GW by 2025, with total electricity generation down 94 TWh in the same year. This experimental run indicates that hourly peak loads can be reduced directly to model energy savings from a peak-coincident end use.

³ This run is saved on the NEMS server, "amichai", under D:/Home/ptc/runs/AEO2003/aps/ccac/std4/AEO_sysld/d012004a

5.1.2 Decrementing 20% of the Topmost Summer Peak Hours

This exercise reduces only the highest summer peak hours. A 20% decrement is taken from as many top peak summer hours necessary to match the same total energy savings and the corresponding CLF_{in} estimated at 6%.⁴ The code changes are made in the same LDSM sub-module where the previous exercise was performed.

The results from this run indicate that a focused summer peak hour decrement produces the very peak coincident National CLF_{out} of 9%. Compared to our previous experimental run, the summer only peak decrement is not as coincident with the system peak which leads to the larger discrepancy between the CLF_{in} and the National CLF_{out} . Total installed generating capacity is reduced 106 GW in year 2025 with total electricity generation down 101 TWh in the same year.

5.1.3 Summary of the Preliminary Runs

The initial results indicate that Berkeley Lab was successful in targeting decrements from the peak hours. Both exercises show CLFs below 10%, which provides a useful lower bound on the CLFs. This is lower than would be expected from a CUAC standard because of the lower peak coincidence.

5.2 Double Decrement Approach Results

Based on the preliminary runs, it was concluded that peak-coincident end uses could be properly modeled in NEMS-BT. Taking a decrement during the highest load hours results in changes to the installed generating capacity inline with what we would expect, i.e. a $CLF < 10\%$. This section presents the initial results from using the double decrement approach. Two sets of results are presented in this section, one assuming the NEMS space cooling end use load shape and the other using the simulated TMY CUAC load shape.

5.2.1 Results Using Double Decrement Approach with NEMS Space Cooling Load Shape

The results for a proposed CUAC TSL 4 standard using the double decrement approach and leaving the NEMS space cooling load shape in place are presented as an example in Table 9.⁵ The CLF results for other TSLs are similar. This example uses 2, 3, and 4 as the multipliers, lower than was used in the traditional approach results presented in subsection 2.4 or in the previous report. The choice of multipliers is not inconsequential, but has a potentially significant effect on the ordering of peak hours that could change the CLF. This was discussed in subsection 2.4 and subsection 6.3.2 will also address this issue. Again, the results are based on modeling only the cooling energy savings from a proposed CUAC standard.

⁴ This run is saved on the NEMS server, "amichai", under D:/Home/ptc/runs/AEO2003/aps/ccac/std4/AEO_sysld/d012004c

⁵ This run is saved on the NEMS server, "amichai", under D:/nems/AEO2003/output/aps/cuac/Ddvalid/CcoolIDD/NEMSSeu/

Table 9. TSL 4 Cooling-Only Results Using Double Decrement Approach with NEMS Space Cooling Load Shape

	2015	2020	2025
Change in Capacity (GW)	-9.0	-16.9	-19.1
Change in Energy Sales (TWh)	-21.5	-31.9	-38.8
National CLF _{out} (%)	27%	21%	23%

The results indicate that the National CLF_{out} of 21% in 2020 is higher than the implicit LF_{in} estimated from the input load profiles. Figure 5 shows that the LF_{in} is typically 10-20% for most EMM regions and likely around 15% for the U.S. As will be discussed in more detail in section 6, non-coincidence plays a significant role in explaining the discrepancy between the LF_{in} and the National CLF_{out} the results.

Compared to the traditional approach results presented in Table 2, the National CLF_{out} of TSL 4 shows a slight decrease from 25% to 21% in year 2020; the difference in the National CLF_{out} is largely due to the use of different multipliers. The traditional approach results in Table 2 use higher multipliers to be more consistent with our previous report, whereas the double decrement results use lower multipliers to be more consistent with our proposed approach for the upcoming CUAC rulemaking. Using smaller multipliers with the traditional approach would have reduced the National CLF_{out} from 25% to 22% for CUAC TSL 4, re-emphasizing the importance of careful multiplier choice.

5.2.2 Results Using Double Decrement Approach with TMY CUAC Load Shape

Berkeley Lab also applied the double decrement approach, but replacing the NEMS space cooling end-use load shape with the TMY simulated CUAC load shape.⁶ Based on the current status of the CUAC rulemaking, this is the most likely shape that will be used. That is, each proposed CUAC standard analysis will decrement from the system load hourly to match the energy savings dictated by the NES model and follow the shape of the simulated TMY CUAC load shape. The analysis will also decrement the commercial demand-side energy savings using the simulated TMY CUAC load shape rather than keeping the end use space cooling load shape in NEMS-BT. The PNNL simulated load shapes are believed to be more representative of the CUAC load profile than the NEMS space cooling shape. The results are presented for all five TSLs in Table 10 for completeness.

Using a different space cooling load shape to the one used in the AEO2003 Reference Case poses a concern. The analysis for previous appliance standard rulemakings has avoided any modifications that would alter the AEO2003 Reference Case because it provides such a convenient and widely accepted baseline for energy policy analysis. Changing the commercial space cooling load shape has a significant effect on the Reference Case, resulting in a 13 GW (17 GW) or 1.2% (1.4%) increase in total U.S. generating capacity in 2020 (2025). Because of this change, the results are presented relative to this new *Reference Case with TMY CUAC Load Shape*.

⁶ This run is saved on the NEMS server, "amichai", under D:/nems/AEO2003/output/aps/cuac/Ddvalid/CcoolDD/TMYeu/

Comparing the TSL 4 results in Table 10 with the results in Table 9, the CLF is further reduced because the simulated TMY CUAC load shape is more coincident with the system load. The CUAC load shape has some cooling load, albeit small, during the winter months while the winter NEMS space-cooling load is essentially zero. This tends to flatten the simulated CUAC load shape and lead to a 1-10% higher input CLF, which is reflected in the results.

Table 10 shows that the National CLF_{out} ranges from 17% to 19% and saves between 8 GW and 41 GW in year 2020. Again, the results are based on runs using a set of lower multipliers for each TSL run. Table 3 shows the multipliers used for each of the TSLs and subsection 6.3.2 discusses the reason for using the lower multipliers in this analysis.

Table 10. Cooling-Only Results for Year 2020 Using Double Decrement Approach with TMY CUAC Load Shape

	Change in Energy Sales (TWh)	Peak Capacity Change (GW)	National CLF _{out} (%)
TSL 1	-12.7	-7.9	18%
TSL 2	-21.3	-14.0	17%
TSL 3	-24.7	-16.3	17%
TSL 4	-31.9	-18.7	19%
TSL 5	-62.3	-40.9	17%

5.2.3 Comparing the Results from the Traditional and Double Decrement Approaches

In general, the double decrement approach using the simulated TMY CUAC load shapes result in a lower National CLF_{out} compared to the analysis using the traditional approach. Comparing the results in Table 10 with those in Table 2, the installed generating capacity reduction is 3 GW to 16 GW greater using the new double decrement approach and the National CLF_{out} is 6% to 14% points lower. Again, this difference is because the simulated CUAC load shape is more coincident with the system load.

5.3 Substitution of TMY System Load and TMY CUAC Load Shape

In addition to substituting the end use CUAC load shape into NEMS, Berkeley Lab also experimented with substitution of the NEMS system load shape for the TMY normalized system load shape.⁷ The main potential benefit of this combination is that the weather pattern embodied in the CUAC shape is identical to that on which the TMY system shape is based. This should result in the most accurate representation of coincidence between CUAC and system loads. The comparison of system load shapes in sub-section 3.3 revealed that the difference between the NEMS and TMY system loads does not appear significant. Sub-section 5.3.1 shows results of

⁷ This run is saved on the NEMS server, "amichai", under D:/nems/AEO2003/output/aps/cuac/Ddvalid/CcoolDD/TMYsl/

this substitution compared to the AEO2003 Reference Case and sub-section 5.3.2 highlights results with the system load substitution in conjunction with the double decrement approach.

5.3.1 Results from Substituting the TMY System Load into NEMS Reference Case

To substitute the system load shape, the system load shapes as well as the end-use load shapes are read into NEMS from the file pointed to by the LDSMDAFN parameter in the *scedes* setup file. The *scedes* file is user-defined and contains any modifications to the NEMS Reference Case. In this case, NEMS-BT reads in the system load.⁸ To replace the default NEMS system load shapes with the TMY system load shapes, Berkeley Lab created a new *ldsmdaf* input file, a binary file requiring a special preprocessor to convert from ascii to binary format. A preprocessor provided by John Holte of OnLocation, Inc. performed the task. It reads in the Reference Case *ldsmdaf* file and allows the user to delete or add system or end-use load shapes to generate a new *ldsmdaf* file. The 13 modified EMM regional system load shapes are: ecarLD, erctLD, maacLD, mainLD, mappLD, ny00LD, ne00LD, fl00LD, str0LD, spp0LD, nwppLD, ra00LD, cnv0LD. After the new *ldsmdaf* is created, the LDSMDAFN parameter in the *scedes* file is modified to point to the location of the newly created *ldsmdaf* file.⁹

Changing out the system load shape in NEMS has a significant effect, resulting in a reduction of the forecast installed capacity of 48 GW by year 2020 and through 2025. So despite the fact that the comparison of the NEMS and TMY system load do not show any consistent trends as shown in subsection 3.3, using the TMY system load does result in a 4% reduction of the peak load forecast.

Changing out both the system and end use load shapes with TMY ones results in a 35 GW (33 GW) decrease in total installed generating capacity by 2020 (2025), with 35 GW (30 GW) from fossil-generating capacity, but almost none (3 GW) from coal. This is roughly a 3% difference from the AEO2003 Reference Case total installed generating capacity of 1085 GW (1182 GW) in 2020 (2025). This implies that the simulated load shape is not quite as peaky as the NEMS system load.

The next section shows some TSL 4 results from simultaneously substituting the system and end use load shapes and using the double decrement approach.

5.3.2 Results from Substituting the TMY System and CUAC Load Shapes into NEMS Using the Double Decrement Approach

Berkeley Lab experimented with replacing the system load and space cooling end use load shape in NEMS with the TMY system and CUAC end use load shapes using the lower multipliers. The results for TSL 4 are shown in Table 11 and indicate that the National CLF_{out} increases from 19% (from Table 10) to 22 % when the TMY system load is substituted. This suggests that the TMY system load is less peaky than the system load shape in the NEMS Reference Case. Although the differences between the NEMS and TMY system load shapes were not significant,

⁸ The default location of this input file is on the NEMS server, "amichai", under D:/nems2003/input/ldsmdaf.v1.4.daf

⁹ This run is saved on the NEMS server, "amichai", under D:/nems/AEO2003/output/aps/cuac/Ddvalid/CcoolDD/TMYsl/reference1/

the peak utility results from the proposed CUAC standard can be significant, as evidenced by the 2.1 GW difference the installed capacity reduction from TSL 4 in year 2020.

Table 11. TSL 4 Cooling-Only Results Using Double Decrement Approach with TMY System Load Shape and TMY CUAC Load Shape

	2015	2020	2025
Change in Capacity (GW)	-8.7	-16.6	-21.1
Change in Energy Sales (TWh)	-21.5	-31.9	-38.8
National CLF _{out} (%)	28%	22%	21%

5.4 Summary of Results

The results from this section indicate reductions in the National CLF_{out} going from the traditional approach to the double decrement approach using lower multipliers and substituting out the NEMS end use space cooling load shape with a simulated TMY one. Table 12 summarizes the National CLF_{out} for each approach we considered. The National CLF_{out} for TSL 4 decreases from 25 % to 19 % in year 2020. Almost all of this reduction is due to the use of lower multipliers to model each TSL, which drops the National CLF_{out} from 25% to 21% in 2020. Substituting in the end use space cooling load shape with the simulated TMY CUAC load shape also reduces the National CLF_{out} further from 21% to 19%.

Table 12. Summary of TSL 4 Cooling-Only Results for Year 2020

Case	Change in Energy Sales (TWh)	Peak Capacity Change (GW)	National CLF _{out} (%)
Traditional Approach	-31.9	-14.5	25%
DD with NEMS Cooling Load Shape	-31.9	-16.9	21%
DD with TMY CUAC Load Shape	-31.9	-18.7	19%
DD with TMY CUAC and TMY System Load Shape	-31.9	-16.6	22%

Section 6 compares input CLFs with output CLFs and attempts to identify the causes of discrepancy.

6. Explaining the Peak Impacts

In the process of developing the double decrement approach to modeling a proposed CUAC standard, a wealth of knowledge was uncovered in our understanding of how discrepancies between input CLFs and output CLFs propagate. This section highlights some of our improved understanding. Subsection 6.1 discusses Berkeley Lab's newfound ability to output the hourly system load. Subsection 6.2 introduces a variation to the CLF used to help understand how the LF_{in} of the end use load shape correlates to the output CLF based on the results of the CUAC NEMS run further discussed in subsection 6.3. Subsection 6.4 then shows how the hourly system load is aggregated into blocks that make up the NEMS LDC and how this output helps our understanding of the peak effects from a proposed CUAC standard NEMS-BT run.

6.1 Output Hourly System Load by EMM Region and Year

In order to verify whether the double decrement approach was properly working, Berkeley Lab output the NEMS-BT hourly system load shape by forecast year and EMM region. Comparing the hourly load between the NEMS Reference Case and a CUAC NEMS-BT run revealed the shape and size of the energy decrement. Doing this comparison assured us that the double decrement approach was properly decrementing the system load at the appropriate hours of the year. Although this comparison was developed for CUAC standard runs, the output hourly system load can be used for any NEMS run. For a more detailed description of the code modifications please see Appendix E. This method has become an invaluable, although still somewhat unrefined, tool in our energy efficiency standards tool chest.

This tool makes analyzing the hourly system load shape very easy for any given run, not just for analysis of a proposed CUAC standard and prints out the hourly system load, hour number (1-864), EMM region, iteration, and forecast year. A total of 864 unique hours represent the entire year in NEMS; this comes from 24 hours per day times three day types per month times 12 months per year. Each month in NEMS is characterized by three different day types – peak day, weekday, or weekend day. The peak day is represented as one day of the month that corresponds to the day with the highest load for the month. Every other day is either a weekday or weekend day where all weekend days and weekdays in a given month are characterized by the same load profile. The hourly output is transferred to a spreadsheet to analyze the variation between regional peak hours, measure the hourly effect of the decrement, compare the change in load shapes across regions, and compute what we call the Regional CLF_{out} by EMM region.

Figure 17 illustrates an example year 2025 LDC for the ECAR EMM region for 6x TSL 4 standard. The two lines represent the NEMS Reference Case and the proposed CUAC standard case using the simulated TMY CUAC load shape. All 8,760 hours of the year are shown, expanded from the 864 hour LDC. This figure illustrates the size and nature of the decrement that results from a 6x TSL 4. The decrement appears greater during the highest peak hours and less at the base load. Including ECAR, six of the EMM regions show a needle-like peak at the peak hours of the year, MAAC, MAIN, NY, NE, and

NWP, with the remaining regions showing less of a vertical orientation at the highest load hours.

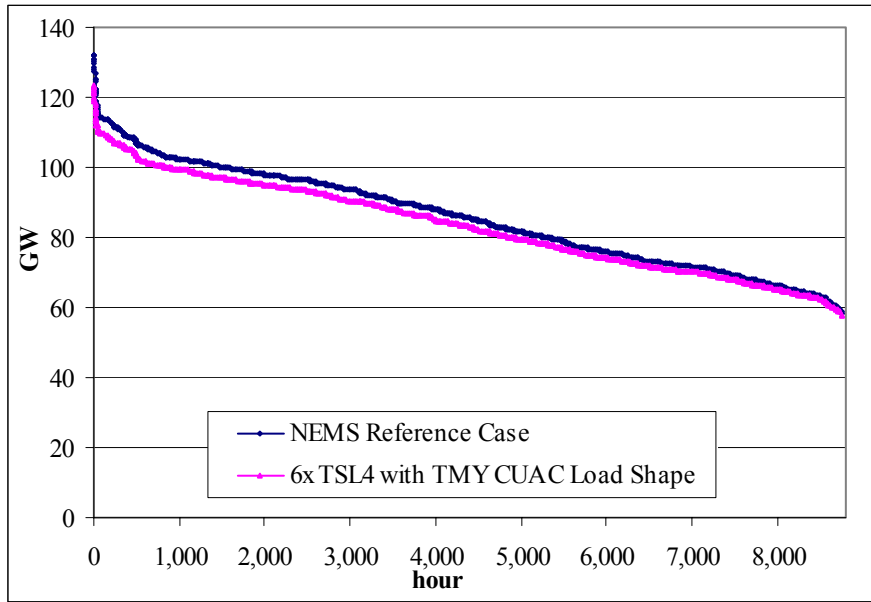


Figure 17. The LDC from 6x TSL 4 for ECAR Region in Year 2025

6.2 The Regional CLF_{out}

The Regional CLF_{out} is based on NEMS-BT hourly system load output. Unlike the National CLF_{out} , which can only be calculated for the U.S. given the data constraints of the NEMS-BT standard output, the Regional CLF_{out} can be estimated by EMM region from dumped regional hourly system load data. As was mentioned previously in Section 2, the Regional CLF_{out} is expressed as,

$$\text{Regional } CLF_{out} = \frac{\Delta \text{ Average Energy}}{\Delta \text{ Peak Load} * 8760 \text{ h}}$$

This metric can be used to measure how a CUAC standard is affected by non-coincidence, error introduced by the iterative process, and error introduced by the magnitude of higher multipliers chosen to model each TSL. The Regional CLF_{out} helps tie together the LF_{in} and the National CLF_{out} . The next section explains in more detail the difference between the LF_{in} and the National CLF_{out} .

Unfortunately, Berkeley Lab has yet to fully understand the relationship between the Regional CLF_{out} and the National CLF_{out} . This discrepancy is likely due to peak non-coincidence between regions. NEMS does not estimate a national peak; the model treats each region separately without having to sum the regional peaks and consider non-coincidence among them. NEMS does not calculate a national peak so it is impossible to determine the degree of non-coincidence between the regional system peaks and the

national system peak. Presumably there are other second-order effects that could also play a role in influencing the transition from Regional CLF_{out} to National CLF_{out}, such as the squelch, changes due to the complex mathematical NEMS solvers, etc.

6.3 Relating LF_{in} and the Regional CLF_{out}

This subsection helps explain why the input load factor, LF_{in}, for CUAC deviates from the estimated Regional CLF_{out} based on the model output. Table 13 shows the LF_{in} and Regional CLF_{out} values by EMM region for two scenarios that use the CUAC double decrement approach for a 3x TSL 4. One scenario uses the default NEMS-BT space cooling end use load shape and the other substitutes in the simulated TMY CUAC end use load shape.

Table 13. Comparison of LF_{in} and the Regional CLF_{out} from 3x TSL 4

EMM #	EMM Region	NEMS Space Cooling Load Shape		TMY CUAC Load Shape	
		LF _{in}	Regional CLF _{out}	LF _{in}	Regional CLF _{out}
1	ECAR	10%	18%	14%	14%
2	ERCOT	15%	26%	19%	19%
3	MAAC	11%	22%	13%	16%
4	MAIN	10%	16%	12%	11%
5	MAPP	10%	13%	11%	9%
6	NY	9%	22%	10%	16%
7	NE	8%	26%	7%	16%
8	FL	16%	21%	25%	28%
9	STV	15%	19%	20%	22%
10	SPP	12%	26%	14%	28%
11	NWP	12%	-737%	12%	-609%
12	RA	12%	14%	16%	12%
13	CNV	12%	15%	17%	17%
	National CLF _{out}		25%		17%

Two important highlights from Table 13 are:

- Region NWP (located in the Pacific Northwest) is winter peaking so the peak hour is unaffected by a CUAC standard, i.e. denominator of zero. However the iterative nature of NEMS leads to a very small increase in the peak hour load resulting in a large negative value for the Regional CLF_{out}.
- In general, the NEMS space cooling load shape is more peaky than the simulated TMY CUAC load shape, except in the NE region as seen by comparing the LF_{in} in both cases. The lower Regional CLF_{out} for the simulated TMY CUAC load shape scenario is due to the closer coincidence between the TMY CUAC peak and the system peak compared to the NEMS cooling load peak in most regions. Peak coincidence will be further explained in section 6.3.1.

The Regional CLF_{out} measures the load factor for the change in the regional system load shape, which should come directly from the LF_{in} if coincidence is perfect. The rest of this section explains how the hourly system load decrement of our new approach was verified by tracing the steps from LF_{in} to the Regional CLF_{out}.

$$LF_{in} = \frac{\text{Average End-Use Load}}{\text{Peak End-Use Load} * 8760 \text{ h}}$$

LF_{in} characterizes an end-use average load relative to its peak load. LF_{in} has an equivalent CLF, the CLF_{in}, which is the exact same measure if the peak decrement is in the exact same proportional to the end use peak as the average decrement is to the average load. This is usually the case with efficiency analyses because there is typically little reason to believe that the effect of an efficiency improvement is uneven over the year.

$$CLF_{in} = \frac{\text{Energy Decrement}}{\text{Energy Decrement}} * \frac{\text{Average End-Use Energy}}{\text{Peak End-Use Load} * 8760 \text{ h}}$$

which in order to be compared to the Regional CLF_{out}, can be written as:

$$CLF_{in} = \frac{\Delta \text{ End-Use Average Energy}}{\Delta \text{ End-Use Peak Load} * 8760 \text{ h}}$$

The Regional CLF equation is rewritten below to illustrate how it differs from CLF_{in}.

$$\text{Regional CLF}_{out} = \frac{\Delta \text{ Total Energy (Reference Case – TSL Case)}}{\Delta \text{ Peak Load (Reference Case – TSL Case)} * 8760 \text{ h}}$$

There are two reasons that explain the difference between CLF_{in} and the Regional CLF_{out}. First is peak non-coincidence, which means that the end-use peak load hour and the system load peak hour are different. The second is system load restoration error, or the imperfection of part two of the double decrement approach. System load restoration error is the difference between the numerators of these two equations, the energy decrement and the change in total energy, as well as the difference between the peak energy decrement and the change in peak load. Berkeley Lab identified a simple factor for each of these reasons, which can be measured to show how each cause relates to the translation of CLF_{in} to the Regional CLF_{out}.

$$\text{Regional CLF}_{out} = LF_{in} * \text{PNF} * \text{SREF}$$

In this expression, PNF is Peak Non-coincidence Factor and SREF is System Restoration Error Factor. The following two subsections describe each of these two factors in more detail.

6.3.1 Peak Non-Coincidence

Non-coincidence between the end use peak and system peak is a normal phenomenon and not an error. Peak non-coincidence simply means that the peak hour for the end-use and the peak hour for the system load do not occur at the same hour, which is likely to be the case for most end-uses. When calculating capacity savings and the National CLF_{out} , the end-use decrement at the system peak hour determines the change in system peak, not the maximum decrement from the end use. Table 14 shows three different peak hours that are important in understanding peak non-coincidence and the Regional CLF_{out} calculation.

Table 14. Identifying Peak Non-Coincidence Between the TMY CUAC End-Use and Reference Case System Load Shapes in Year 2025

EMM Region	TMY CUAC End Use Peak Day hour	Reference Case System Peak Hour	3x TSL 4 System Peak Hour	Reference Case System Peak Hour	3x TSL 4 System Peak Hour	Decrement at TMY CUAC Peak Hour	Change in System Peak Hour (Ref - 3x TSL 4)	PNF
	A	B	C	D	E	F	G	H
ECAR	July 4 pm	June 3 pm	June 5 pm	132.3	128.2	4.27	4.09	104%
ERCOT ^a	July 3 pm	<i>July 5 pm</i>	<i>July 5 pm</i>	75.5	72.3	3.39	3.13	108%
MAAC	June 4 pm	June 5 pm	July 5 pm	69.8	66.6	3.92	3.24	121%
MAIN	July noon	July 5 pm	June 4 pm	62.1	60.2	2.31	1.87	124%
MAPP	July 3 pm	July 1 pm	July 1 pm	39.3	38.2	1.20	1.08	111%
NY	July 4 pm	June 3 pm	June 3 pm	32.1	30.2	1.94	1.90	102%
NE	August 2 pm	July 5 pm	July 5 pm	29.3	28.2	1.53	1.13	135%
FL	August noon	June 5 pm	June 5 pm	61.1	59.0	2.89	2.12	136%
STV	July 3 pm	June 2 pm	June 5 pm	216.0	208.5	9.00	7.47	120%
SPP	August 3 pm	Sept. 5 pm	Sept. 5 pm	49.8	48.6	2.40	1.17	205%
NWP	July 4 pm	Dec. 11 am	Dec. 11 am	71.8	71.1	2.88	0.62	465%
RA	June 4 pm	July 4 pm	July 4 pm	47.9	46.2	1.98	1.73	114%
CNV	July 3 pm	Sept. 4 pm	Sept. 4 pm	95.7	92.8	3.98	2.85	140%

^a ERCOT peak hours in italics are weekday peaks, not peak day peaks. So end-use peak is on July peak day, while system peak hour is on July weekday.

The first column, denoted as A, shows the end-use peak hour by region, column B shows when the Reference Case system peak occurs, and column C shows the new system peak hour after the energy savings decrement is applied, in this case for a 3x TSL 4. Only three of the 13 EMM regions have the TMY CUAC end-use peak (column A) and system load peak (column B) on the same day, although at different hours: MAAC, MAIN, and MAPP. NWP is the only region where the end-use and system peaks occur in opposite seasons, summer for the end use and winter for the system peak. The remaining regions

have differing peak hours, although the difference remains in the summer months. Thus, most regions do not share the CUAC end use peak and system peak on the same day.

In general, peak non-coincidence leads to less of a peak hour decrement than expected from the CLF_{in} for two reasons. First, the system peak hour may change after a decrement. Regions ECAR, MAAC, MAIN, and STV all fit this profile, which can be seen in Table 14 by comparing columns B and C. Second, the system peak hour is subject to less of a decrement than the end-use peak hour. The CUAC end use load shape, not the system load, dictates the decrement, and non-coincidence between their two peaks diminishes the overall peak reduction. Columns D, E, F, and G of Table 14 provide a quantitative explanation of these two effects. Columns D and E show the peak load for the hours in columns B and C. Column F shows the decrement applied to the hour reported in column one. If the peak hour were the same for columns A, B, and C then the difference between columns D and E would be equivalent to the value in column F. The last column, column G, shows the actual difference between columns D and E. The ratio of column G to column F is the measure we call PNF in column H, which is defined below.

$$PNF = \frac{\Delta \text{ EU Peak Hour Load (Reference Case – TSL Case)}}{\Delta \text{ Peak Hour Energy Load (Reference Case – TSL Case)}}$$

The region with the least coincidence between the TMY CUAC end use and system load is NWP, as shown by the high PNF value, which is due to the seasonal difference between these two loads. The SPP region also exhibits a significant degree of non-coincidence, with NY and ECAR showing the greatest degree of coincidence.

Identifying this PNF has another use as well. The PNF can be used to evaluate how the larger multipliers chosen for each TSL can affect the results. Using the traditional approach, the guiding principal was to use multipliers that provided a generally linear scatter of the generation and capacity variable and were high enough to escape the range of numerical noise in NEMS. The PNF helps indicate when a chosen multiplier becomes problematic, as the next subsection explains.

6.3.2 Multiplication Error

The PNF proves a useful metric that shows how higher magnitude multipliers can have a significant effect on increasing the peak non-coincidence. While peak-non-coincidence is normal, changes to it caused by the arbitrary use of multipliers is not. Higher multipliers are more likely to disrupt the ordering of the LDC and the overall magnitude of the load at the peak hour. The linear regression of results cannot correct for this effect. The problem exists when the use of a higher multiplier moves the peak hour. When the peak hour moves as a legitimate result of the decrement, the Regional CLF_{out} is still valid as defined. If, however, it moves because of the multiplier, which is an arbitrary tool of the analysis, then the Regional CLF_{out} estimate is less accurate.

An example that shows both regular non-coincidence and the multiplier error effect is illustrated in Figure 18. This figure shows various multiplier runs for five selected nonconsecutive hours in year 2025 for the MAPP region. The four scenarios are the NEMS Reference Case and the 1x, 3x, and 6x multipliers for TSL 4 using the NEMS space cooling load shape. The reason these five hours are shown is because they illustrate the peak effect among these different scenarios. Hour “b” in this figure represents the Reference Case peak hour at 39.28 GW and hour “c” represents the CUAC end-use peak hour at 39.08 GW in for this region. In this example, the 1x TSL 4, or modeling the CUAC standard without inflating the savings, shifts the peak hour from hour “b” to hour “d”. However, the 3x TSL 4 and 6x TSL 4 runs each result in different peak hours, hours “a” and “e”, respectively. Ideally, multipliers would be chosen to make sure the run results in the same peak hour as the 1x TSL 4. Of course, looking at the 3x TSL 4 line, the load difference between hour “a” and hour “d” is trivial. Significant error is introduced in this example when a 6x TSL 4 leads to the difference between hour “e” and hour “d”.

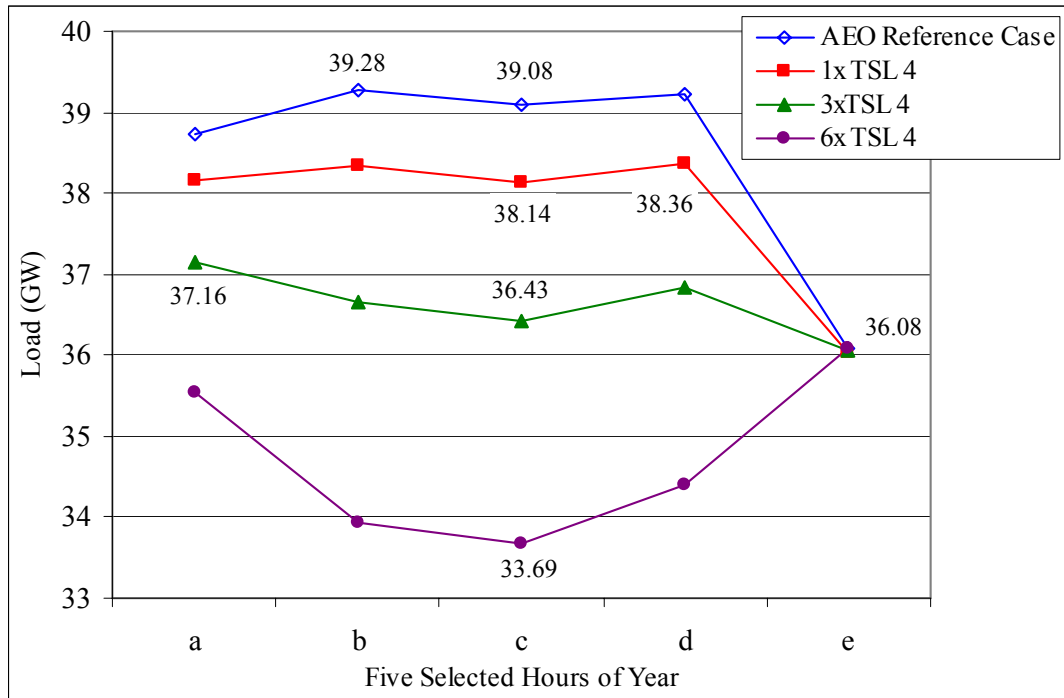


Figure 18. Example of Peak Non-Coincidence in MAPP in 2025 for Selected Multiples of TSL 4

This example can be further demonstrated by comparing the PNF across different multipliers. Table 15 shows that for 1x TSL 4, even though peak non-coincidence exists, it is pretty insignificant. To help explain these percentages, the maximum decrement of the CUAC end use peak in the MAPP region is 0.94 GW (39.08 GW - 38.14 GW), while the change in the peak system load is 0.92 GW (39.28 GW - 38.36 GW). The 1.03 in Table 15 is the result of dividing 0.94 by 0.92. In general, the table below shows that higher multipliers tend to result in a higher measure of the PNF. As the higher

multipliers shift the peak hour in the 3x and especially in the 6x scenarios, the PNF increases.

The PNF also indicates how peak reductions are dampened. As this work reveals, the use of higher multipliers has a significant impact on the non-coincidence between the CUAC end use and system load shapes. The greater non-coincidence that results from higher multipliers leads to reduced peak utility impacts as a result of the decreased correlation between the end use and system load. This means that a significant error associated with our peak utility impacts is due to the multipliers chosen to model each TSL.

Table 15. Peak Non-coincidence Factor by Region for Selected Multiples of TSL 4 in Year 2025

EMM Region	Peak Non-Coincidence Factor		
	1x TSL 4	3x TSL 4	6x TSL 4
ECAR	1.52	1.62	1.62
ERCOT	1.66	1.66	1.65
MAAC	1.75	1.80	1.79
MAIN	1.32	1.53	1.58
MAPP	1.03	1.25	1.69
NY	1.77	1.86	2.19
NE	1.49	2.08	2.91
FL	1.35	1.39	1.65
STV	1.30	1.35	1.35
SPP	2.08	2.11	2.28
NWP	n/a	n/a	n/a
RA	1.11	1.13	1.44
CNV	1.42	1.41	1.45

The PNF values that are in bold indicate when multipliers increase the PNF value by more than an additional 10% beyond the 1x scenario PNF, an arbitrary cut off to identify when the multiplier becomes problematic. That said, the 3x scenario shows a multiplier problem in three EMM regions, MAIN, MAPP and NE, as indicated by the bolded values in Table 15. The 6x scenario shows a problem in seven regions, most of which raise the PNF by 0.20 to 1.42 from the 1x scenario.

Berkeley Lab will in the future use the PNF to evaluate whether multipliers chosen for each TSL significant risk of further altering the LDC. Berkeley Lab expects to use lower multipliers as a result of this finding that retain the general ordering of the peak system load hours.

6.3.3 Restoration Error

Earlier it was explained that part two (as shown in Figure 16) of the double decrement approach restores the system energy to the Reference Case, thereby correcting for decrements to the demand side of NEMS in part one. If this restoration were not made, the decrement would be double counted, once on the demand side and again by the load shape decrement. The restoration is performed by mathematically restoring the term that is removed by the demand side decrement in part one of the double decrement approach. Appendix B, section III shows the coding modifications for this restoration.

However, by restoring the energy to the load shape without restoring it to the demand, other demand side factors affected by part one of the approach are not corrected for. The main second order effect is the price change induced by a demand reduction. Therefore, beyond the first iteration, perfectly restoring the system load back to the Reference Case is theoretically impossible given that one goal of the restoration process is to leave the demand side effects static.

For example, the reduced commercial sector space cooling energy consumption affects end use electricity and fuel prices that lead to second order effects that also affect the system load. This discrepancy in the system load or second order effect is referred to in this work as the restoration error. Restoration error represents the difference between the Reference Case and Restored Reference Case system load shapes. Berkeley Lab can compare these two loads shapes by using the same method described in subsection 6.1, by outputting the hourly system load for the Restored Reference Case. The magnitude of restoration error is explained for one example scenario in the following two tables.

For CUAC 3x TSL 4, Table 16 shows the regional energy decrement in year 2025. Columns B and C show the total energy by summing the load across all hours of the year. Column D shows the effective energy decrement relative to the NEMS Reference Case and column E shows the energy decrement input into NEMS-BT relative to the Restored Reference Case. The ratio of the two energy decrements is called the Total Energy correction Factor (TEF), and may be higher or lower than 1.0.

$$\text{TEF} = \frac{\Delta \text{ Total Energy (Reference Case – TSL Case)}}{\Delta \text{ Total Energy (Restored Reference Case – TSL Case)}}$$

Table 16. Energy Decrement for 3x TSL 4 by Region in Year 2025 (TWh)

EMM Region	NEMS Reference Case	Restored Reference Case	3x TSL 4 Case	Energy Decrement NEMS Reference Case	Energy Decrement Restored Reference Case	TEF
	A	B	C	D = A-C	E = B-C	D/E
ECAR	749.0	748.7	739.4	9.60	9.25	1.038
ERCOT	404.8	404.4	396.4	8.47	8.09	1.047
MAAC	355.3	354.3	346.3	8.92	7.95	1.123
MAIN	331.8	331.7	327.3	4.50	4.43	1.015
MAPP	227.6	227.6	225.2	2.45	2.41	1.017
NY	176.4	175.3	171.9	4.55	3.46	1.313
NE	159.7	158.5	156.0	3.73	2.47	1.512
FL	307.0	307.6	299.7	7.27	7.89	0.922
STV	1,204.9	1,207.0	1182.6	22.25	24.30	0.915
SPP	258.8	258.8	253.9	4.96	4.93	1.007
NWP	377.3	377.4	371.3	5.98	6.05	0.988
RA	250.0	249.5	245.1	4.87	4.36	1.117
CNV	421.1	422.6	413.2	7.95	9.42	0.844
Total	5,223.8	5,223.3	5128.3	95.50	95.00	

Furthermore, the restoration error can also lead to another problem involving differences in peak energy demand. That is, the demand from the Restored Reference Case peak hour varies from the NEMS Reference Case. Table 17 shows the regional peak hour for the NEMS Reference Case compared to the Restored Reference Case. While these values seem similar, a small discrepancy can have a significant effect because the change in peak hour determines the Regional CLF_{out}. The ratio of the two measured differences, the Restored Reference Case minus the standard case and the Reference Case minus the standard case, is referred to in this work as the Peak Discrepancy correction Factor (PDF).

$$PDF = \frac{\Delta \text{ Peak Hour Energy Load (Restored Reference Case – TSL Case)}}{\Delta \text{ Peak Hour Energy Load (Reference Case – TSL Case)}}$$

Table 17. Peak Hour Demand for 3x TSL 4 by Region in Year 2025 (TWh)

EMM Region	Peak Hour Demand, NEMS Reference Case	Peak Hour Demand, Restored Reference Case	Peak Hour Demand, TSL	NEMS Reference – TSL	Restored Reference - TSL	PDF
	A	B	C	D = A-C	E = B-C	E/D
ECAR	132.3	132.6	126.2	6.0	6.3	1.051
ERCOT	75.5	75.4	71.7	3.7	3.7	0.989
MAAC	69.8	69.8	65.2	4.6	4.6	0.997
MAIN	62.1	62.4	58.9	3.2	3.5	1.080
MAPP	39.3	39.4	37.2	2.1	2.2	1.043
NY	32.1	32.0	29.7	2.4	2.2	0.955
NE	29.3	29.5	27.7	1.7	1.8	1.086
FL	61.1	61.3	57.1	4.0	4.2	1.051
STV	216.0	216.8	202.4	13.6	14.4	1.058
SPP	49.8	49.8	47.6	2.2	2.2	1.014
NWP	71.8	71.9	71.9	-0.1	0.0	#DIV/0!
RA	47.9	47.9	44.1	3.8	3.8	0.984
CNV	95.7	96.2	89.6	6.1	6.6	1.089

Table 17 shows that the PDF is variable across the regions and not consistent to either side of one. Four regions (ERCOT, MAAC, NY, and RA) indicate a restoration to a level below the NEMS Reference Case, with eight regions showing an overcorrection for the demand-side decrement on the supply side of NEMS.

Based on analysis of the restoration error portion of the double decrement approach, Berkeley Lab has developed a simple expression that relates the PDF and TEF factors presented in this section with the SREF, or System Restoration Error Factor, previously discussed:

$$\text{SREF} = \text{TEF} * \text{PDF}$$

This expression provides a better understanding of the factors that contribute to the overall error associated with the restoration. Both the TEF and PDF metrics show unbiased variability, as evidenced by values both above and below a level of perfect restoration. The PDF appears more variable than the TEF metric, indicating the importance of properly restoring the load at the peak hour.

6.4 Summarizing our Findings

This section presents a number of different factors used to help understand the differences between the LF_{in} and Regional CLF_{out} examined in this work. The PNF identifies the degree of non-coincidence between the NEMS Reference Case and a standard, while proving a useful metric for evaluating the higher multipliers required when modeling each TSL. The TEF and PDF help quantify the restoration error effect. The TEF and PDF result from differences in the total energy decrement and peak hour

decrement, as calculated by comparing the NEMS Reference Case to the Restored Reference Case. Table 18 shows an example of these factors in MAPP for different multiples of TSL 4. The implicit LF_{in} is 10%, yet the resulting Regional CLF_{out} is 14%, 13%, and 17%, for the 1x, 3x, and 6x TSL 4 cases, respectively. For the 1x TSL 4 case, there is only a three-percentage point difference due to peak non-coincidence (PNF) and peak discrepancy (PDF) with most of the difference between the input 10% and output 14% due to the TEF. For the 3x TSL 4 case, the largest factor contributing to the difference between LF_{in} and the Regional CLF_{out} appears to be due to the PNF factor, and in the 6x TSL 4 case the seven-percentage point difference is largely driven by peak non-coincidence. Thus, the peak non-coincidence is clearly more problematic with higher multipliers, yet the restoration error does indicate a potentially significant factor, especially in the 1x TSL case.

Table 18. Summary of Metrics used to Evaluate Selected Multiples of TSL 4 for MAPP

	1x TSL 4	3x TSL 4	6x TSL 4
LF_{in} & CLF_{in}	10%	10%	10%
PNF	1.03	1.25	1.69
TEF	1.45	1.02	0.99
PDF	0.97	1.04	1.02
Regional CLF_{out}	14%	13%	17%

6.5 The 11 Blocks that Represent the LDC in NEMS

Additionally, Berkeley Lab was able to output LDC information from NEMS-BT, which helped clarify how higher decrement CUAC runs affect the LDC. After NEMS computes the hourly system load, the EMM module groups the hours into blocks by season and time of day.

NEMS characterizes the system load into eleven different blocks that represent the 8760 hours of the year. The blocks sort the load for each EMM region by season and time of day. Table 19 shows each of the eleven blocks, the months corresponding to each season, the hours indicating the time of day, and the number of hours corresponding to each block type.

Table 19. Summary of Load Duration Curve Parameters in NEMS

Block	Load Group	Months	Hours of the Day	# Hours of the Year
1	summer day peak	June-September		67
2	winter morning/evening peak	December-March		67
3	winter day	December-March	7:00am-6:00pm	968
4	summer day non-peak	June-September	7:00am-6:00pm	1275
5	winter morning/evening non-peak	December-March	5:00am-7:00am, 6:00pm-12:00am	1264
6	spring/fall day	April-May, October-November	7:00am-6:00pm	1220
7	summer morning/evening	June-September	5:00am-7:00am, 6:00pm-12:00am	976
8	spring/fall morning/evening	April-May, October-November	5:00am-7:00am, 6:00pm-12:00am	1098
9	winter night	December-March	12:00am-5:00am	605
10	summer night	June-September	12:00am-5:00am	610
11	spring/fall night	April-May, October-November	12:00am-5:00am	610

Recent work with developing this new approach has provided a greater understanding of how these blocks are used. In an experimental run with 6x TSL 4, we identified a shift in the ordering of these blocks such that a normally summer peaking load in three EMM regions switched to winter peaking as a result of the large decrement from this summer peaking end use.¹⁰ This run estimated a 225 TWh reduction in electricity sales in 2025 and a 112 GW reduction in total installed generating capacity for the same year. As a result, the winter peak block was superceded by the peak summer block in the MAPP, NE, and NY regions. This is a concern because the peak load is no longer dictated by summer demand, potentially altering the behavior of capacity planning in each EMM region. Berkeley Lab is still working on resolving this problem.

The nine seasonal and time of day blocks are: (1) spring/fall night, (2) spring/fall morning and evening, (3) spring/fall day, (4) winter night, (5) winter morning and evening, (6) winter day, (7) summer night, (8) summer morning and evening, and (9) summer day. Within each of the blocks, the hourly loads are sorted in descending order as can be seen in Figure 19. The summer day and winter morning/evening block are further subdivided into non-peak and peak blocks. A fixed percentage of 5 % or 67 hours out of the year (as specified in the ldsinstr.txt file) from the highest load end of summer day and winter morning/evening blocks is designated as peak blocks. The 11 blocks are then sorted in descending order to provide a compact representation of the load duration curve.

The 11 LDC blocks by the 13 EMM regions were output. Comparing the block information from the NEMS Reference Case to runs modeling the impact from a proposed CUAC standard, this output helped identify an interesting phenomena: decrementing the system load in the standards case can cause the peak to switch from summer season to winter season. By noting the decrease in the peak blocks versus the annual saving, the CLF can be computed for each EMM region. Berkeley Lab also

¹⁰ This run is located on the “amichai” server used for running NEMS under D:/nems/AEO2003/output/aps/cuac/Ddvalid/CcoolIDD/NEMSeu/6xstd4/d121503b

output the entire (864 hours) system load shape for the NEMS reference and the CUAC standard cases in order to compute the Regional CLF_{out} based on the peak hours. Comparison of this output revealed that the Regional CLF_{out} computed from the LDC blocks are in close agreement with those calculated from the hourly system load itself.

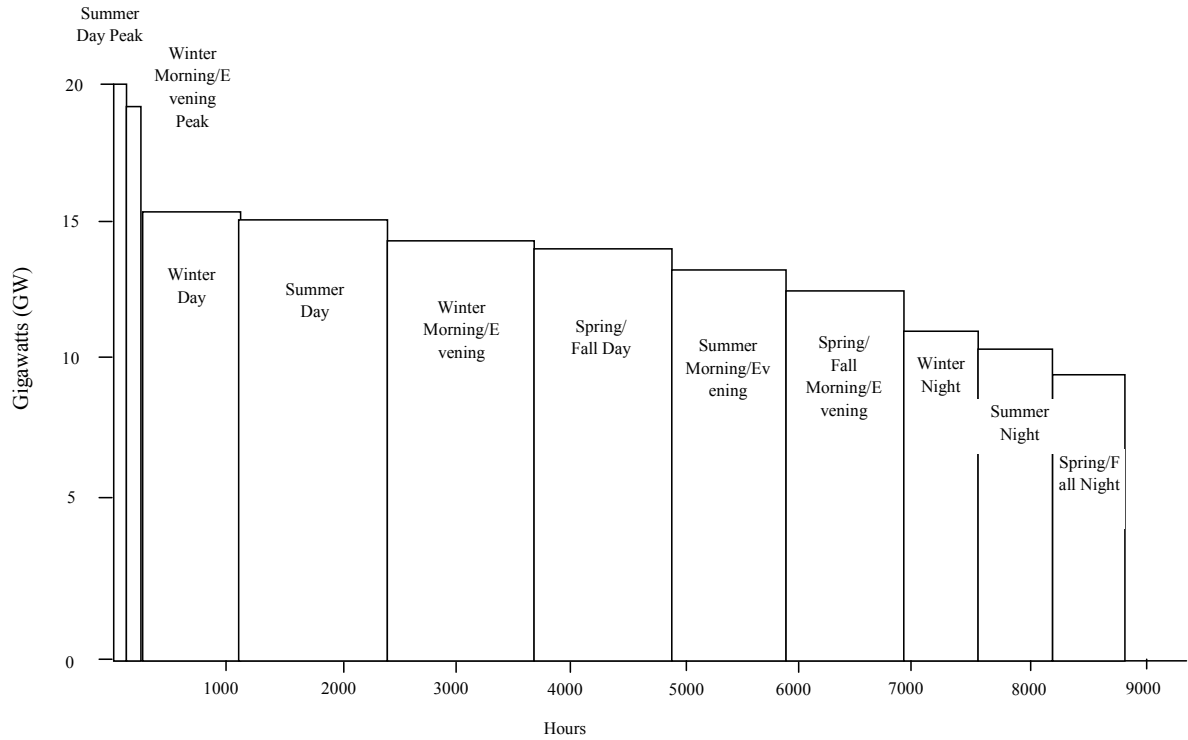


Figure 19. An Example of the Load Duration Curve in NEMS

The transition from a summer to winter peaking system load only occurs with higher multipliers. Lowering the magnitude of the multiplier yet still ensuring that the impacts are safely out of the range of numerical noise minimized the risk of this phenomenon occurring.

7. Summary of Findings and Conclusions

Because of previous unsuccessful modeling of the utility effects from an appliance standard on a peaky end use in NEMS-BT, Berkeley Lab has developed the new double decrement approach for modeling the effects from a proposed CUAC standard.

The following summarizes the key findings and conclusions from this work:

- The double decrement approach reduces the hourly system load shape directly to ensure the effects from a proposed CUAC standard are properly lowering the peak and properly accounting for changes on the supply side of the model. The approach also decrements the commercial space cooling consumption to account for changes on the demand side of the model, with a restoration step designed to eliminate any potential double counting of the energy savings.
- Although Berkeley Lab believes the simulated TMY CUAC load shape developed by PNNL are more representative of the CUAC load profile, this simulated load shape is characteristically less peaky than the end use space cooling load shape currently used in NEMS, approximately 1-10 percentage points higher in the input CLF, LF_{in} .
- A comparison of the standard system load shape in NEMS and the TMY system load shows no significant identifiable differences between these two sources.
- Berkeley Lab was successful at targeting decrements from the highest system load peak hours in a preliminary NEMS-BT run, resulting in National CLF_{out} values that are very peak coincident, i.e. less than 10% by 2020.
- The use of lower magnitude multipliers for our higher decrement runs increases our peak impacts equivalent to roughly 2-5 percentage points in the National CLF_{out}. This work revealed that higher multipliers alter the shape of the LDC such that capacity planning results are no longer representative of a proposed CUAC standard.
- The National CLF_{out} using the double decrement approach is not significantly different than the National CLF_{out} using the traditional approach.
- The non-coincidence between the end-use CUAC load profile and the NEMS-BT system load account for nearly all of the discrepancy between the input CLF of the space cooling or CUAC simulated TMY load shape input to NEMS-BT and the National CLF_{out} based on the results of implementing a proposed CUAC standard.
- Using the simulated TMY CUAC load shape in place of the NEMS space cooling end use load shape increases the peak utility effects, amounting to a 2 percentage-point reduction of the National CLF_{out} for TSL 4 in year 2020. The simulated end use load shape is more coincident with the system load with somewhat more usage during the off-peak periods of the day.
- Berkeley Lab proposes using the double decrement approach in conjunction with switching out the NEMS space cooling end use load shape with the simulated CUAC load shape.

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Appendix A. Mathematical Representation of Load Demand in NEMS

I. Calculation of System Load in NEMS

This section describes the differences between two mathematical representations of the system load. One representation corresponds to what is shown in the model documentation of NEMS. We call this the *Original Delta Approach*. It should be noted that there are lines of code for the *Original Delta Approach* in the NEMS source code, but the lines have been commented out and the code is thus inactive. The other representation is what is actually implemented in NEMS. This second representation is a modification to the *Original Delta Approach* involving a scaling factor. We call this representation the *Current Delta Approach* because that is currently used in NEMS to calculate hourly system loads.

The mathematical representation of the hourly system load using the *Original Delta Approach* as shown in the model documentation is:

$$SysLoad_{-O}^{yr}(h) = p_s(h) \cdot TE^{2001} + \sum_e^{all\ e} p_e(h) \cdot (EU_e^{yr} - EU_e^{2001}) \quad \dots\dots\dots (1)$$

- where
- e = end-uses index
 - yr = year index
 - $SysLoad^{yr}(h)$ = system load at hour h in year yr (SYLOAD in documentation)
 - TE^{2001} = total system load in the base year, which is 2001 in AEO2001 version of NEMS
 - $p_s(h)$ = historical hourly load shape for the system at hour h (DistLo_s in documentation)
 - $p_e(h)$ = normalized load shape of end use e at hour h (DistLo_e in documentation)
 - EU_e^{yr} = Annual end-use load for end-use e in year yr (load1_e in documentation)
 - EU_e^{2001} = Annual End-use load for end-use e in base year (2001)

The *Current Delta Approach* as shown below calculates the hourly system load using a slightly modified form of the *Original Delta Approach*:

$$SysLoad_{-C}^{yr}(h) = p_s(h) \cdot TE^{yr} + \sum_e^{all\ e} p_e(h) \cdot \left(EU_e^{yr} - \frac{TE^{yr}}{TE^{2001}} \cdot EU_e^{2001} \right) \quad \dots\dots\dots (2)$$

- where TE^{yr} = total system load in year yr

In (2), $p_s(h)$ is multiplied by the total system load of the current year, TE^{yr} , instead of TE^{2001} as in (1). Also EU_e^{2001} is multiplied by a scaling factor $\frac{TE^{yr}}{TE^{2001}}$.

II. Comparison to the Bottom-up Approach

The bottom-up approach calculates the system hourly load for each hour h as follow:

$$SysLoad_B^{yr}(h) = \sum_e^{all\ e} p_e(h) \cdot EU_e^{yr} \dots\dots\dots (3)$$

Rearranging equation (1), the hourly system load using the *Original Delta Approach* becomes

$$\begin{aligned} SysLoad_O^{yr}(h) &= \sum_e^{all\ e} p_e(h) \cdot EU_e^{yr} + \left(p_s(h) \cdot TE^{2001} - \sum_e^{all\ e} p_e(h) \cdot EU_e^{2001} \right) \\ &= SysLoad_B^{yr}(h) + diff(h) \dots\dots\dots (4) \end{aligned}$$

where

$$diff(h) = \left(p_s(h) \cdot TE^{2001} - \sum_e^{all\ e} p_e(h) \cdot EU_e^{2001} \right)$$

Note: $diff(h)$ represents how much the historical system load shape in the base year 2001 differs from the sum of all the NEMS end-use load shapes at hour h .

By rearranging equation (2), the hourly system load using the *Current Delta Approach* becomes

$$\begin{aligned} SysLoad_C^{yr}(h) &= \sum_e^{all\ e} p_e(h) \cdot EU_e^{yr} + \frac{TE^{yr}}{TE^{2001}} \cdot \left(p_s(h) \cdot TE^{2001} - \sum_e^{all\ e} p_e(h) \cdot EU_e^{2001} \right) \\ &= SysLoad_B^{yr}(h) + \frac{TE^{yr}}{TE^{2001}} \cdot diff(h) \dots\dots\dots (5) \end{aligned}$$

For the *Original Delta Approach*, $diff(h)$ is added to the bottom-up system load. For the *Current Delta Approach*, $diff(h)$ is multiplied by the factor TE^{yr}/TE^{2001} (which EIA calls the *load balancing factor*) before added to the bottom-up system load. In fact, both the *Original Delta Approach* and the *Current Delta Approach* squelch the bottom-up sum of the end-use hourly loads. The hourly system load using the *Original Delta Approach* squelches the system load at hour h by a constant amount $diff(h)$ every year while the *Current Delta Approach* squelches the bottom-up sum according to the growth of total annual energy.

III. Impact on Conservation Load Fact with Current Delta Approach

Suppose the only end-use that we are varying in the Standards Case is AC. Let $TE1$ and $TE2$ be the total annual energy, $EU1_{AC}$ and $EU2_{AC}$ be the annual AC energy use for the Base Case and the Standards Case respectively.

Using the *Bottom-up Approach*, the system hourly load for the Base Case and the Standards Case are given by:

$$SysLoad_B_{Base}^{yr}(h) = \sum_e^{all\ e \neq AC} p_e(h) \cdot EU_e^{yr} + p_{AC}(h) \cdot EU1_{AC}^{yr} \dots\dots\dots (6)$$

$$SysLoad_B_{Stds}^{yr}(h) = \sum_e^{all\ e \neq AC} p_e(h) \cdot EU_e^{yr} + p_{AC}(h) \cdot EU2_{AC}^{yr} \dots\dots\dots (6a)$$

Using the *Current Delta Approach*, the system hourly load for the Base Case and the Standards Case are:

$$SysLoad_C_{Base}^{yr}(h) = \sum_e^{all\ e \neq AC} p_e(h) \cdot EU_e^{yr} + p_{AC}(h) \cdot EU1_{AC}^{yr} + \frac{TE1^{yr}}{TE^{2001}} \cdot diff(h) \dots\dots\dots (7)$$

$$SysLoad_C_{Stds}^{yr}(h) = \sum_e^{all\ e \neq AC} p_e(h) \cdot EU_e^{yr} + p_{AC}(h) \cdot EU2_{AC}^{yr} + \frac{TE2^{yr}}{TE^{2001}} \cdot diff(h) \dots\dots\dots (7a)$$

Since the only end-use that we are decrementing in the Standards Case is AC, the total annual system energy saving is the same as the annual energy saving for the end-use AC.

$$TE2^{yr} = TE1^{yr} - D^{yr} \quad \text{and } D^{yr} \text{ is decrement in year } yr$$

$$EU2_{AC}^{yr} = EU1_{AC}^{yr} - D^{yr}$$

The Conservation Load Factor, CLF, is defined as the ratio of the average hourly saving to the peak energy saving.

$$\begin{aligned} CLF &= \frac{(TE1^{yr} - TE2^{yr})}{8760 \times (\text{difference in peak energy})} \\ &= \frac{D^{yr}}{8760 \times (\text{difference in peak energy})} \dots\dots\dots (8) \end{aligned}$$

If the system peak hour, $pkhr$, in the Base Case remains the same in the Standards Case, then from (6) – (6a)

$$\begin{aligned} \text{difference in peak energy(Bottom-up)} &= \text{Sysload}_{Base}^{yr}(pkhr) - \text{Sysload}_{Stds}^{yr}(pkhr) \\ &= p_{AC}(pkhr) \cdot D^{yr} \dots\dots\dots (9) \end{aligned}$$

Again, if this system peak hour, $pkhr$, is the same for the Base Case and the Standards Case using the *Current Delta Approach*, then from (7) – (7a)

$$\begin{aligned} \text{difference in peak energy(Current Delta)} &= \text{Sysload}_{Base}^{yr}(pkhr) - \text{Sysload}_{Stds}^{yr}(pkhr) \\ &= p_{AC}(pkhr) \cdot D^{yr} + \frac{(TE1^{yr} - TE2^{yr})}{TE^{2001}} \cdot \text{diff}(pkhr) \\ &= p_{AC}(pkhr) \cdot D^{yr} + \frac{D^{yr}}{TE^{2001}} \cdot \text{diff}(pkhr) \\ &= \left(p_{AC}(pkhr) + \frac{1}{TE^{2001}} \cdot \text{diff}(pkhr) \right) \cdot D^{yr} \dots (10) \end{aligned}$$

Calculating the CFL using (8),

$$CLF_{Bottom-up} = \frac{D^{yr}}{8760 \times (p_{AC}(pkhr) \cdot D^{yr})} = \frac{1}{8760 \times p_{AC}(pkhr)} \dots\dots\dots (11)$$

$$CLF_{Current Delta} = \frac{1}{8760 \times \left(p_{AC}(pkhr) + \frac{1}{TE^{2001}} \cdot \text{diff}(pkhr) \right)} \dots\dots\dots (12)$$

From equation (11) and (12), the difference between $CLF_{Bottom-up}$ and $CLF_{Current Delta}$ depends on the term $\frac{1}{TE^{2001}} \cdot \text{diff}(pkhr)$. This term is comparatively much smaller than $p_{AC}(pkhr)$ and the effect on the CLF calculated is insignificant.

e.g. For EMM region 9, STV, the system peak hour is at the 17th hour of the June peak day,

$p_{AC}(pkhr)$ is 0.58×10^{-3} and $CLF_{Bottom-up}$ would be 20%. With the *Current Delta Approach*, $\frac{1}{TE^{2001}} \cdot diff(pkhr)$ is -0.000029×10^{-3} and $CLF_{Current Delta}$ is almost identical to $CLF_{Bottom-up}$.

This illustrates that in the case where the peak hour does not change from Base Case to Standards Case, the Current Delta Approach does not significantly impact the CLF calculation. However, in reality, the peak hour does change in the Standards Case. This is due to the non-coincidence of the AC load shape and the system load shape. Furthermore, the peak hours using the *Bottom-up Approach* and the *Current Delta Approach* can be different because of the adjustment made in the latter. It is this non-coincidence of system peak hours that is a major factor affecting the outcome of the CLF calculation.

Appendix B. Code Modifications for Implementing the Double Decrement Approach

Code additions/changes were made to four subroutines, one in the commercial demand module and three in the LDSM module. The subroutine modified in the commercial module is `COMConsumption` and in the LDSM module they are `DSMACM`, `DSMNWS` and `DSMHLM`.

The following shows the steps taken to implement the decrement to the hourly system load.

I. SUBROUTINE `COMConsumption`:

1. Read in annual national energy saving for Commercial A/C – `LBL SavingsCool (yr)`
2. Read in Commercial A/C hourly load shape by NERC region – `CCACfr (i, reg), i=1, 864`
3. Read in fraction of national total by Census region to distribution total saving to Census regions – `rc (CR)`

The above 3 steps are done when `year = 13`

After year 13, the total cooling electricity use for each Census region `CR`, `totC`, is calculated using the following equation.

$$\text{totC} = \sum_{\text{bldg}} \text{EndUseConsump}(1, 2, \text{bldg}, \text{CR}, \text{year})$$

where `EndUseConsump(1, 2, ...)` is the electricity consumption for commercial cooling by building type `bldg`, census region `CR` and `year`.

The energy saving for Census region `CR` is calculated by distributing the national annual energy saving, i.e. `LBL SavingsCool (year) * rc (CR)`

The ratio of the energy saving in `CR` to the total cooling electricity use in `CR`, `drC (CR, year)`, is calculated as follow.

$$\text{drC}(\text{CR}, \text{year}) = \text{LBL SavingsCool}(\text{year}) * \text{rc}(\text{CR}) / \text{totC}$$

Then we assume that the cooling energy for all building types in the Census region `CR` are reduced equally by the same ratio `drC (CR, year)`, i.e. for every building type `bldg`

$$\begin{aligned} \text{EndUseConsump}(1, 2, \text{bldg}, \text{CR}, \text{year}) &= \\ \text{EndUseConsump}(1, 2, \text{bldg}, \text{CR}, \text{year}) * (1 - \text{drC}(\text{CR}, \text{year})) \end{aligned}$$

```

SUBROUTINE COMConsumption
!---LBNL START
!   COOLING AND HEATING SAVINGS FOR COMM CAC - KSHL
!   HEATING SERVICE INDEX=1
!   COOLING SERVICE INDEX=2
IF(Y.EQ.13) THEN
  write(*,*) 'LBNL about to open input file'
  open(unit=1, file='savings.dat', status='unknown')
  write(*,*) 'LBNL successfully opened input file'
  DO i=14,36
    write(*,*) 'LBNL reading year', i
    READ (1,*) TEMP1, LBLsavingsCool(i), LBLsavingsHeat(i)
    WRITE(*,*) TEMP1, LBLsavingsCool(i), LBLsavingsHeat(i)
  END DO
!
!   Read CCACfr(864,13) - load shape for CCAC by NERC region
  open(unit=2, file='ccacldshape', status='unknown')
  DO iNERCReg = 1,13
    I = 0
    DO iMon = 1,12
      READ (2,2001)
      DO iHr = 1,24
        READ (2,*) TEMP1, ccac1(iHr,1), ccac1(iHr,2), ccac1(iHr,3)
      END DO
      DO iDay = 1,3
        DO iHr = 1,24
          I = I + 1
          CCACfr(I,iNERCReg) = ccac1(iHr,iDay)
        END DO
      END DO
    END DO
  END DO
!   Read in rC(census region) - fraction by Census Region to distribute saving
  DO iCReg = 1,MNUMCR
    READ (2,*) TEMP1, rC(iCReg)
  ENDDO
END IF

2001 FORMAT(1X)
close(1)
CLOSE(2)
!
IF(Y.GE.14) THEN
!   Calculate total cooling (totC), summed over Bldg types
!   in each census region (r)
!   rC(r) is % of total decrement attributed to region (r)
!   dr(r,y) is % decrement for cooling in region (r) for year (y)
  DO r=1, MNUMCR-2
    totC = 0.
    DO b=1, CMnumBldg
      totC = totC + EndUseConsump(1,2,b,r,y)
    END DO
    drC(r,y) = LBLsavingsCool(y) * rC(r) / totC
!
    DO b=1, CmnumBldg ! apportion saving to cooling consumption by bldg
      EndUseConsump(1,2,b,r,y) = EndUseConsump(1,2,b,r,y) * (1-drC(r,y))
    END DO
  END DO
END IF
!---END LBNL

```

II. SUBROUTINE DSMACM:

Subroutine DSMACM maps Census region level commercial sector energy use to energy use by NERC region.

We need to calculate the decrement by end use (commercial A/C by building type) by NERC region, to be stored in the variable `LBLdel(LFinum)`. This will be used in the restoring to the Reference Case load shape. The cooling energy by Census region is in the variable `CENSUSvalues(k)` where `k` is the Census region number. Note that `CENSUSvalues(k)` already has the saving decremented.

The saving `tmpSavC(k)` can be calculated by

$$\text{tmpSavC}(k) = \text{CENSUSvalues}(k) / (1 - \text{drC}(k, \text{year})) * \text{drC}(k, \text{year})$$

Then SUBROUTINE DSMMEMV is called and it maps `tmpSavC(k)` from Census region to NERC region, which is then stored in the variable `LBLdel(LFinum)`.

```
SUBROUTINE DSMACM(WHOOPS)
!---LBL Addition 7-28-2003
!   Calculate decrement for Commercial A/C enduses (LBLdel)
!   LBLdel(LFinum) is set to 0, for end uses other than Comm. A/C
!   tmpSavC is enduse saving by Census region
!   Calling tmpSavC with DSMMEMV will map to NERC region
      LBLdel(LFinum) = 0.0
      IF (UBASEYR.GE.14 .AND. j.eq.2) THEN !Service j=2 is Cooling
        DO k=1, nCENSUSreg
          tmpSavC(k) = CENSUSvalues(k) / (1 - drC(k, UBASEYR)) * drC(k, UBASEYR)
        ENDDO
        CALL DSMMEMV(tmpSavC, RNB, SEC(COM), load)
        LBLdel(LFinum) = load * UNCONFA * FORESIGHTadj
      ENDIF
!---END of LBL Addition
```

III. SUBROUTINE DSMNWS:

In subroutine DSMNWS, the calculations to generate the hourly system load is modified to restore it to the Reference case, i.e. before the energy decrement.

```
SUBROUTINE DSMNWS(NUMREC,LFpointer,SECTOR)
!***** Description of the Program/Subprogram
! This subroutine adds up current item's load to the system load
!-----
!      Written by Adam Kreczko, ICF Resources, Inc., phone: (703)-934-3353
!*****
      IMPLICIT NONE
!***** Typing, Declaring and Initializing Constant Parameters ****
      include 'parametr' !<< nems parameter declarations
      include 'dsmdimen' !<< all ldsm parameter declarations
!***** Typing and Declaring Variables
      INTEGER*2 K ! month pointer
      INTEGER*2 L ! day pointer
      INTEGER*2 M ! hour pointer
      INTEGER*2 SECTOR ! sector number or 0 if not to process sectoral loads
      INTEGER*2 LFpointer ! pointer to LoadForec array or 0 if SystemLoad
      INTEGER*2 NUMREC ! number of record ond DAF-LSR-DB with current lsr
      REAL*4 DistLo(MAXHOUR) ! distribution of annual load over hours
      REAL*8 load1 ! temporary variables for annual load forecast orig. appr.
      REAL*8 load2 ! temporary variables for annual load forecast delta appr.
      REAL*8 load92 ! holds load2 before the restoration to Reference
      CHARACTER*8 LSRname ! Current lsr name
      INTEGER*2 I
      Real*4 LBLdelTotal(MNUMYR)
      Real*4 LBLdel(150)
      Real*4 LBLsavingsCool(MNUMYR) ! LBNL
      COMMON /LBLccac/ LBLsavingsCool, LBLDel
      Real*4 SYLOAD9(MAXHOUR)
      COMMON /LBLSYLOAD/ SYLOAD9
      LOGICAL EUorECM ! flag depicting if the item is an eu (T) or ecm (F)
!***** COMMON and EQUIVALENCE
      include 'ncntrl' !<< acces to nems global variables like
      include 'emmparm' !<<
      include 'dsmcaldr' !<< calendar data
      include 'dsmhelm' !<< helm algorythm variables
      include 'dsmsectr' !<< sector secific data and other associated variables
      include 'dsmunits' !<< msg output unit
      include 'dsmtfefp' !<< communication with efp
!***** Initializing Variables
!***** Body of the Program/Subprogram
! Read a record from the Direct Access File
      READ(IODB,REC=NUMREC) LSRname, &
         (DistLo(M),M=1,nhour)
!
!---LBL Additions
!      Modify load2 to be used later to restore to Reference system load
!      load92 is original NEMS load2 before restoration
!      load1=LoadForec(LFpointer,1) + LBLdel(LFpointer)
!      Try leaving sectoral load alone 8/21/2003
!
!      IF(LFpointer.NE.0) THEN ! non System Load
         load1=LoadForec(LFpointer,1)
         load2=LoadForec(LFpointer,2) + (LBLdel(LFpointer) - &
            BaseYrLd(LFpointer,RNB)/BaseYrSysLd(RNB)*LBLdel(LFinum+1))
         load92=LoadForec(LFpointer,2)
```

```

ELSE                                     ! System Load
  load1=0.0
  LBLdel(LFinum+1) = 0.0                !set LFinum+1 to Sum of LBLdel
  DO I = 1,LFinum
    LBLdel(LFinum+1) = LBLdel(LFinum+1) + LBLdel(I)
  ENDDO
  load2=SystemLoad + LBLdel(LFinum+1)
  load92=SystemLoad
  IF (RNB.EQ.1) LBLdelTotal(CURIYR) = 0
  LBLdelTotal(CURIYR) = LBLdelTotal(CURIYR) + LBLdel(LFinum+1)
ENDIF
!
IF(load2.NE.0.0) THEN
  DO M=1,nhour
    SYLOAD(M)=SYLOAD(M)+DistLo(M)*load2
    ! Calculate un-Restored System Load also (for comparison)
    SYLOAD9(M)=SYLOAD9(M)+DistLo(M)*load92
  ENDDO
ENDIF
!---END LBL Addition
!
IF(SECTOR.NE.0) THEN
  TotSecLoad(RNB,SECTOR)=TotSecLoad(RNB,SECTOR)+load1
  IF(K1.EQ.CURIYR) THEN
    DO M=1,nhour
      SectorLoad(M,SECTOR)=SectorLoad(M,SECTOR) &
        +DistLo(M)*load1
    ENDDO
!   write(IMG,*)'LSRNAME   ',LSRname
& !   WRITE(IMG,*)'load1,DistLo(1..10),SectorLoad(1..10)'
!   ,load1,(DistLo(M),M=1,10),(SectorLoad(M,SECTOR),M=1,10),nhour
  ENDF
ENDIF
!***** Termination of the Program/Subprogram
RETURN
END

```

IV. SUBROUTINE DSMHLM:

In subroutine DSMHLM, the restored hourly System Load is again decremented based on the Commercial A/C load shape and the NERC regional energy savings.

```

      SUBROUTINE DSMHLM
!***** Description of the Program/Subprogram
! This subroutine runs the HELM algorithym subroutines
!-----
!       Written by Adam Kreczko, ICF Resources, Inc., phone: (703)-934-3353
!*****
      IMPLICIT NONE
!***** Typing, Declaring and Initializing Constant Parameters
      INTEGER*2 ZERO,ONE
      PARAMETER(ZERO=0,ONE=1)
      include 'parametr' !<< nems parameter declarations
      include 'dsmdimen' !<< all ldsm parameter declarations
      include 'emmparm' !<<
      include 'control'
!***** Typing and Declaring Variables
      INTEGER*2 I,J,K,L,M,N ! multi-purpose pointers
      REAL*4 td ! t&dloss expansion factor
!
      REAL*4 SystLo !system load
      REAL*4 SystLo,systlo2 !system load
      integer srec ! rec num for DAF file for system loads
      real*8 osyload(maxhour),dsyload(maxhour)
      REAL*4 SYLOAD1(MAXHOUR) !matrix with system load sorted in descending ord.
      INTEGER*2 Hindex(MAXHOUR) ! indexes of hours

!-- LBL 08/18/03
      Real*4   LBLdel(150)
      Real*4   LBLsavingsCool(MNUMYR) ! LBNL
      Real*4   SYLOAD9(MAXHOUR)
      Real*4   CCACfr(864,15)
      COMMON /LBLccac/ LBLsavingsCool, LBLdel
      COMMON /LBLccac2/ CCACfr
      COMMON /LBLSYLOAD/ SYLOAD9
      INTEGER iMon, iHr, iPk, nPk, nI, i1
      INTEGER Hr1(MAXHOUR)
      REAL*4 dLoad, totLoad, pkLoad, SumPkLoad
!-- END LBL 08/18/03
!***** COMMON and EQUIVALENCE
      include 'ncntrl' !<< acces to nems global variables like
      include 'dsmunits' !<< include file with unit number for ldsm message file
      include 'dsmsectr' !<< sector secific data and other associated variables
      include 'dsmhelm' !<< helm algorithym variables
      include 'dsmnemsc' !<< results of ldsm to be passed to the rest of nems
      include 'dsmtfecp' !<< communication with ecp
      include 'dsmttoefd' !<< communication with efd
      include 'dsmtfefp' !<< communitcation with efp
      include 'dsmnercr' !<< nerc region data
      include 'dsmcaldr' !<< calendar data
      include 'dispett'
!***** Initializing Variables
      IF (K1.EQ.CURIYR) THEN
        DO I=1,MAXHOUR
          DO K=1,MAXSEC
            SectorLoad(I,K)=0.0
          ENDDO
        ENDDO
      ENDIF

```

```

        ENDDO
    ENDDIF
    DO K=1,MAXSEC
        TotSecLoad(RNB,K)=0.0
    ENDDO
    DO I=1,MAXHOUR
        SYLOAD(I)=0.0
        SYLOAD9(i) = 0.0
    ENDDO
!***** Body of the Program/Subprogram *****
!*** Calculate base system load
    IF (SystemLoad.GT.0.0) THEN
        CALL DSMNWS(NERClsrN(RNB),ZERO,ZERO)
    ELSE
        WRITE(IMG,*) '<)) Warning from subroutine DSMHLM'
        WRITE(IMG,*) ' System load for region: ',NERCnam(RNB), &
            ' year:',K1,' <= 0.0'
    ENDDIF
!
! write out 864 array here = syload()
! syload is 1990 864 curve with current yr energy
!
! write out syload here for projected yr 864 syload
! compare to syload below with changes for end-use consumption
! calculate delta 864 curve and write out
!
    if (USW_POL .GE. 2) then
        do j=1,864
            osyload(j) = syload(j)
        enddo
    endif
!
!*** Now modify base system load according to changes in system structure
    K=0 ! pointer on the list of end-uses
    SystLo=0.0
    DO I=1,NumSec ! do for each sector
        DO J=1,NEUSES(I) ! do for each end-use in a sector
            K=K+1
!            write(IMG,*) 'NumSec',I,'NEUSE',J
            CALL DSMNWS(EUrecNUM(K,RNB),K,I)
        ENDDO
        SystLo=SystLo+TotSecLoad(RNB,I)
    ENDDO
!
!---LBL 09/30/03
    totLoad = 0.
    DO iHr = 1,864
        totLoad = totLoad + SYLOAD9(iHr)*HourlyWeights(iHr)
    ENDDO
    WRITE (93,9300) CURIYR, CURITR, RNB, totLoad
9300 FORMAT (' BEFOR RESTORING TO REF - CURIYR,CURITR,RNB,totLoad',3i5,F12.3)
    totLoad = 0.
    DO iHr = 1,864
        totLoad = totLoad + SYLOAD(iHr)*HourlyWeights(iHr)
    ENDDO
    WRITE (93,9301) CURIYR, CURITR, RNB, totLoad
9301 FORMAT (' AFTER RESTORING TO REF - CURIYR,CURITR,RNB,totLoad',3i5,F12.3)

    dLoad = LBLdel(LFinum+1)
! dLoad is total decrement (sum of ccac enduses) for the region RNB
! CCACfr is ccac load shape (same used for ccac decrement)
    DO iHr = 1,864

```



```

        SYLOAD(iHr) = SYLOAD(iHr) - dLoad*CCACfr(iHr,RNB)
    ENDDO
!
    totLoad = 0.
    DO iHr = 1,864
        totLoad = totLoad + SYLOAD(iHr)*HourlyWeights(iHr)
!
    EZG 8/03 code to print out new shapes LBL
    IF ((CURIYR.GE.11).AND.(CURITR.GE.3).AND.(K1.le.CURIYR)) THEN
        write (CURIYR+189,*) CURIYR,CURITR,rnb,iHr, SYLOAD(iHr)
    ENDIF
    ENDDO
    WRITE (93,9302) CURIYR, CURITR, RNB, totLoad
9302 FORMAT (' AFTER DECREMENT TO REF - CURIYR,CURITR,RNB,totLoad',3i5,F12.3)
!---END LBL 09/30/03
!
    if (curiyr .eq. 3 .and. RNB .eq. 1) then
        write(IMG,*) ' Ffirst 50 system load '
        WRITE(IMG,'(8H SYLOAD=/8F10.3)') (SYLOAD(I),I=1,50)
    endif
! Expand load by t&d loss factor
! and find system peak, total system load,system load factor
!
    stop
    td=1.0+NERCtdloss(RNB)*ULOSSADJ(CURIYR)
    systlo2=systlo
    SystLo=SystLo*td
!
! calculate delta syload for 864 array
! delta 864 = syload(new end use/yr,rgn) - syload(projected/yr rgn)
    if (USW_POL .GE. 2) then
        do j=1,864
            dsyload(j) = syload(j) - osyload(j)
        enddo
    endif
!
    DO I=1,nhour
        SYLOAD(I)=SYLOAD(I)*td
        SYLOAD1(I)=SYLOAD(I)
        Hindex(I)=I
    ENDDO
    CALL DSMQSR(SYLOAD1,Hindex,ONE,nhour,MAXHOUR)
    SystemPeak(K1)=SYLOAD1(1)
!
    write(msg,*) 'SYLOAD1(1..10)',(SYLOAD1(I),I=1,10)
!
    write(msg,*) 'K1, SystemPeak(K1)',K1, SystemPeak(K1)
    SystemPeakHour(K1)=Hindex(1)
    TotSystemLoad(K1)=SystLo
    J=0
    DO I=1,nhour
        DO K=1,HourlyWeights(Hindex(I))
            J=J+1
            IF(J.GT.NpeakH) GOTO 300
            SysPeakHour(J)=Hindex(I)
        ENDDO
    ENDDO
300 CONTINUE
!***** Termination of the Program/Subprogram
    RETURN
    END

```

Appendix C. Comparison Plots of Space Cooling and Ventilation Load Shapes in NEMS with Simulations

Source: Intermediary output from AEO2003 version of NEMS and simulated load shapes developed by Berkeley Lab

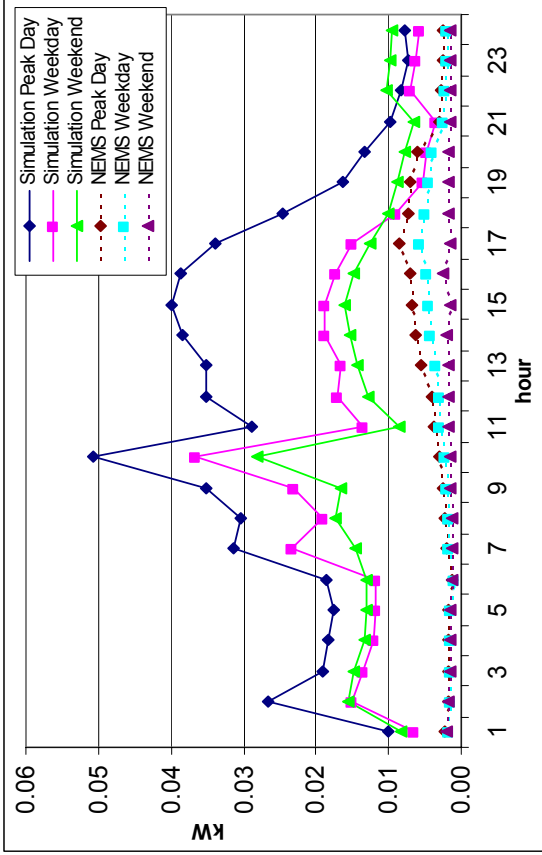


Figure 3. January Space Cooling Load Shape for EMM Region 1 (ECAR)

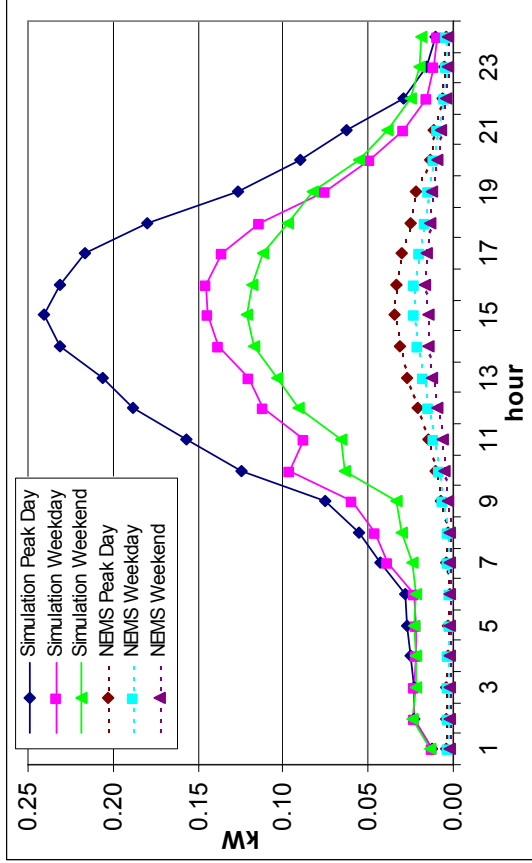


Figure 4. April Space Cooling Load Shape for EMM Region 1 (ECAR)

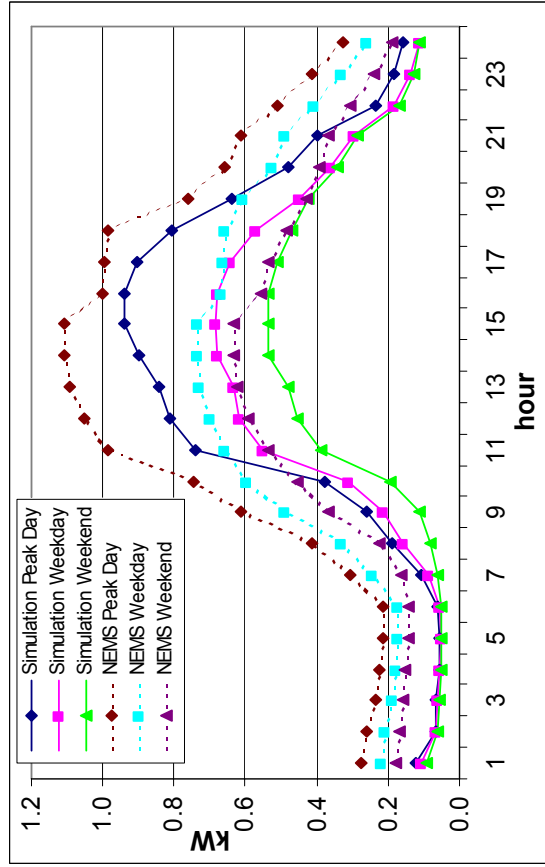


Figure 5. July Space Cooling Load Shape for EMM Region 1 (ECAR)

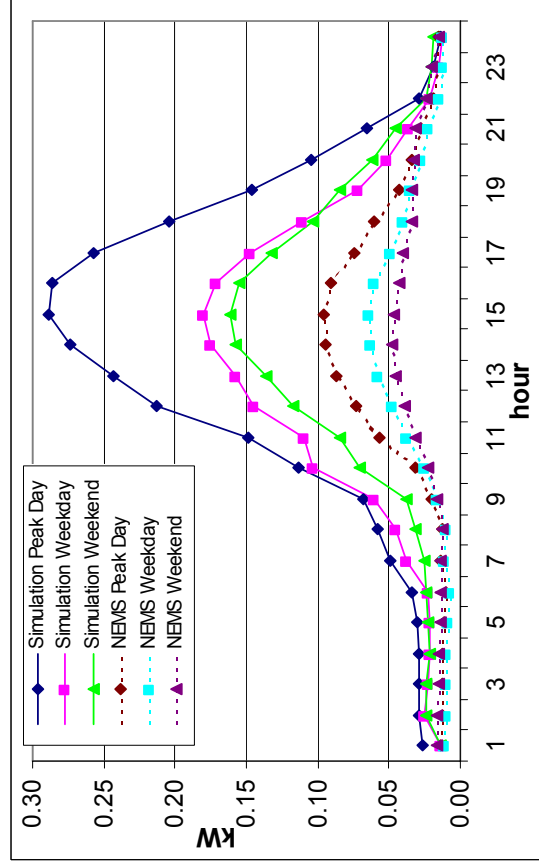


Figure 6. October Space Cooling Load Shape for EMM Region 1 (ECAR)

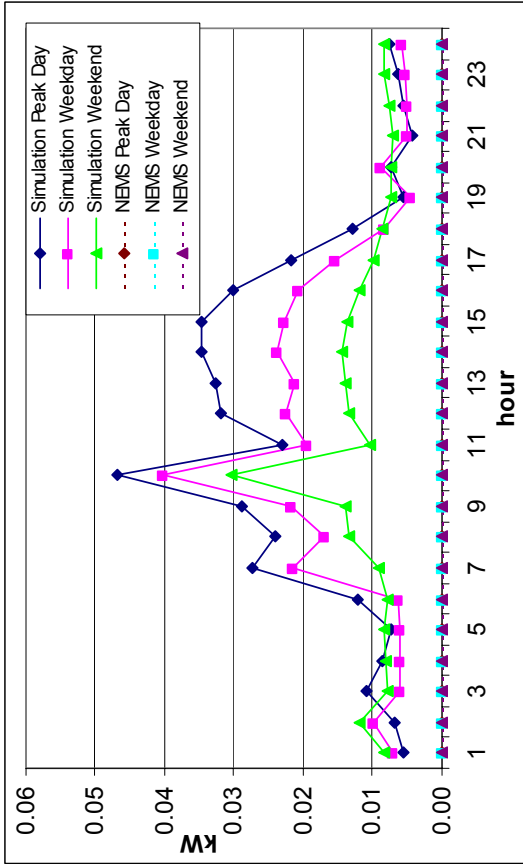


Figure 7. January Space Cooling Load Shape for EMM Region 7 (NE)

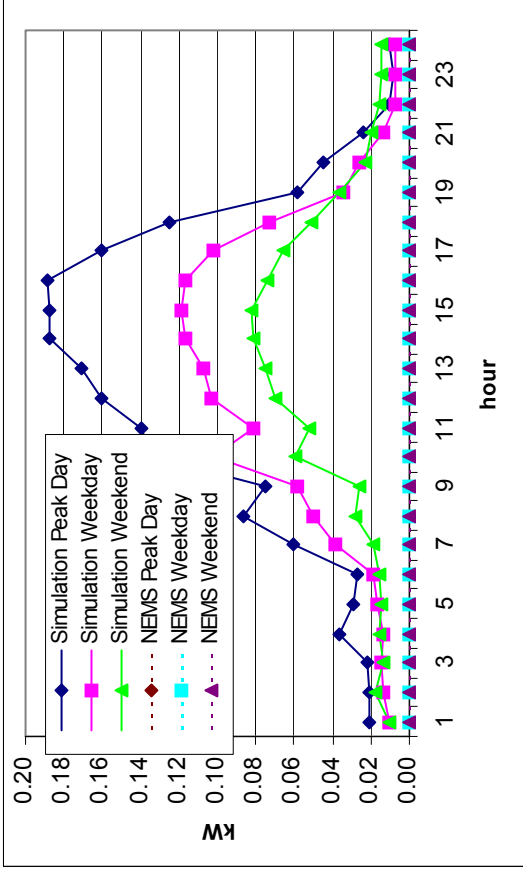


Figure 8. April Space Cooling Load Shape for EMM Region 7 (NE)

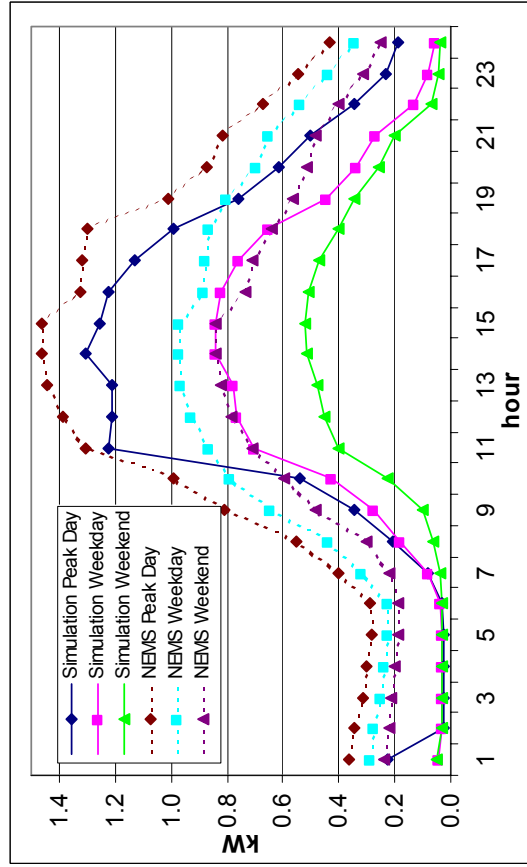


Figure 9. July Space Cooling Load Shape for EMM Region 7 (NE)

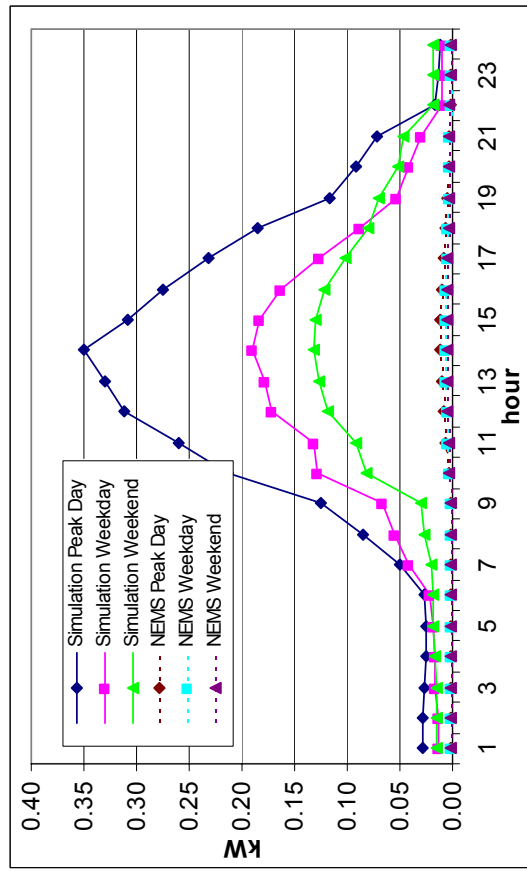


Figure 10. October Space Cooling Load Shape for EMM Region 7 (NE)

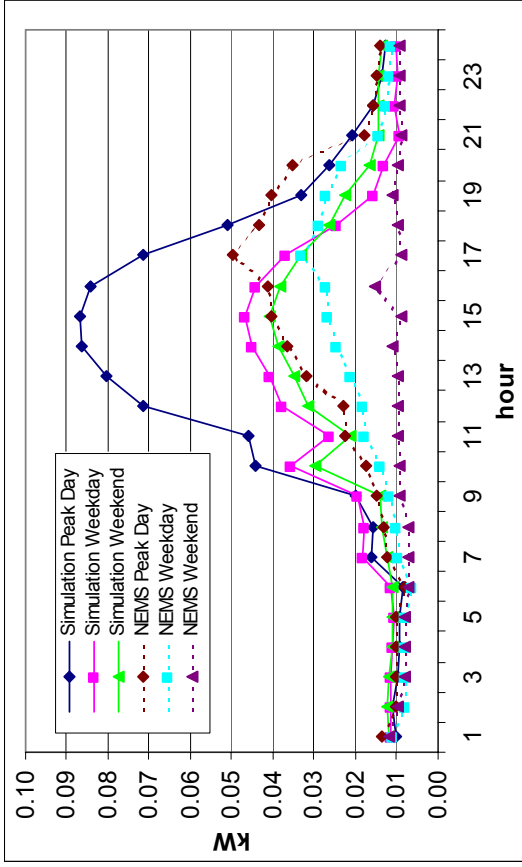


Figure 11. January Space Cooling Load Shape for EMM Region 9 (STV)

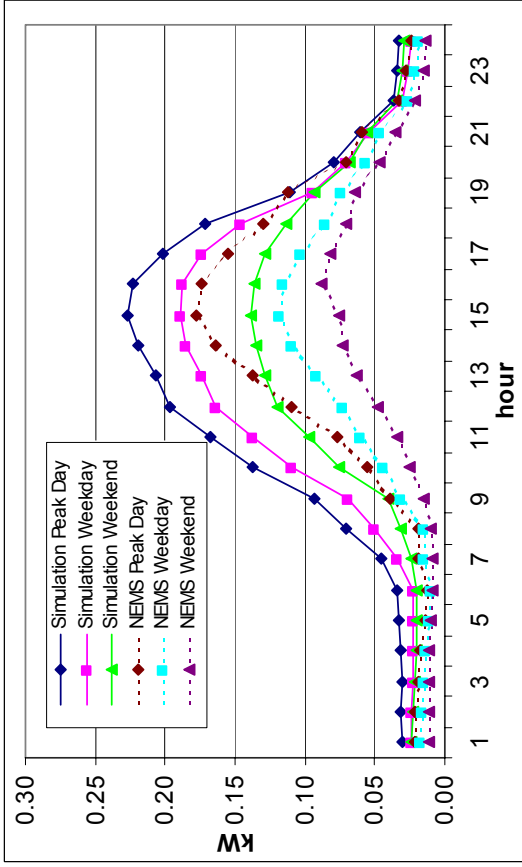


Figure 12. April Space Cooling Load Shape for EMM Region 9 (STV)

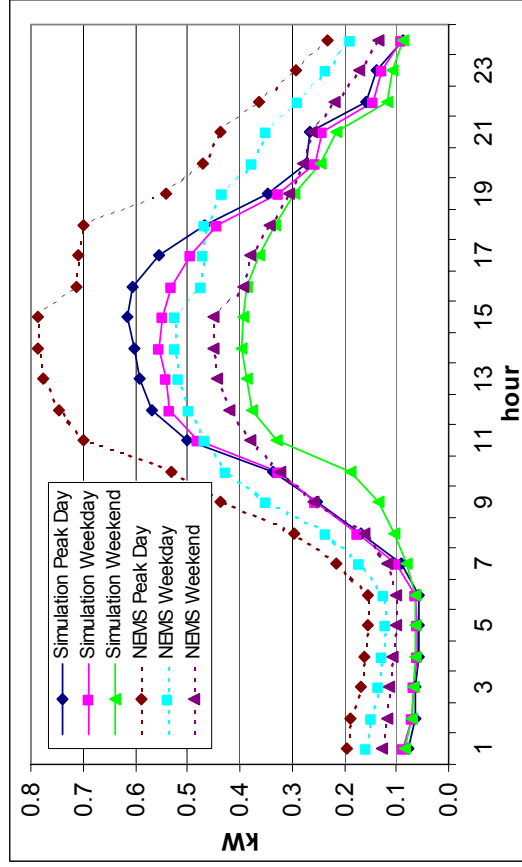


Figure 13. July Space Cooling Load Shape for EMM Region 9 (STV)

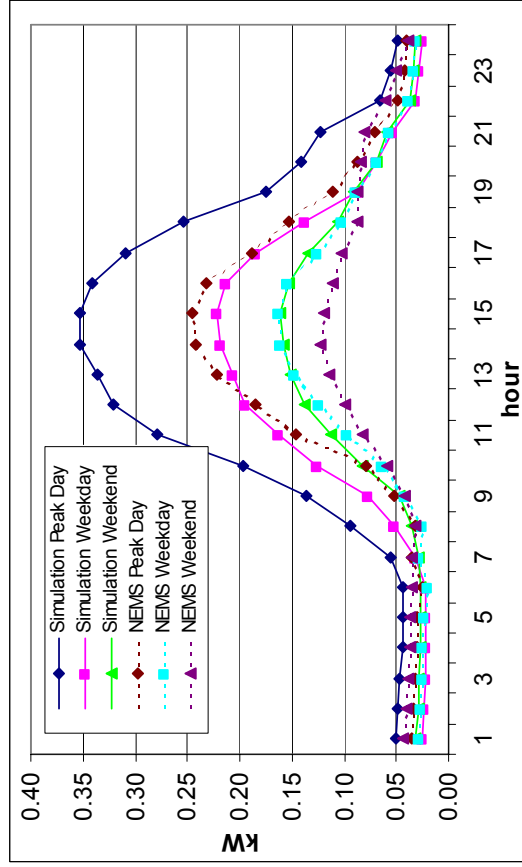


Figure 14. October Space Cooling Load Shape for EMM Region 9 (STV)

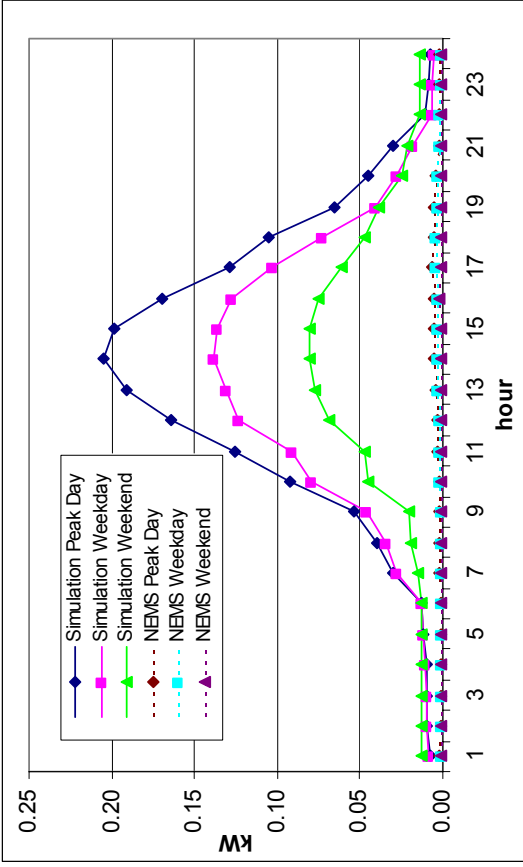


Figure 15. January Space Cooling Load Shape for EMM Region 13 (CNV)

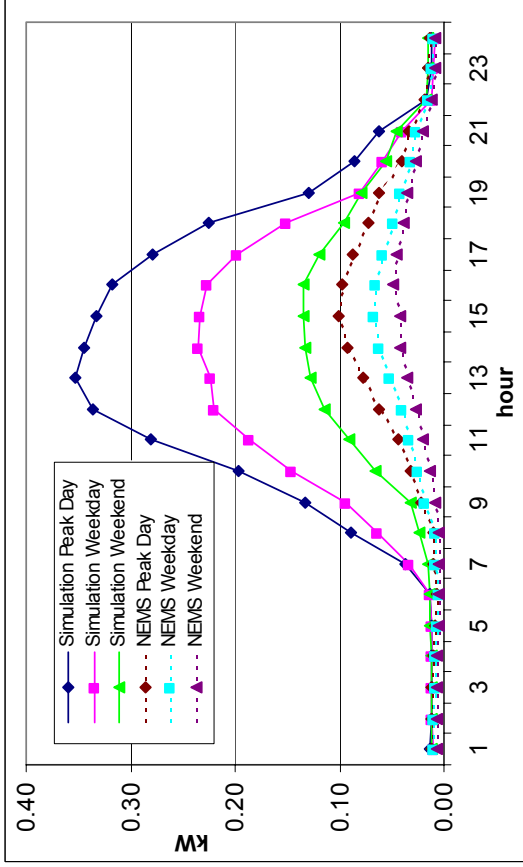


Figure 16. April Space Cooling Load Shape for EMM Region 13 (CNV)

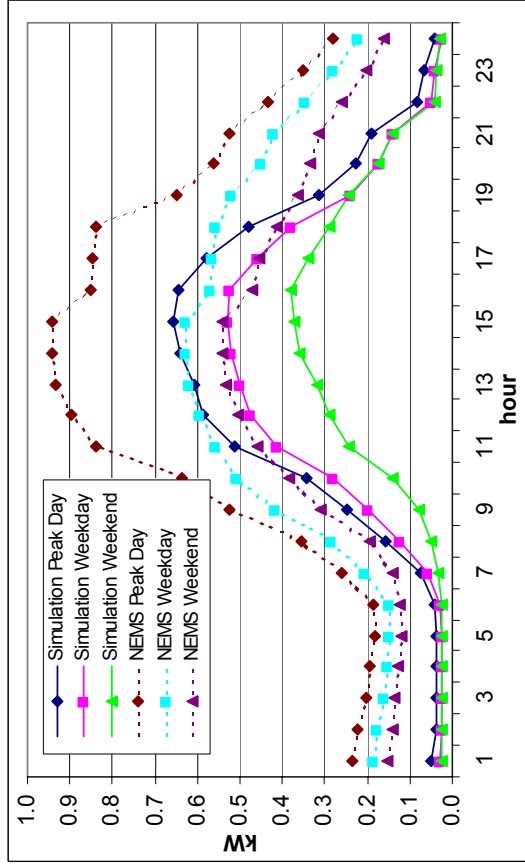


Figure 17. July Space Cooling Load Shape for EMM Region 13 (CNV)

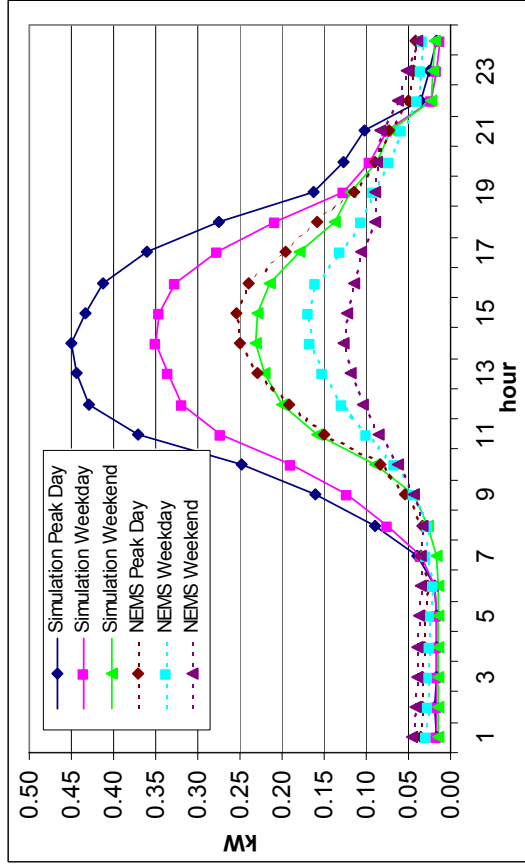


Figure 18. October Space Cooling Load Shape for EMM Region 13 (CNV)

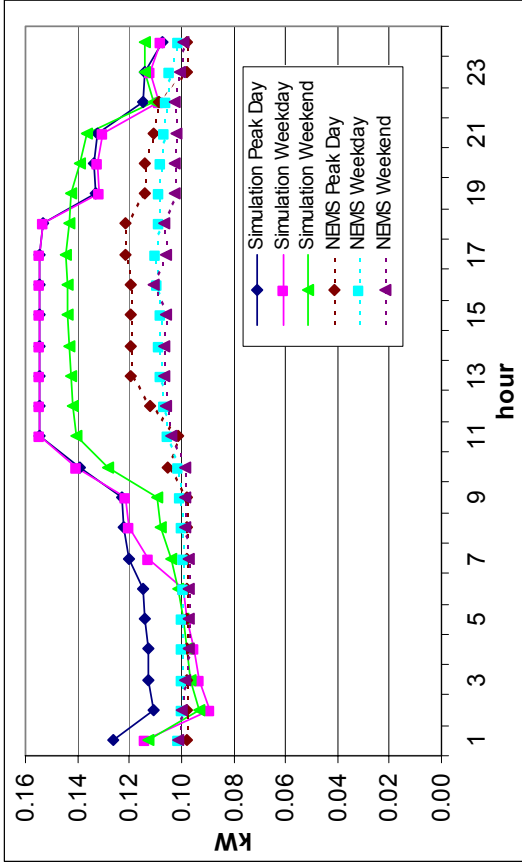


Figure 19. January Ventilation Load Shape for EMM Region 1 (ECAR)

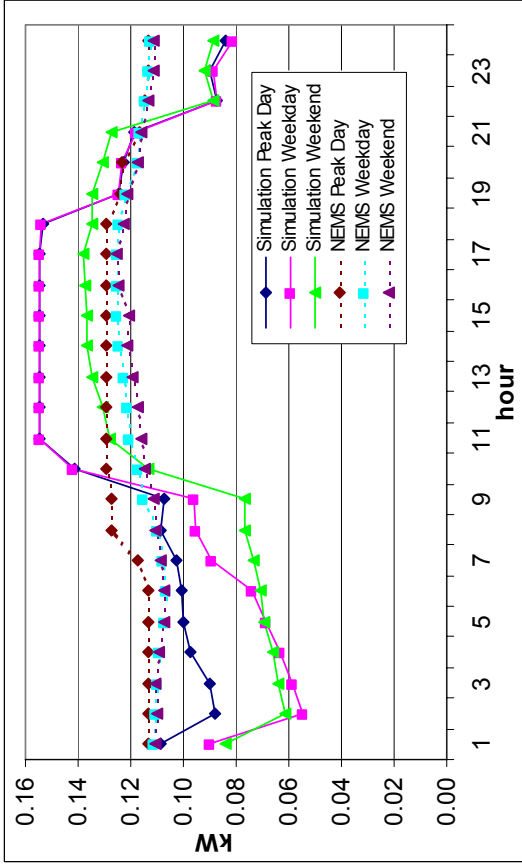


Figure 20. April Ventilation Load Shape for EMM Region 1 (ECAR)

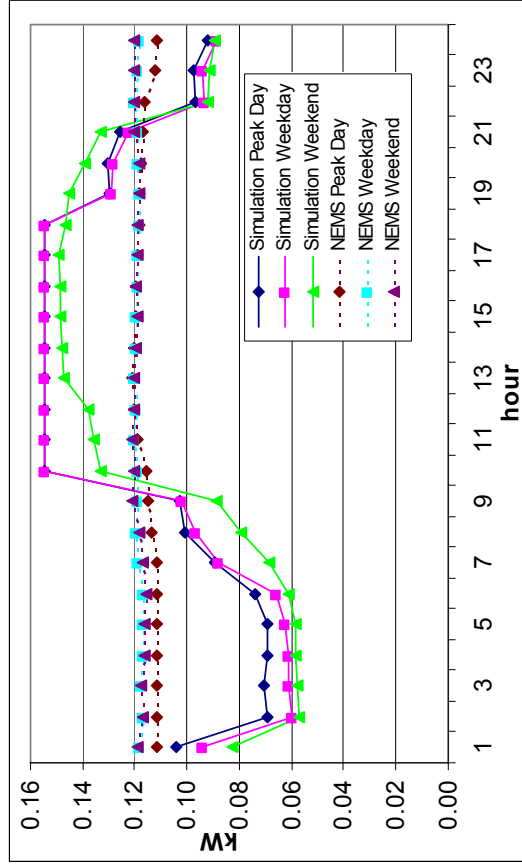


Figure 21. July Ventilation Load Shape for EMM Region 1 (ECAR)

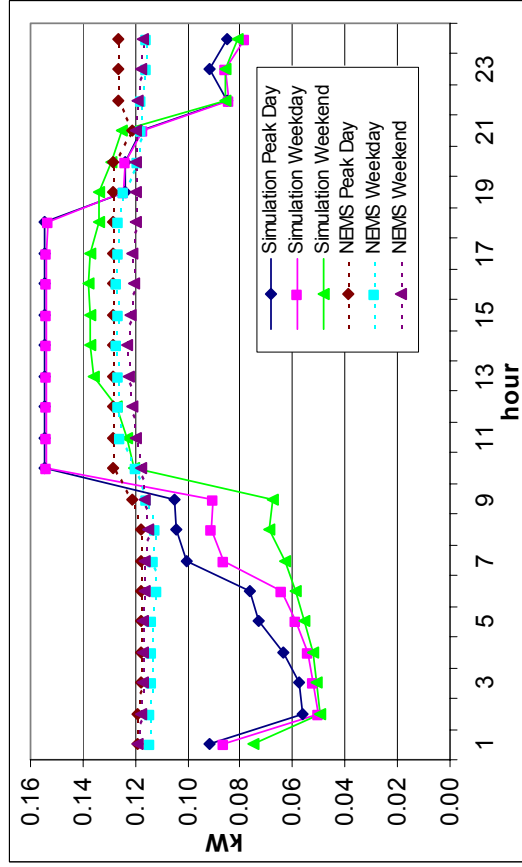


Figure 22. October Ventilation Load Shape for EMM Region 1 (ECAR)

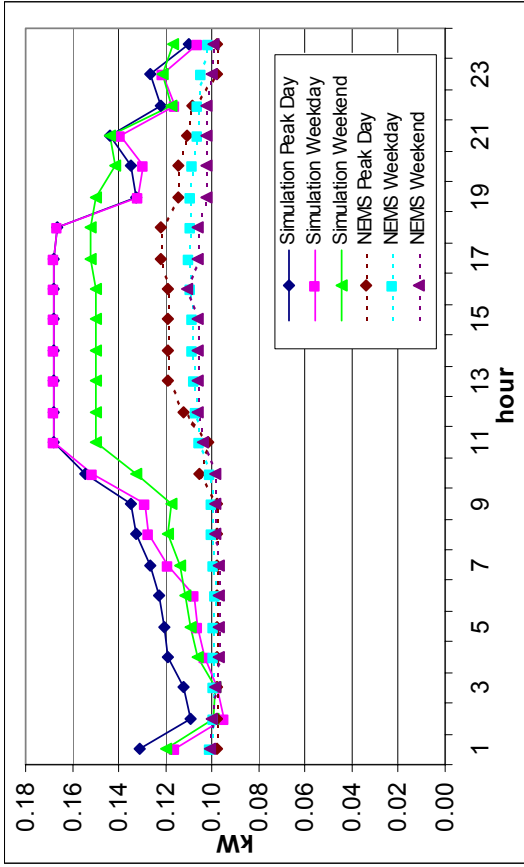


Figure 23. January Ventilation Load Shape for EMM Region 7 (NE)

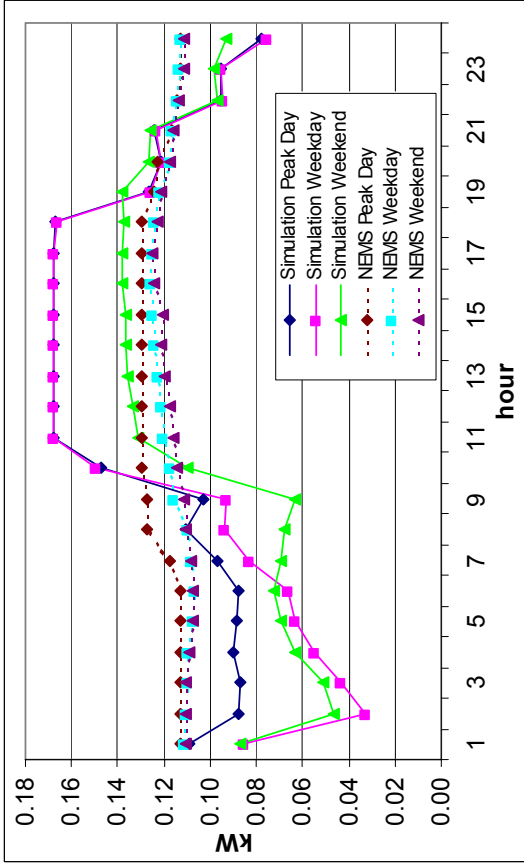


Figure 24. April Ventilation Load Shape for EMM Region 7 (NE)

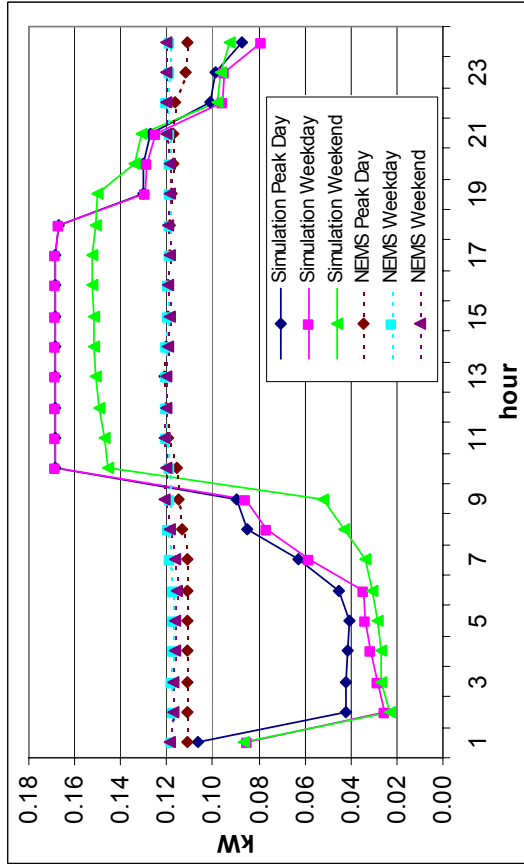


Figure 25. July Ventilation Load Shape for EMM Region 7 (NE)

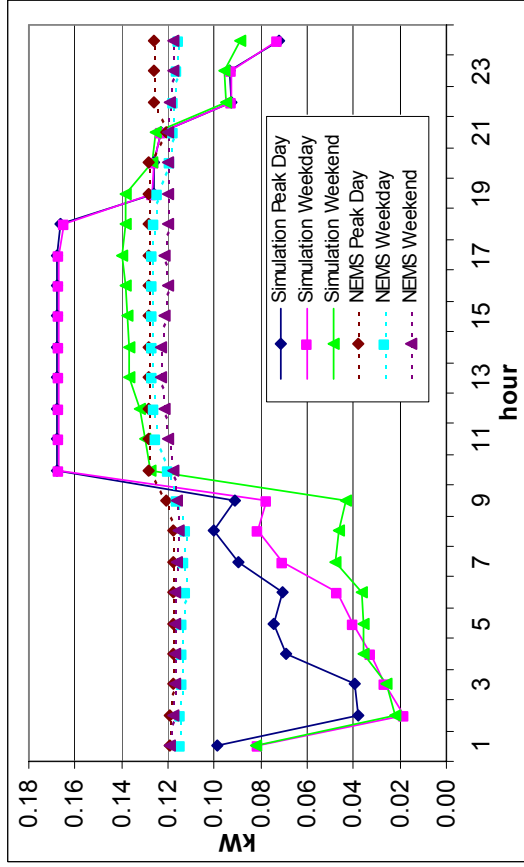


Figure 26. October Ventilation Load Shape for EMM Region 7 (NE)

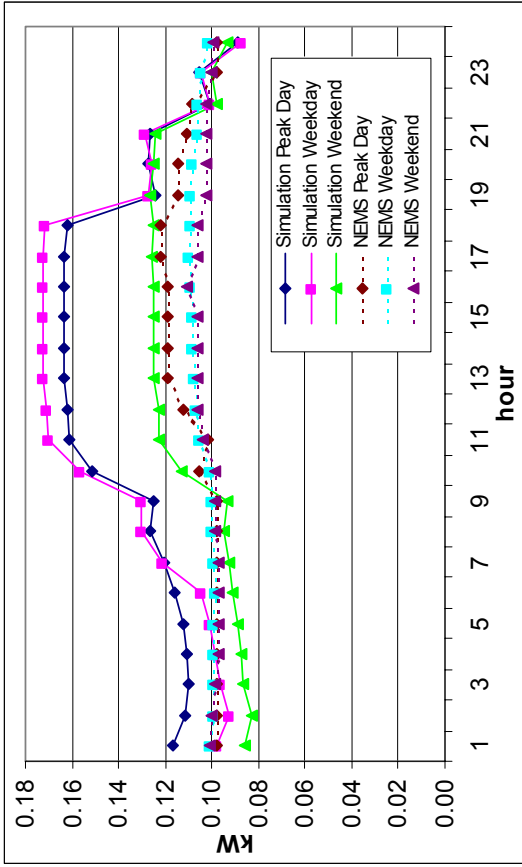


Figure 27. January Ventilation Load Shape for EMM Region 9 (STV)

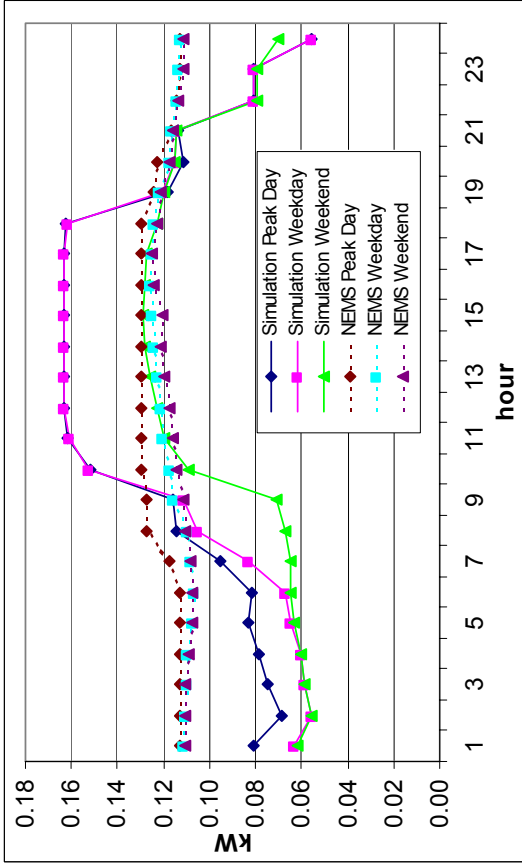


Figure 28. April Ventilation Load Shape for EMM Region 9 (STV)

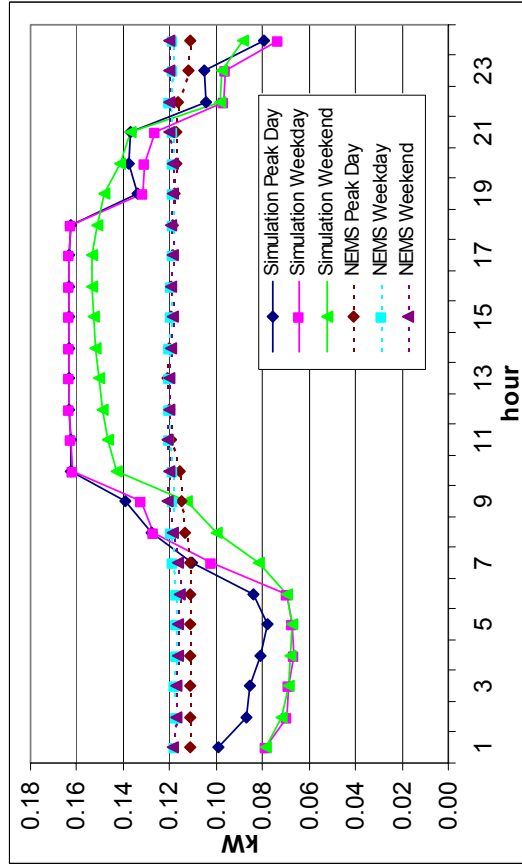


Figure 29. July Ventilation Load Shape for EMM Region 9 (STV)

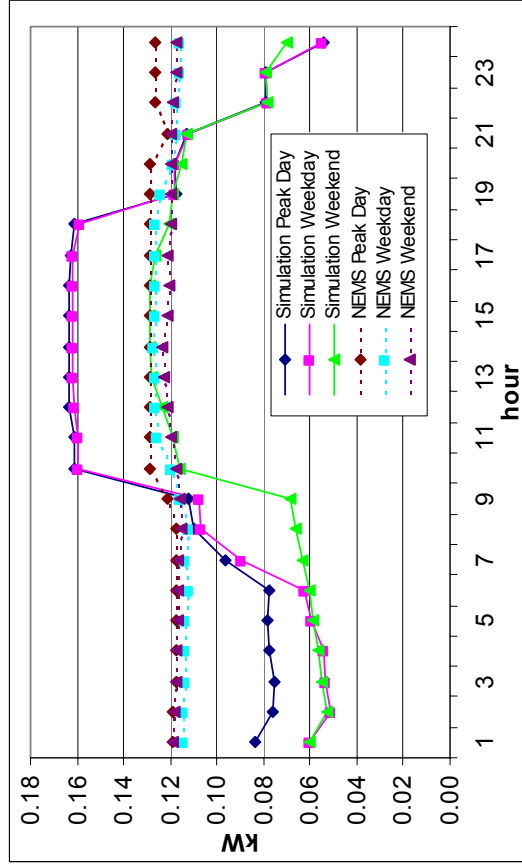


Figure 30. October Ventilation Load Shape for EMM Region 9 (STV)

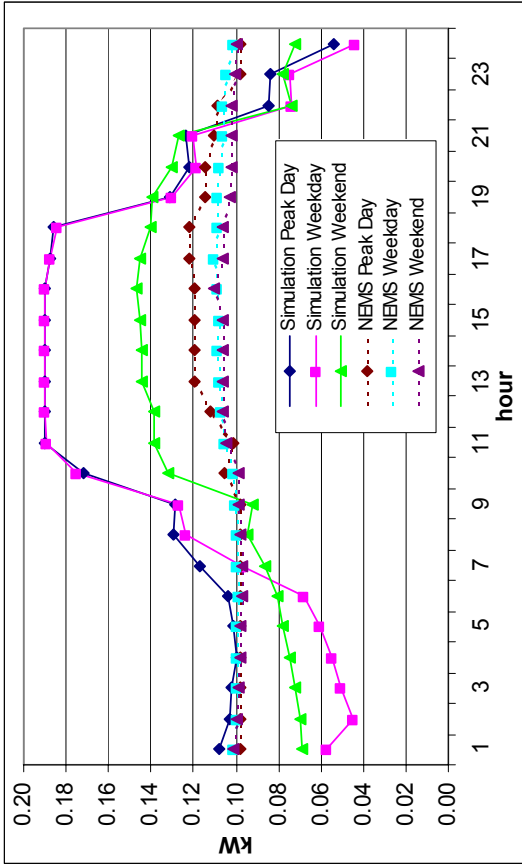


Figure 31. January Ventilation Load Shape for EMM Region 13 (CNV)

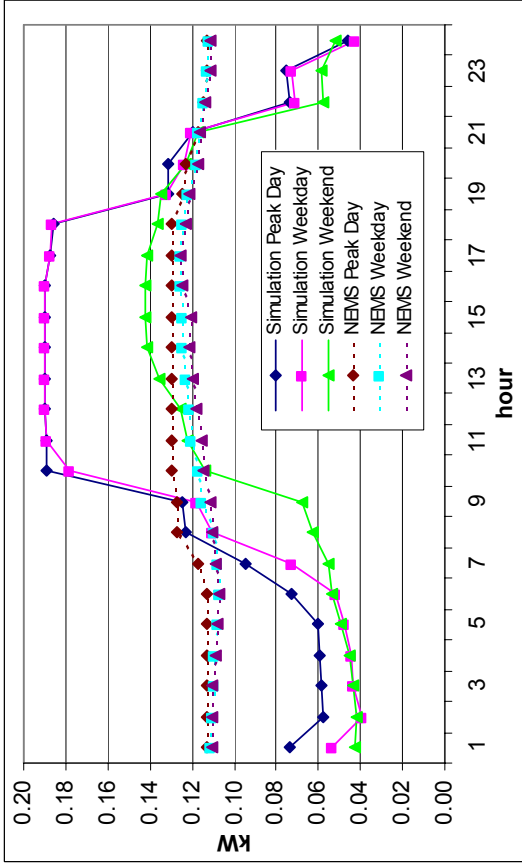


Figure 32. April Ventilation Load Shape for EMM Region 13 (CNV)

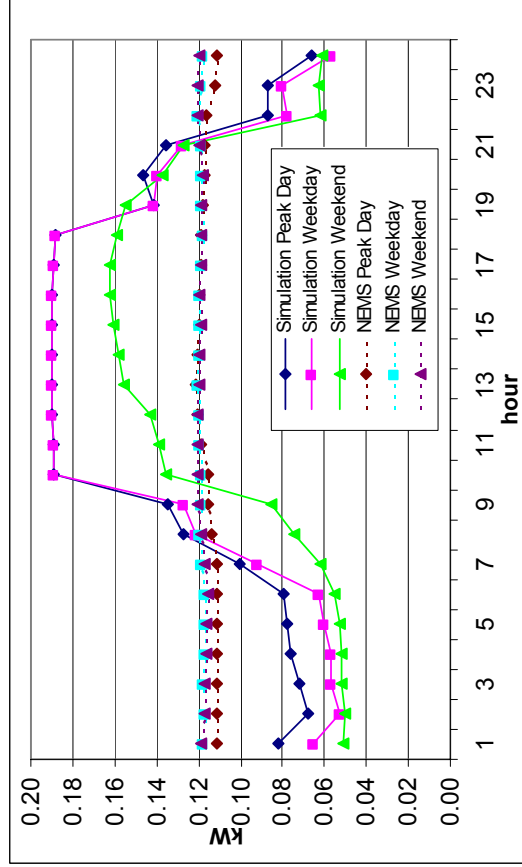


Figure 33. July Ventilation Load Shape for EMM Region 13 (CNV)

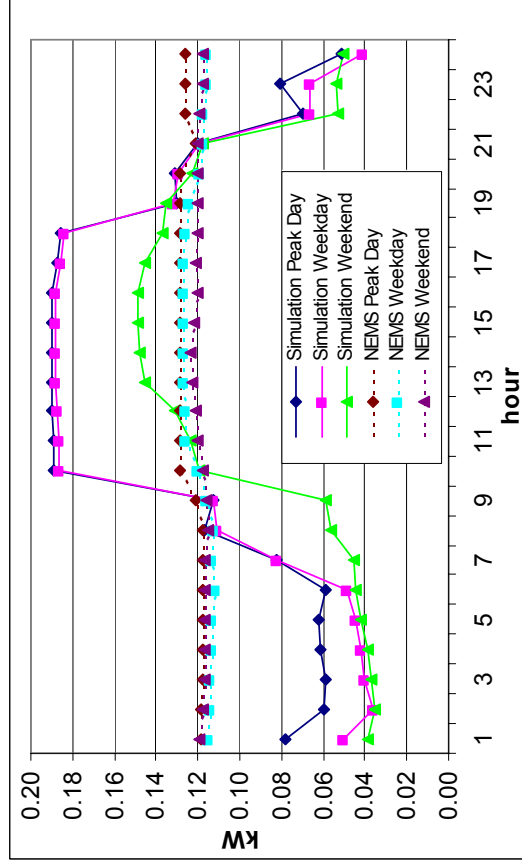


Figure 34. October Ventilation Load Shape for EMM Region 13 (CNV)

Appendix D. Derivation of Code Changes to Restore Decrement System Hourly Loads

To construct the system load using a bottom-up approach, the system load at a particular hour h is given by:

$$SysLoad^{yr}(h) = \sum_e^{all\ e} p_e(h) \cdot EU_e^{yr}$$

where EU_e^{yr} is the annual energy use of end use e in year yr .

$p_e(h)$ is the fraction of the annual energy use at hour h for end use e .

The total annual energy use for each year yr , $TE^{yr} = \sum_e^{all\ e} EU_e^{yr}$

The method (the squelch approach) used in the NEMS model to calculate the system load at a particular hour h is given by:

$$SysLoad^{yr}(h) = p_s(h) \cdot TE^{yr} + \sum_e^{all\ e} p_e(h) \cdot \left(EU_e^{yr} - \frac{TE^{yr}}{TE^{2001}} \cdot EU_e^{2001} \right) \dots\dots\dots (1)$$

where $p_s(h)$ is the fraction of the total annual system energy use at hour h , and year 2001 is the base year.

Let $SysLoad1^{yr}(h)$ and $SysLoad2^{yr}(h)$ represent the system loads at hour h for the Base Case and the Standards Case respectively.

$$SysLoad1^{yr}(h) = p_s(h) \cdot TE1^{yr} + \sum_e^{all\ e} p_e(h) \cdot \left(EU1_e^{yr} - \frac{TE1^{yr}}{TE^{2001}} \cdot EU_e^{2001} \right)$$

$$SysLoad2^{yr}(h) = p_s(h) \cdot TE2^{yr} + \sum_e^{all\ e} p_e(h) \cdot \left(EU2_e^{yr} - \frac{TE2^{yr}}{TE^{2001}} \cdot EU_e^{2001} \right)$$

where $TE1^{yr} - TE2^{yr} = D^{yr}$

$$EU1_e^{yr} - EU2_e^{yr} = d_e^{yr}$$

note: $d_e^{yr} = 0$ for non commercial A/C end uses and $\sum_e d_e^{yr} = D^{yr}$

Then

$$\begin{aligned}
& SysLoad1^{yr}(h) - SysLoad2^{yr}(h) \\
&= p_s(h) \cdot (TE1^{yr} - TE2^{yr}) + \sum_e^{all\ e} p_e(h) \cdot \left(EU1_e^{yr} - \frac{TE1^{yr}}{TE^{2001}} \cdot EU_e^{2001} - EU2_e^{yr} + \frac{TE2^{yr}}{TE^{2001}} \cdot EU_e^{2001} \right) \\
&= p_s(h) \cdot D^{yr} + \sum_e^{all\ e} p_e(h) \cdot \left(EU1_e^{yr} - EU2_e^{yr} - \left(\frac{TE1^{yr}}{TE^{2000}} \cdot EU_e^{2001} - \frac{TE2^{yr}}{TE^{2000}} \cdot EU_e^{2001} \right) \right) \\
&= p_s(h) \cdot D^{yr} + \sum_e^{all\ e} p_e(h) \cdot \left(d_e^{yr} - \frac{EU_e^{2001}}{TE^{2001}} \cdot (TE1^{yr} - TE2^{yr}) \right) \\
&= p_s(h) \cdot D^{yr} + \sum_e^{all\ e} p_e(h) \cdot \left(d_e^{yr} - \frac{EU_e^{2001}}{TE^{2001}} \cdot D^{yr} \right)
\end{aligned}$$

So, to restore the decremented system load $SysLoad2^{yr}(h)$ to the Reference case system load $SysLoad1^{yr}(h)$, D^{yr} is added to the term Load1, and $\left(d_e^{yr} - \frac{EU_e^{2001}}{TE^{2001}} \cdot D^{yr} \right)$ is added to Load2 in equation (1).

Appendix E. Code Modifications for Outputting the Hourly System Load

In order to output the hourly system load from a NEMS-BT run, code was added at line 6,277 of the *uldsm.f* source code. The code modification is shown below and is positioned within other programmatic loops such that all EMM regions are written to an intermediate output file.

```
DO i=1,nhour
  IF ((CURIYR.GE.11).AND.(CURITR.GE.3).AND(K1.EQ.CURIYR)) THEN
    WRITE((CURIYR+189,*) CURIYR, CURITR, RNB, I, SYLOAD(i)
  ENDIF
ENDDO
```

where the NEMS variables are:

i = counter for the number of hours represented in one year
nhour = number of hours to represent the year (864 hours)
CURIYR = current forecast year (when *curiyr* is 1 it is 1990)
CURITR = iteration number, each year iterates from 3 to 7 times until convergence is met
K1 = look-ahead variable, set to current year or up to 6 years ahead
RNB = EMM region number (1-13)
SYLOAD(i) = regional system load demand at hour *i*

The additional lines of code above make analyzing the hourly system load shape very easy for any given run, not just for analysis of a proposed CUAC standard. The code prints out the hourly system load, hour number (1-864), EMM region, iteration, and forecast year. This information is output to a file named *fort.2XX*, where *XX* ranges from 00 for year 2000 to 25 for year 2025. The intermediate output file is written out when the look-ahead variable is set to the current year (or not looking ahead), the iteration number is three or greater, and the year is 2000 or beyond.

Each month in NEMS is characterized by three different day types – peak day, weekday, or weekend day. The peak day is represented as one day of the month that corresponds to the day with the highest load for the month. Every other day is either a weekday or weekend day where all weekend days and weekdays in a given month are characterized by the same load profile. The 864 hours that represent the entire year in NEMS comes from 24 hours per day times three day types per month times 12 months per year.

The last 11,232 lines of the *fort.2XX* represents the final iteration for a given year, where 11,232 is the product of the 13 EMM regions times 864 hours in the year. The hourly system loads are then evaluated in Excel. The spreadsheet analyzes the variation between regional peak hours, measures the hourly effect of the decrement, compares the change in load shapes across regions, and computes what we call the Regional CLF_{out} by EMM region.

Appendix F. The Innocence of the Squelch: Understanding the Difference Between the Years 2001 and 2003 “No Squelched” Results

As noted in this report, our analysis revealed that the removal of a *squelching* factor in the 2003 version of NEMS resulted in little to no change to the peak impacts, which is different from what we saw in our previous report using the 2001 version of NEMS. This appendix helps explain why the two versions of NEMS produce such different results.

In order to keep the forecasted system load in line with historical trends, NEMS adjusts the sum of end use loads in each forecast year based on the difference between the sum of end use loads in the base year and the historical system load. The original Delta approach uses that difference directly for adjustment while the current Delta approach scales that difference by a scaling factor before adjusting the bottom-up sum.

It is important to point out one very important assumption made in the previous analysis. This original work used the 2001 version of NEMS, which incorporated a different set of end use load shapes than is used in the 2003 version of the model. A number of residential, commercial and industrial load shapes were updated for the 2002 version of NEMS, which accounts for a significant portion of the difference we saw in the results. Essentially, by using the updated end use load shapes, the bottom-up sum of the end use loads in the base year is now much closer to the historical system load. Figures F-1a and F-1b respectively show the difference in the base year between the bottom-up sums and the historical system load (in GW) for NERC region 9 using the AEO2001 and the AEO2003 end use load shapes. In Figure F-1b, the differences between the monthly peaks of the bottom up sums and the historical monthly peaks are much smaller than those in Figure F-1a.

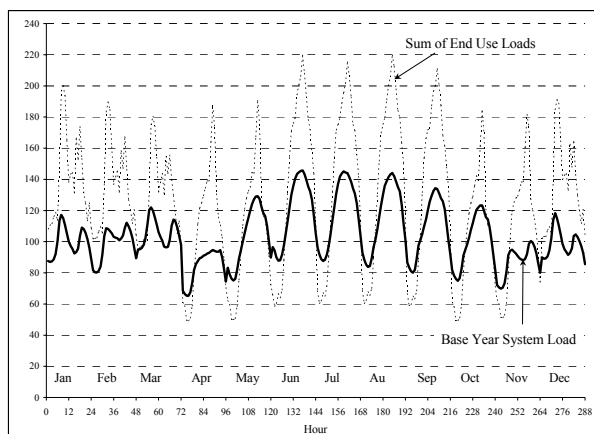


Fig F-1a. Sum of End Use Loads in the Base Year versus Historical System Load – NERC region 9 AEO2003 with AEO2001 Load Shapes

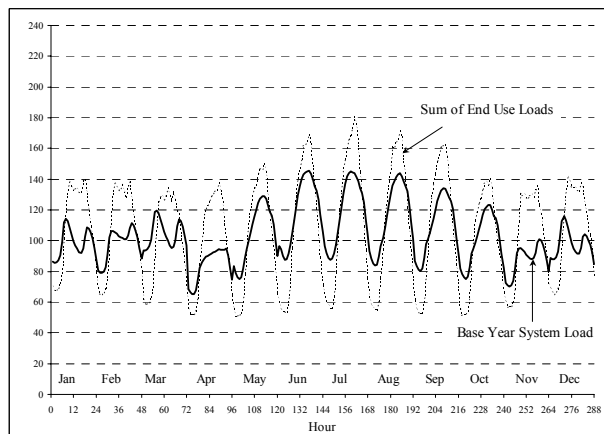


Fig F-1b. Sum of End Use Loads in the Base Year versus Historical System Load – NERC region 9 AEO2003 with current Load Shapes

When the adjustments based on those differences are smaller using the new set of load shapes, the effect of the scaling factor we have dubbed the squelch is minimized. The scaling factor ranges from 1.0 to ~1.4 in year 2020. Figures F-2a and F-2b show, respectively, the effect on the adjustments made to the bottom up sum for the Reference Case when the AEO2001 load shapes and the current load shapes are used. When the AEO2001 load shapes are used, the unscaled adjustment for June peak hour is -69 GW and the squelched adjustment is -100 GW in year 2020. When the current load shapes are used, the unscaled adjustment for June peak hour is -22 GW and squelched adjustment is -32 GW for the same year. In other words, the peak load for the Reference Case is 31 GW lower using the Current Delta approach as compared to the Original Delta approach when the AEO2001 load shapes are used. That difference narrows to 10 GW when the current load shapes are used.

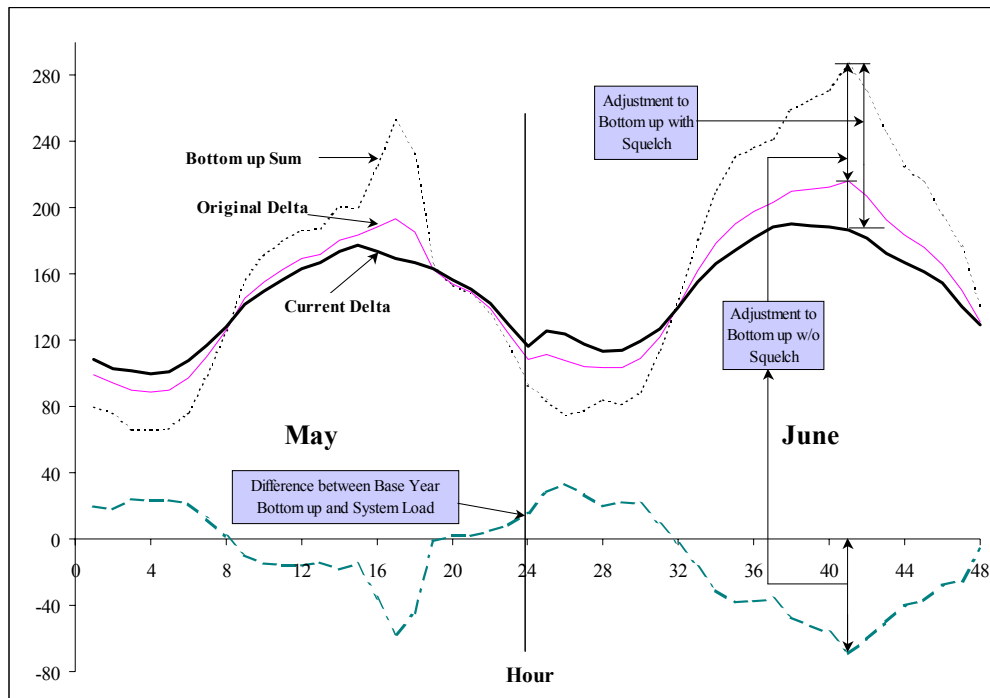


Figure F-2a. Hourly Loads for May and June Peak Days in 2020 – NERC Region 9 AEO2003 with AEO2001 Load Shapes – Reference Case

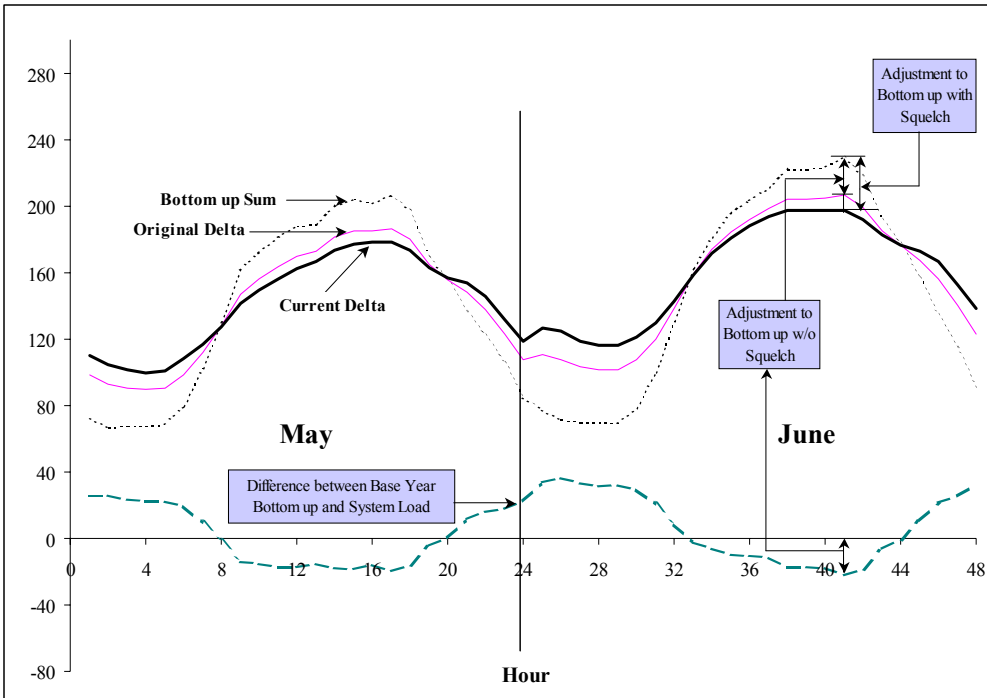


Fig F-2b. Hourly Loads for May and June Peak Days in 2020 – NERC Region 9 AEO2003 with Current Load Shapes – Reference Case

Figures F-3a and F-3b illustrate for EMM region 9 (SERC) how the Original Delta and Current Delta approaches, respectively, affect the reduction of the peak load using the AEO2001 end use load shapes. There are two reasons why the reduction in peak load is higher when the AEO2001 end use load shapes are used. First, as shown in Fig F-2a, the difference between the bottom-up sum of end use loads and the historical system load in the Reference Case is larger. When this difference is scaled up by the squelching factor in the Current Delta approach, the resulting system load for the Reference Case after adjustment has much lower peaks. In Figure F-3b, the June peak for the Reference Case is 187 GW, which is much lower than the June peak is 216 GW in Figure F-3a. Secondly, as shown Figures F-3a and F-3b, the hourly decrement (indicated as negative) from the end use is based on the load shape of that end use, which is peaky and non-coincident with the system load shape. This results in a system load shape for the Decrement Case, which is quite different in shape to that of the Reference case. The peak ends up shifting to May from June. These two effects result in the reduction of peak load being much higher in the Original Delta approach (48 GW) than that in the Current Delta approach (28GW).

Figures F-4a and F-4b are similar to Figures F-3a and F-3b except showing the effect using the current end use load shapes to illustrate the more dampened and similar effect between the Delta and Current approaches. EMM region 9 is shown because this region accounts for roughly 15% of the total U.S. load and therefore has a significant effect on the impact from a proposed standard.

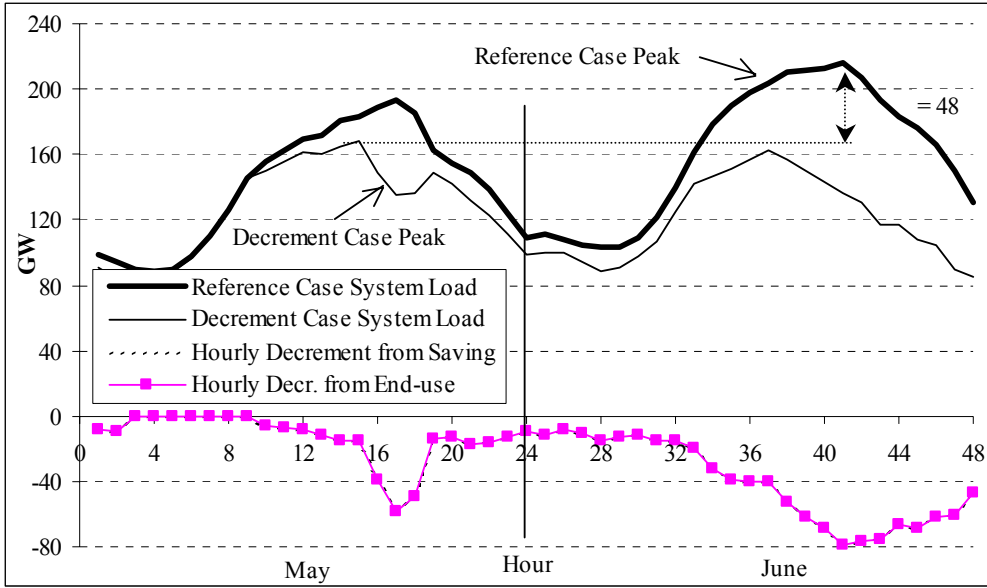


Figure F-3a. Hourly Loads for May and June Peak Days in 2020 - NERC Region 9 AEO2003 with AEO2001 Load Shapes - Original Delta Approach

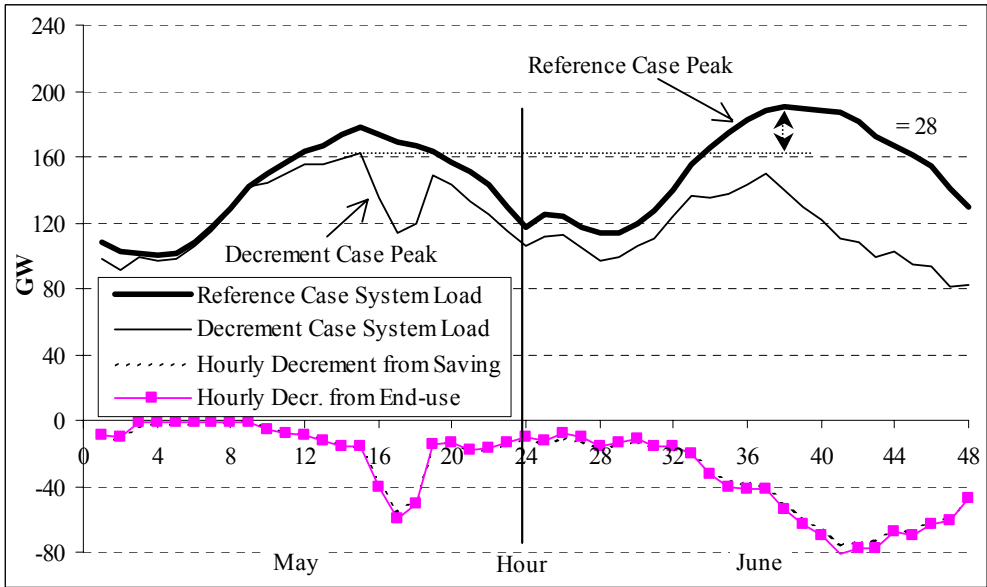


Figure F-3b. Hourly Loads for May and June Peak Days in 2020 - NERC Region 9 AEO2003 with AEO2001 Load Shapes - Current Delta Approach

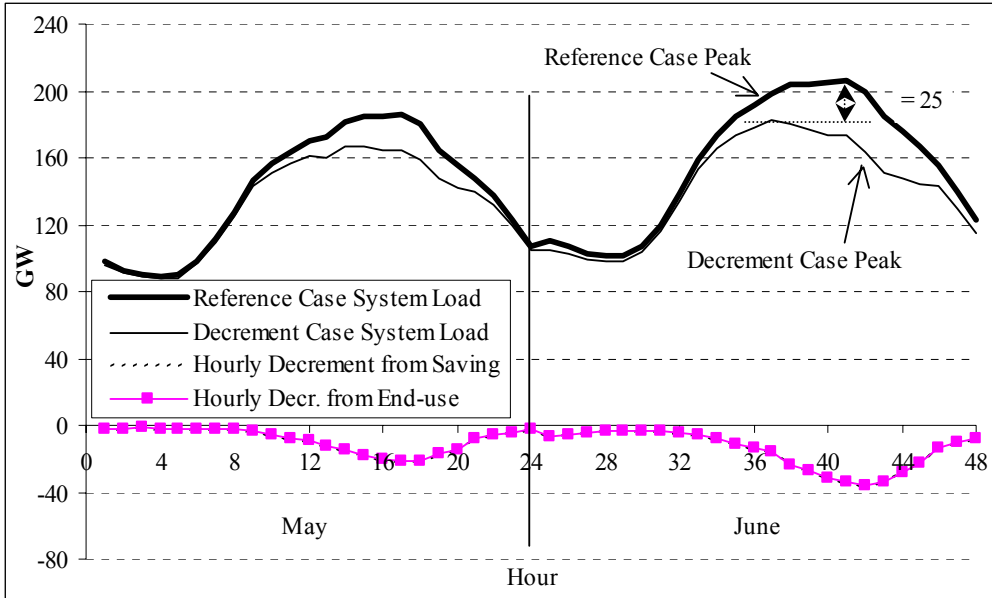


Figure F-4a. Hourly Loads for May and June Peak Days in 2020 - NERC Region 9 AEO2003 with Current Load Shapes - Original Delta Approach

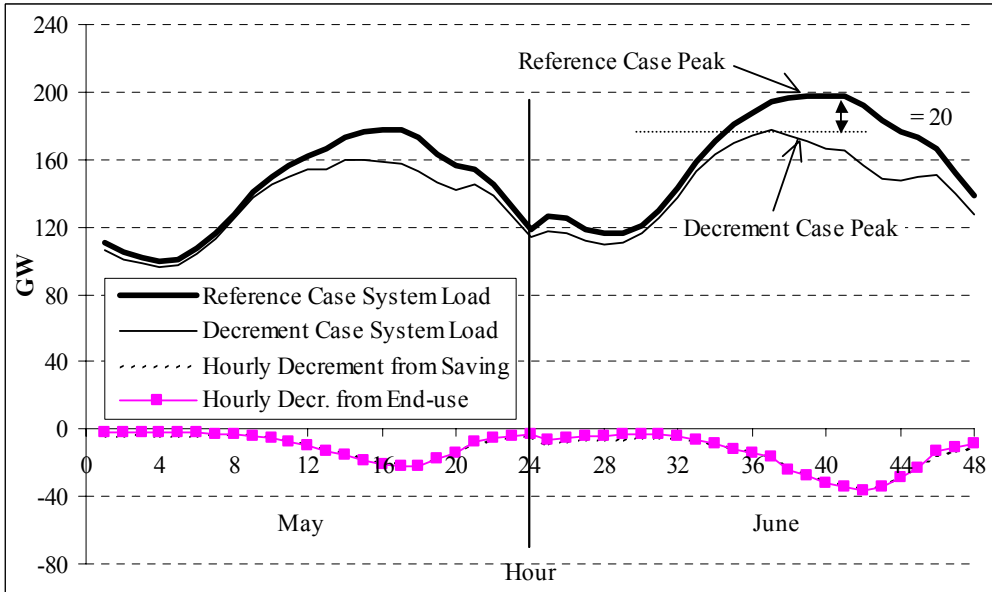


Figure F-4b. Hourly Loads for May and June Peak Days in 2020 - NERC Region 9 AEO2003 with Current Load Shapes - Current Delta Approach

The plots show the peak day for two months in 2020, May and June, to illustrate a shift in the peak hour. The bold black line represents the AEO2003 Reference Case peak day hourly load and the thin black line shows the hourly peak for the decrement case, which in this case is represented by a 4x TSL 4 CUAC run. The pink box-symbol line represents the decrement made as a result of 4x TSL 4.

Figures F-3a and F-3b show the change in the peak day in these two months. The decrement to the end-use, as shown by the pink box –symbol line, is almost identical in both figures. The thin dashed line represents the difference between the Reference Case peak and Decrement Case peak lines, which almost exactly matches the decrement made to the end use load shape. Comparing these two figures, we see that the squelch caused the Reference Case peak to lower in magnitude from over 200 GW to under 200 GW. Another notable difference between these two figures is the change in the magnitude of the peak hour, which is 48 GW lower in Figure F-1a and 28 GW lower in Figure F-1b from the Reference Case. This amounts to a 20 GW (48 GW – 28 GW) shift in the peak hour load as a result of using the Original Delta or Current Delta approach with the AEO2001 load shapes. However, this effect is not nearly as significant using the current end use load shapes.

Figures F-4a and F-4b show a similar story except using the current end use load shapes. In these two figures the peak day load difference between the Reference Case and Decrement Case are significantly lower than in Figures F-1a and F-1b. Again, the Reference Case peak lowers between these two figures, although the difference is much less from just above 200 GW to just less than 200 GW. Comparing Figures F-3a and F-3b with Figures F-4a and F-4b illustrates the significant dampening effect that updating the end use load shapes has on the decrement (pink box line). The decrement is clearly smoother and smaller with the new load shapes compared to the original AEO2001 load shapes. With the current load shapes, the reduction of the peak load is less, only 25 GW and 20 GW for the Original and Delta approaches, respectively, compared to the 48 GW and 28 GW using the old load shapes. This amounts to only a 5 GW (25 GW – 20 GW) shift as a result of using the Original Delta or Current Delta approach with the current load shapes. Comparing the 5 GW shift using the current load shapes with the 20 GW shift using the AEO2001 load shapes shows how significant the updated load shapes are in bridging the gap between the Original and Delta approaches in NEMS.

This Appendix illustrates the significant effect the updated end use load shapes have in correcting the inconsistency between the Original and Current Delta approaches. As a result of the improved load shapes, the difference between the bottom-up and traditional method for calculating the system load is almost insignificant. That is, the end use loads properly add up to the system load. Thus, the removal of the squelching scaling factor, which impacts the difference between the summed bottom up end use and system loads in the AEO2003 version of NEMS does not produce the significant effect seen in the AEO2001 analysis.

Appendix G. Effect of Modified TMY System Load

As noted in this report, our analysis revealed switching out the NEMS system load with the TMY system load results in a 48 GW reduction in the peak load growth forecast by 2025. This significant difference from the AEO2003 Reference Case initiated an effort to try and minimize this difference.

The NEMS system load is based on historic system load data, although little is known about where this data originated. According to Lessly Goudarzi of OnLocation, Inc., the NEMS system load was likely last updated around the year 2000 version of NEMS, suggesting the current system load is based on data from 1999 or earlier. One major flaw in using actual system load data in NEMS is that the data is almost certainly biased to reflect that year's weather, which could be anomalously hot or cold. This appendix explores the possibility of replacing the NEMS system load with the TMY system load in order to correct for such biases, while minimizing the deviation from the AEO2003 Reference Case.

The TMY system loads are believed to be an improvement to the system loads currently represented in NEMS because it represents typical meteorological conditions. The TMY system load therefore does not include extreme weather years that could potentially bias the system load and lead to over- or underestimations of the forecasted system loads because the system load is forecasted relative to a base year input system load.

Without any correction to the TMY system load, the substitution of this system load into NEMS results in a 48 GW reduction in the peak load forecast, a 4 % deviation from the AEO2003 Reference Case that would be nearly impossible to justify as part of the CUAC Rulemaking analysis. As a result, Berkeley Lab performed a series of runs that increase the peak day of the system load, compensated by an decrease during all non-peak hours by a total of the same amount to ensure the same amount of total energy demanded. Three different scenarios were run that increase the peak day in all 13 EMM regions of the TMY system load by 5 %, 7%, and 15% to prove that we could achieve a forecast similar to the AEO2003 Reference Case using the TMY system load shapes.

Based on our scenario runs, a 7% increase to the peak day in all 13 EMM regions resulted in the closest forecast to the AEO2003 Reference Case. Table 20 shows the total installed generating capacity of the three scenarios and the difference from the AEO2003 Reference Case (in parentheses). The 15% scenario overshoots the Reference Case by over 70 GW throughout the forecast. In contrast, the 5% scenario undershoots the target by over 20 GW in 2025. Of the three scenario runs, the 7% scenario targets the AEO2003 Reference Case the best, forecasting total installed capacity within ± 10 GW from year to year.

Table 20. Total Installed Capacity (and Difference from AEO2003 Reference Case) in GW

	2010	2020	2025
AEO2003 Ref Case	934.8	1,085.0	1,182.5
5%	935.2 (+0.4)	1,069.0 (-16.0)	1,160.6 (-21.9)
7%	945.9 (+11.1)	1,083.5 (-1.5)	1,179.7 (-2.8)
15%	1008.2 (+73.4)	1,164.9 (+79.9)	1,258.3 (+75.8)

So based on our experimental runs, this analysis proves that the TMY system load can be modified to better correlate with the NEMS system load. By reducing the annual peak hour of the TMY system load in every region and increasing the equivalent load during off-peak hours, the system load is more consistent with the NEMS system load, yet does not suffer from the influence due to extreme weather phenomena. A 7% increase to the TMY system load regional peak hour therefore reduces the deviation from the AEO2003 Reference Case, while correcting the system load for possible weather anomalies commonly inherent in real historic data.

Based on this exercise, Berkeley Lab analyzed historic weather maximum temperatures to determine reasonable percentages of deviation to help support a reduction to the TMY system load peak.