



State of California

M e m o r a n d u m

Date: December 7, 2021

To: California Energy Efficiency Program Administrators

CC: Amy Reardon, CPUC
Coby Rudolph, CPUC
Jordan Christenson, CPUC

From: Peter Biermayer P.E., Utilities Engineer, EE Planning & Forecasting Section, Energy Division, CPUC

Subject: CPUC MEASURE PACKAGE GUIDANCE FOR LOAD SHAPES

This memo provides guidance for the specification, development, and application of energy impact load shapes to be referenced in deemed measure packages. Hourly energy load shapes are essential for determining peak demand reductions resulting from energy efficiency measures, energy used during specific time-of-use periods, and for cost effectiveness and GHG impacts when combined with hourly avoided-costs. The topics covered in this memo include:

- Background including terminology, the need for hourly load shapes, and how they are used by the cost-effectiveness tool (CET)
- Load shape resources including where they are stored, how to view or download, references regarding the development of and transition to the library of Generalized Load Shape Parameters (GLSPs)
- Guidance for selecting from existing load shapes within the library of GLSPs
- Guidance for generating new sets of GLSPs and aggregating multiple sets for use with all tiers of a given measure
- Notification, criteria, process, and timing for CPUC review and approval of new sets of GLSPs for use in measure packages
- Timing of GLSP updates during the transition of deemed measure packages to a 2-year program cycle and with the two-year, avoided-cost update cycle

BACKGROUND

Energy efficiency goals and program impacts are measured in terms of total energy saved annually to avoid or defer building new generation to meet increasing state energy demand. Furthermore, both the level and value of energy efficiency savings vary throughout the year and must be accurately quantified to calculate the avoided costs and reliability benefits of energy efficiency. Load shapes describe the hourly distribution

of equipment fuel usage so that peak demand reductions and hourly avoided costs can be determined for energy efficiency measures and their programs.

Load shapes can be influenced by equipment efficiency, equipment operations that are governed by controls, building shell characteristics, weather, and occupant behavior. Load shapes are distinct from load level—the magnitude of the load—in that load shapes describe the pattern of the load distribution of load level. Hence, a given load shape can be applied to multiple energy efficiency measures that have the same hourly pattern by scaling them to the load levels for each case.

Load shapes can be developed from building simulation outputs, calculation tools, or from measurement and verification data (end-use metered or whole-building consumption) and stored in the Database for Energy Efficiency Resources (DEER) as described in Table 1.

Table 1. Load shape descriptions and storage locations

| Load shape type | Description | Stored in DEER databases | |
|---------------------|---|---|---|
| | | Tables | Description |
| Base case | Load shape without energy efficiency or demand-side management intervention | LoadShapeElec_2022 LoadShapeGas_2022 | <ul style="list-style-type: none"> • Baseline-case TechIDs and associated GLSPs for DEER2021, DEER2022, and DEER2023 measures |
| Measure case | Load shape with energy efficiency or demand-side management intervention | | <ul style="list-style-type: none"> • Measure-case TechIDs and associated GLSPs for DEER2021, DEER2022, and DEER2023 measures • Measure-case associated GLSPs for aggregated metered, measure-case load shapes gathered during impact evaluations. |
| Impact | Difference between base and measure case load shapes | ElecImpactProfile GasImpactProfile | These tables contain 16 legacy E3 electric load shape IDs, 3 gas load shape IDs, and PA-specific load shape IDs. These load shapes have not been modified since the DEER2011 update. |

Depending on the type of measure, the signatures¹ of the hourly load shapes may differ between the base and measure cases (e.g., via modified operations or control strategies such as economizers) or be very nearly the same, as with pure efficiency upgrades without operational changes. The measure-case load shapes developed for DEER measures are generated using either a combination of DEER building prototypes and the DOE2/eQUEST simulation engine² or an approved version of the DEER water heater calculator. The generated load shapes are then converted from 8,760-hour values to generalized

¹ The signature describes the overall shape of the annual hourly load for any given shape.

² MASControl3 is the software application used by staff consultants and stakeholders to establish and model measures using DEER building prototypes, the DOE2/eQUEST simulation engine, and building-type weights based on California building stock data.

load shape parameters (GLSPs) using a four-step process described in detail in DNV’s Generalized Load Shape Parameter Methodology Memo.³

The primary application for the end use load shapes in California energy efficiency programs regulated by the CPUC is in assessing measure and program cost effectiveness using the Cost Effectiveness Tool (CET).⁴ End use load shapes are combined with the load level (annual kWh savings) and avoided electricity and gas costs from the Avoided Cost Calculator (ACC) to produce the avoided cost benefits (in dollars) that make up the benefits side of the benefit-to-cost ratios used in the total resource cost (TRC), the program administrator cost (PAC), and other cost tests. For more information on CPUC cost effectiveness visit the webpage: <https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/energy-efficiency/idsm>.

The Avoided Cost Calculator (ACC) is used for cost-effectiveness analysis of distributed energy resource (DER) programs and policies. D.16-06-007 adopted annual updates to the ACC and D.19-05-019 adopted a schedule for both major and minor changes to the ACC, with minor changes occurring in odd-numbered years by CPUC-initiated Resolution. The most recent update to the ACC was through Resolution E-5150, issued June 24, 2021.⁵ Shortly thereafter, the CET is updated each year with new avoided costs and any other necessary updates.

LOAD SHAPE RESOURCES

This section provides a description of the various load shape resources.

DOCUMENTATION

The four-step process for converting from calendar-year specific 8,760-hour load shapes to GLSPs is described in detail in DNV’s Generalized Load Shape Parameter Methodology Memo located at <http://www.deeresources.com/index.php/deer-load-shape>.⁶

DEER DATABASE TABLES

The DEER databases contain two tables—LoadShapeElec_2022 and LoadShapeGas_2022—that provide libraries of GLSPs for the following:

- All DEER2021 through DEER2023 measures
- Some DEER2020 measures as listed in Resolution E-5082 DEER2022 Update (for those measures found to contain unit energy savings omissions or errors requiring new simulations)
- E3 load shapes from DEER2008 and DEER2011
- E3 load shapes from DEER2011
- Aggregated load shapes from recent EM&V studies

³ *Generalized Load Shape Parameter Methodology Memo*, DNV, July 2020, at <http://www.deeresources.com/index.php/deer-load-shape>.

⁴ https://cedars.sound-data.com/cet_ui/ (Log-in is required, but registration is free.)

⁵ <https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M382/K179/382179225.PDF>

⁶ This link is only valid through December 31, 2021; as of January 1, 2021, all existing and future contents of www.deeresources.com will be available within the DEER module at <https://cedars.sound-data.com/>.

GLSP CONVERTERS

Two tools have been developed to enable stakeholders to either generate GLSPs from 8,760 load shape profiles that are specific to a given calendar year, or vice versa:

- An Excel™ version of the GLSP converter is available in a zip file that contains an Excel workbook: LOADLIBA-8760-v14-CPUC-DEER.xlsx
- A Python version of the GLSP converter is available in a zip file containing Python™ code and companion Jupyter notebooks that provide examples of conversions, in both directions. The components of this tool are described in the subsection that follows.

PYTHON MODULES

Many weather-dependent measures involve hundreds of permutations of energy savings and warrant the development of batch-processing features. Using the Python code, the conversions can be performed many times and written to a SQL database or other compact and efficient formats.

DNV developed two methods using Python to transform an array of load-shape values (8760x1) to another array of the same load-shape values (365x24) and then to a much smaller array of GLSPs (36x12). Both modules convert load shapes for a given building vintage, climate zone, and building type.

The first Python method involves using OpenPyXL⁷ to repeatedly copy and paste measure load shapes from a single Excel file, Convert8760toGLS.xlsx, and save them into multiple Excel files named GLS-CPUC-DEER-LoadShapeLibrary-v**.xlsx (where “*” represents a wildcard character). Using this method, one set of transformations can take up to four hours.

The second method involves using DNV’s Python module, Lopeshape.py, to perform the same load shape transformation entirely in Python using pandas data structures, as described in Section 2.2 of DNV’s Generalized Load Shape Parameter Memo. Lopeshape.py performs the same described array conversions and then formats them for export into a SQL database and for download as an Excel file. Using this module, one set of transformations takes two to three seconds.

Lopeshape.py produces two output files. The first contains three columns of peak, weekday, and weekend hourly load shapes for each permutation, identified by an ID. The second output contains three columns of monthly load ratios, Monthly % load, PDAF, and Weekend/Weekday Ratio, for each permutation, identified by an ID. The load shapes and ratios can be exported into Excel, as shown in Figure 1 and Figure 2.

⁷ <https://openpyxl.readthedocs.io/en/stable/>

Figure 1. Hourly load shapes

| Month | ID | Hour | Peak | Avg | End |
|-------|--|------|----------|----------|----------|
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 1 | 0.575696 | 0.532958 | 0.602329 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 2 | 0.506415 | 0.445887 | 0.523001 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 3 | 0.488087 | 0.411073 | 0.469926 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 4 | 0.483871 | 0.397684 | 0.444235 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 5 | 0.479839 | 0.396432 | 0.427966 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 6 | 0.515579 | 0.434996 | 0.466056 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 7 | 0.567082 | 0.492418 | 0.515563 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 8 | 0.668255 | 0.600863 | 0.563086 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 9 | 0.651576 | 0.595171 | 0.549836 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 10 | 0.672287 | 0.564849 | 0.572433 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 11 | 0.619868 | 0.528926 | 0.541437 |
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 12 | 0.592925 | 0.519564 | 0.527055 |

Figure 2. Monthly load shape ratios

| Month | ID | Mo Brk | PDAF | Wknd/Wkd |
|-------|--|----------|----------|----------|
| 1 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.088528 | 1.127368 | 1.000999 |
| 2 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.079143 | 1.081757 | 0.972678 |
| 3 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.086152 | 1.077968 | 0.998020 |
| 4 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.082564 | 1.100314 | 0.993977 |
| 5 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.082268 | 1.060015 | 0.997227 |
| 6 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.078725 | 1.044077 | 1.001442 |
| 7 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.081095 | 1.018522 | 0.998898 |
| 8 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.081817 | 1.025520 | 0.997568 |
| 9 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.080678 | 1.060166 | 0.996527 |
| 10 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.085072 | 1.071028 | 0.981171 |
| 11 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.084842 | 1.129131 | 1.001946 |
| 12 | RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | 0.089116 | 1.121250 | 0.980516 |

In addition to exporting to Excel, Lopeshape.py can easily convert the output for storage in a SQL database. The load shapes and ratios are transformed to include one set of GLSPs per load shape—including 864 hourly profiles and 36 monthly factors—that are then exported to a SQL database. A sample of the SQL data formatting is shown in Figure 3.

Figure 3. SQL export format

| EnergyImpactID | Version | MaxDayJanHr01 | AvgWkdayJanHr01 | AvgWkendJanHr01 | MaxDayJanHr02 | AvgWkdayJanHr02 | AvgWkendJanHr02 |
|--|----------|---------------|-----------------|-----------------|---------------|-----------------|-----------------|
| RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ01 | DEER2022 | 0.575696 | 0.532958 | 0.602329 | 0.506415 | 0.445887 | 0.523001 |
| RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ02 | DEER2022 | 0.537488 | 0.519154 | 0.584173 | 0.486465 | 0.431066 | 0.503386 |
| RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ03 | DEER2022 | 0.630339 | 0.550909 | 0.607983 | 0.556864 | 0.471346 | 0.529876 |
| RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ04 | DEER2022 | 0.577830 | 0.539424 | 0.612539 | 0.513970 | 0.462857 | 0.541671 |
| RefgChg-Res-16pct-Inc-TXV-rDXGF-DMoMH00-CZ05 | DEER2022 | 0.578152 | 0.540077 | 0.608834 | 0.526366 | 0.468102 | 0.545387 |

LOAD SHAPE VIEWER

DNV developed a third Python module to plot multiple load shapes to allow for comparisons between two sets of GLSPs. This visualization module can be used to view both output formats described in the previous section (Excel and SQL).

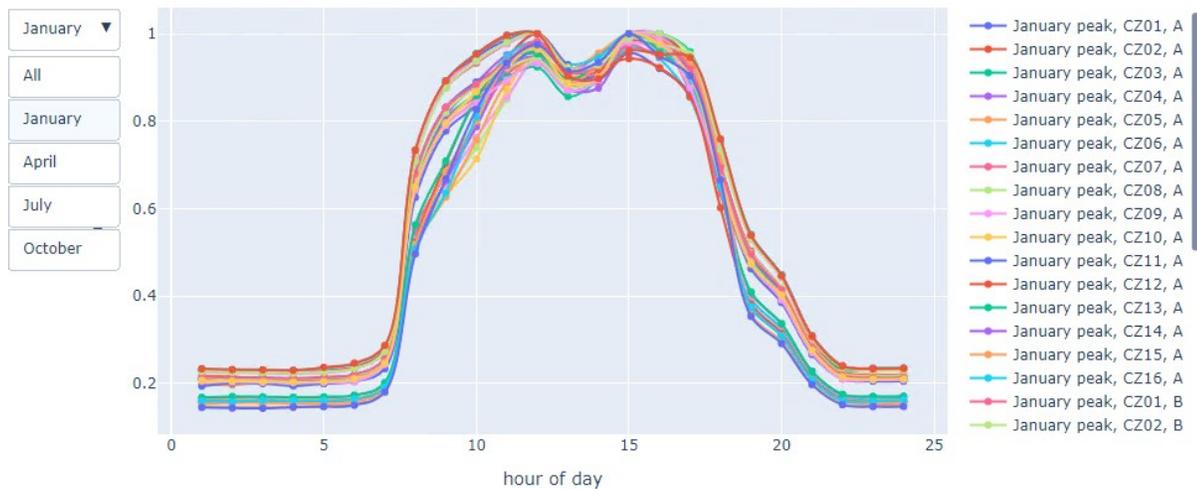
The web-based Python tool allows users to compare any two existing load shape libraries by plotting the monthly load shapes for all climate zones on the same plot and facilitates comparisons between building simulation results based on old (CZ2010) and new weather (CZ2022) for a building type. By integrating the module with Jupyter notebooks, users can select file paths to a library of GLSPs. Figure 4 illustrates a sample comparison plot⁸ of two daily load shapes in January. The feature to view and compare daily load shapes offers the ability to spot anomalous building simulation results that may reveal a need to review or update simulation assumptions.

The viewer can be accessed at <https://loadshape-viewer-cpuc.azurewebsites.net/>. (Note: the viewer works best using Microsoft’s Internet Explorer browser.)

⁸ As of the writing of this memo, DNV continues to improve and expand the capabilities of the load shape viewing tool.

Figure 4. Snapshot of web-based load shape viewing tool

January (All CZ, A and B)



AVAILABLE GLSPS

The end use load shapes that can be used in the CET are listed in Specifications on the CEDARS cost-effectiveness tool website.⁹ While the website requires users to log in, anyone can register and create a free account.

The existing load shapes that are carried over from the CET include those for:

- Residential lighting
- Residential appliances
- Residential plug loads
- Commercial food service
- Commercial refrigeration
- Commercial process/other
- Commercial chillers
- The electric end-use load shapes are listed in the Avoided Cost Combo table. Each electric end-use shape (labelled E3MeaElecEndUseShape) is allowed for use only to specific combinations of Program Administrator (PA), target sectors, and climate zones. This is because the process of multiplying the end-use load shape by the avoided costs (from the ACC) is done outside of the CET and only the averaged quarterly results of that vector multiplication are stored in the CET. Further, the avoided costs vary by PA, climate zone, and target sector so the results are stored separately for each combination.

⁹ https://cedars.sound-data.com/cet_ui/

- The gas end-use load shapes are listed in the E3 Gas Savings Profile table. At this time, the gas savings profiles (Annual, SummerOnly, and WinterOnly) have no restrictions on which PA, climate zone, or target sector combination is used.

In the DEER tables that contain both libraries of GLSPs—electric and gas—users can find entries for the following types of measures:

- New load shapes from recent DEER updates include those for:
 - HVAC measures, residential and commercial
 - Domestic water heating, residential and commercial
 - Gas furnaces and boilers, residential and commercial
 - Residential appliances
- New loadshapes from EM&V
 - HER
 - Smart thermostats
 - Commercial lighting
 - PTAC controls
 - Some residential HVAC measures

DEER measures use “MeasTechID” as the basis for the name of the GLSP record. When selecting a TechID for use with a given measure, the best fit within the same sector and end use should be chosen. Some options are shown in Table 2. Proposed mapping of current E3-generated load shapes to TechID-based load shapes by end-use category.

Table 2. Proposed mapping of current E3-generated load shapes to TechID-based load shapes by end-use category

| Use Category | Current E3MeaElecEndUses ID | Proposed/sample electric TechID-based ¹⁰ load shape |
|--------------|-----------------------------|--|
| AppPlug | DEER:RefgFrzr_HighEff | DEER-RefgFrzr_HighEff (until DEER2024) |
| | DEER:Res_ClothesDishWasher | TBD |
| HVAC | DEER:HVAC_Chillers | TBD |
| | DEER:HVAC_Duct_Sealing | TBD |
| | DEER:HVAC_Eff_AC | e.g., MsrNResPkgAC-55to65kBtu/h-2Sp-S15.0-Econ |
| | DEER:HVAC_Eff_HP | e.g., MsrNRes-PkgHP-135to240kBtuh-E11.5-C3.2-2SpP |
| | DEER:HVAC_Split-Package_AC | e.g., MsrNRes-SpltPkgAC-65to134kBtu/h-2Sp-E11.5-Econ |

¹⁰ Some TechID-based load shapes may be consolidated due to a high degree of cross-correlation (threshold has not yet been determined as of this memo).

| Use Category | Current E3MeaElecEndUses ID | Proposed/sample electric TechID-based10 load shape |
|--------------|-----------------------------|---|
| | DEER:HVAC_Split-Package_HP | e.g., MsrNRes-SplitPkgHP-65to134kBtuh-E12.0-C3.4-2Sp-Econ |
| | N/A | PTAC Controls |
| Lighting | DEER:Indoor_Non-CFL_Ltg | Kilolumen LEDs T-LEDs |
| | DEER:Indoor_CFL_Ltg | LEDs |
| SHW | N/A | Stor_COP-ElecHP-120gal-4.2COP Stor_UEF-ElecHP-050gal-3.09UEF Stor_UEF-ElecHP-050gal-3.31UEF Stor_UEF-ElecHP-065gal-2.91UEF Stor_UEF-ElecHP-065gal-3.33UEF Stor_UEF-ElecHP-080gal-3.00UEF Stor_UEF-ElecHP-080gal-3.42UEF |
| WhlBldg | DEER:Res_BldgShell_Ins | DEER:Res_BldgShell_Ins (until DEER2024) |

NEW LOAD SHAPE SUBMISSIONS

When new load shapes are needed, measure package sponsors must consider the following:

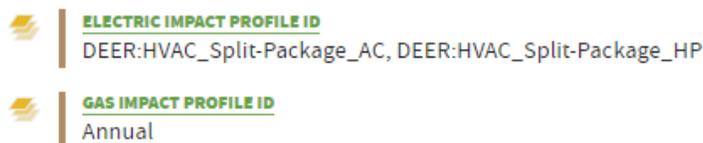
- The CPUC’s Measure Package review team will review proposed additions to the load shape library at the time when a new measure is submitted for approval.
- If measure package sponsor wishes to have a new load shape approved for an existing measure, that would be addressed during the next measure package submittal and review process.
- In all cases, the source data and process used to develop the new load shape will need to be provided as supporting documentation for the measure package. If developed by the measure package sponsor, it will be subject to review and approval by CPUC during the normal measure package submittal and review process.
- A maximum of 30 new sets of GLSPs are expected to be added per year.
- New GLSPs will be added to DEER and the CET annually, in July, after the ACC update.
- DOE2/eQUEST/MASControl3 or EnergyPlus building simulations must use CPUC-approved scripts and templates.
- Aggregation of multiple or selection of a single record-level GLSP TechID for each building type and climate zone combination is to be considered: a load shape for every unique measure configuration may be duplicative (size range, efficiency range or tiers, etc.).
 - For example, one set of GLSPs may be sufficient to represent all high-efficiency packaged air-conditioners at an Assembly building type in CZ10 (instead of multiple TechIDs for each efficiency rating, SEER 15, 16, 17,18, 19, 20, 21).
- AMI-based load shape analyses using hourly levels must be converted to GLSP format using existing tools described in Section 2.3 of this memo.

- Other methods (monthly bills, spreadsheet calculators) without hourly outputs must review DNV's Generalized Load Shape Parameter Methodology Memo.

MEASURE PACKAGE UPDATES

Program Year 2023 will be the first year to consistently use the new GLSPs and it is expected that all shapes will be documented within each measure package. TechID-based load shapes are to be documented for each measure in the eTRM on the Supporting Data tab, under the Measure Parameter column.

Figure 5. Example loadshapes in the eTRM for the unitary air conditioner or air-cooled heat pump measures



The CPUC will prioritize reviewing the 2022-2023 measure packages that were used for filing and approved prior to this guidance. Any 2022 measure packages that are suspected of containing misalignments will also be reviewed as we gear up for PY2022—the first program year to start utilizing new shapes.

GLOSSARY

Hourly end-use load shapes. The annual hourly pattern of loads consumed by equipment in buildings represented by a vector made up of 8,760 elements, one element corresponding to each hour of the year. The value in each hour represents the proportion of annual energy used in that hour and is in units of (hours)⁻¹. The value in each element can be multiplied by the annual energy consumption (kWh) to provide the electric demand (kW) in that hour.

Generalized Load Shape Parameters (GLSPs). A GLSP set is a series of dimensionless ratios designed to a) facilitate scaling, calibration, specific year output, weather adjustment/normalization and b) provide standardized format regardless of the load shape data source or method.

Load shape library database. This is the database of hourly end use or measure level load shapes that will be referenced for all measures. Raw 8760-hour load shapes are processed into the GLSP format for storage in the database.

Load shape first day of the year. The day of the week (Monday, Tuesday, etc.) that is used for January 1st in the load shape data. This value and whether a given year is a leap year determine the weekday-weekend-holiday basis for the load shapes.

Load shape calendar year. This is another way to specify the year associated with the load shape that determines the weekday-weekend-holiday basis for the load shapes.

Avoided Cost Calculator (ACC). The ACC provides the avoided costs of electricity generation, transmission, and distribution in each hour for each California utility in the current year and projected forward 30 years.

Cost Effectiveness Tool (CET). The CET is used to calculate the cost effectiveness of a measure and/or portfolio of measures. The CET uses the avoided cost combo values developed from the avoided costs and the hourly end use load shapes.

E3MeasElecEndUseShape. This DEER database field contains the labels used for the end use load shapes. The shapes were historically generated by E3.

8760-hour. The total number of hours in a normal year (not a leap year) = 365 days x 24 hours