

Facility Energy Decision System

Release 8.0 User's Guide



June 2020

Pacific Northwest National Laboratory
Richland, WA USA



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Facility Energy Decision System (FEDS) Release 8.0

1 Introduction to FEDS

The Facility Energy Decision System (FEDS) is a building energy simulation and analysis software system designed to provide a comprehensive approach to fuel-neutral, technology-independent, integrated energy resource planning and acquisition. It offers a flexible and user-friendly Windows-based software program for assessing the energy efficiency resource potential of facilities ranging from single buildings to multi-building campuses, large federal installations, and communities. FEDS assists energy managers, engineers, and building owners understand energy use within their facilities and identify cost-effective approaches for enhancing energy efficiency and resilience.

FEDS has been developed at the Pacific Northwest National Laboratory (PNNL) with support from a number of agencies including the U.S. Department of Energy Federal Energy Management Program, Rebuild America Program, U.S. Army (Office of the Deputy Assistant Secretary of the Army for Energy and Sustainability, Construction Engineering Research Laboratory, Installation Management Command, Forces Command, Reserve Command, and Office of Energy Initiatives), Defense Commissary Agency, U.S. Naval Facilities Engineering Command, U.S. Air Force Office of Energy Assurance, Tennessee Army National Guard, U.S. Coast Guard, U.S. General Services Administration, U.S. Agency for International Development, and Public Services and Procurement Canada. Additional input has been contributed by select commercial, municipal, non-profit, and educational licensees.

The scalable FEDS approach allows data input to range from minimal to highly detailed. With limited inputs, FEDS can be used as a top-down, first-pass energy systems analysis and energy resource acquisition decision tool for buildings and facilities. Providing FEDS with more detailed input allows the user to generate optimized building retrofits and provides actionable information on project recommendations, including energy, electric demand, cost, and emissions impacts.

Users may enter only high-level installation information (number, age, size, and types of buildings and energy systems) and the internal database of typical energy-system configurations and performance data then infers likely building parameters and the sophisticated hourly energy simulation and optimization models estimate the current and proposed energy use and the net present value of potential energy retrofits. More

detailed building models may also be developed, where the inferred information is augmented with user-supplied building and related energy system parameters. The result provides more accurate and robust technology selection and supporting economic information.

Please report any software bugs and refer any recommendations, comments, and/or questions of a technical nature to FEDS.Support@pnnl.gov. Also, visit the FEDS web site at FEDS.pnnl.gov for additional information and notices regarding software updates or licensing.

1.1 General Description of FEDS

FEDS provides a flexible and comprehensive building and campus energy resource planning approach to help meet a variety of energy management needs and goals. The basic intent of the model is to provide information needed to determine the minimum life-cycle cost (LCC) configuration of an installation's or campus' energy generation and consumption infrastructure. The model has no fuel or technology bias; it simply selects the technologies that will provide an equivalent or superior level of service (e.g., heating, cooling, illumination) at the minimum LCC.

When determining the minimum LCC configuration of building and end-use technologies, all interactive effects between energy systems are explicitly modeled. For example, when considering a lighting retrofit, the model evaluates the change in energy consumption in all building energy systems rather than just the change in the lighting energy. The value or cost of these interactive effects varies by building type (level of internal gain), building size (portion of heating, ventilation, and air conditioning loads attributable to internal gains versus envelope gains/losses), climate (whether a particular building is cooling- or heating-dominated), occupancy schedule, and a number of other factors. Thus, there is no simple solution, and detailed modeling, as is done in FEDS, is the best way to provide a credible estimate of the savings impact.

In determining the optimal retrofit for each technology, the interactions at the installation level are considered by determining the impact on the installation's electric energy and demand cost, as well as the interactive effects among end-uses. This is important because the peak electric demand in any individual building may not occur at the same time as the installation's peak demand. Since the buildings on large federal installations are often not individually metered, the installation is billed based on the combined demand of all buildings. Thus, proper valuation of the changes in an individual building's electric demand must be done in the context of the impact on the installation's demand profile—including time-of-day pricing and demand ratchets.

1.2 New in Release 8.0

FEDS 8.0 introduces the next generation of the Facility Energy Decision System building energy analysis software. This latest version of FEDS focuses on enhancing the user experience and utility for meeting evolving needs. Key improvements include an

updated graphical user interface, new control retrofit options, detailed hourly profile input and output capabilities, updated technology performance and cost data, and more.

1.2.1 New Improved Graphical User Interface

FEDS 8.0 features a new and more modern graphical user interface (GUI) for an improved user experience and greater stability. The new GUI updates a number of the options of the prior version such as the locking of inputs and provides new feature enhancements. A new model navigation pane offers quick and intuitive access to the entire case at a glance and click of the mouse. A summary results page provides quick access to both tabular and graphical display of energy use by fuel type, in annual or monthly totals, to quickly see how your model is performing. An improved display of integrated help, tracking of input changes, and other updates offer improved support and clearer guidance on model status. Additionally, FEDS 8.0 provides improved performance with Windows 10 and accommodates a much larger range of display resolutions and settings than previous versions.

1.2.2 HVAC and Lighting Control Measures

FEDS 8.0 adds HVAC and lighting control measures to its suite of energy efficiency retrofit options that can be evaluated automatically. These include:

- Heating and cooling zone temperature setback
- Ventilation scheduling
- Lighting occupancy control

New inputs have been added to support these new retrofit measures. On the HVAC side, this includes control method and number of thermostats. For lighting, additional inputs include space type, presence of existing lighting controls, number of sensors required, and controlled utilization factors to allow detailed modeling of the impact of controls.

1.2.3 Hourly Profile Input and Output Capability

FEDS 8.0 adds an option for advanced hourly input of select model parameters for more detailed specification and modeling. This includes support for real-time electricity pricing, occupancy characteristics, heating and cooling setpoints, lighting and other equipment utilization, and hot water demand. Further, hourly energy use details are available for the site, each building, and each technology, for both baseline and post-retrofit scenarios, which are useful in evaluating the daily and seasonal consumption patterns as well as the impact of efficiency measures on electric loads and resilience requirements.

1.2.4 Updated Regional Costs, Technology Cost and Performance Modeling

The FEDS regional labor rates, material cost factors, and sales tax rates have been fully updated, at both the state and intra-state levels (based on the zip code). Additionally, a number of updates are included for the technologies that FEDS models and evaluates as

energy efficiency measures. A significant improvement was made to the chiller cost and performance models. LED and other lighting costs were reviewed and updated. The costs of advanced storm window panels were also reviewed and updated based on latest data, among other technologies. Finally, the project cost model was improved to report a breakdown of implementation cost components related to Materials and Equipment, Labor, and Indirect Costs, on the retrofit CSV report.

1.2.5 Completely Updated Emissions Tracking

The tracking of air emissions related to building system energy use has been fully updated. FEDS now tracks and reports emissions impacts for carbon dioxide, sulfur oxides, nitrogen oxides, nitrous oxide, methane, and total greenhouse gases (CO₂ equivalent). Emissions factors for each pollutant were updated to reflect the latest data including electricity generation resource mix, for each U.S. state and Canadian province. See section 4.1.6 for more information.

1.2.6 New Reports

High level tabular and graphical reporting of the simulation energy use by fuel type has been added within the FEDS application for both baseline and post-retrofit results. Text-based reports can now be created in either portable document format (PDF) or rich text format (RTF) for improved readability without extra formatting. Additionally, a new report has been added to further assist federal agencies in meeting EISA 2007 Section 432 auditing requirements. This new spreadsheet output summarizes the results of an EISA-compliant assessment, to facilitate reporting to the Compliance Tracking System (CTS). The report automatically compiles the details from the assessment to assist in the reporting of assessed floor area and identified energy savings potential. Measures are also categorized in the CTS format, across all buildings evaluated, to provide the count of each type of measure identified. The FEDS software has been proven as a tool for

assisting agencies in meeting their EISA auditing requirements, and now this additional reporting option will help ease the associated reporting requirement.

1.2.7 Other Additions and Enhancements

A significant number of additional enhancements plus data and performance updates are included, such as:

- A weather station import capability has been added to allow for seamless use of additional available weather station data
- A new input allows the specification of minimum contract demand, as applicable to some electric rates
- Specific DOE/EIA energy price escalation rate projections can be specified via the addition of an explicit energy rate sector input (allowing users to select from residential, commercial, or industrial rates)
- The number of thermal zones that can be modeled for a building increased from 5 to 20
- White roofs can be modeled with a new roof color input option
- Improved modeling of exterior lighting operation, according to seasonally variable hours of darkness
- Building HVAC operation can be controlled seasonally, and for specific thermal zones
- Updated equipment performance and other inference data improvements
- New technology retrofit restrictions
- Additional reporting detail including monthly electricity peak demand, billed demand, and use area annual operating hours
- The latest DOE/EIA discount and energy escalation rates for life-cycle cost analysis.

2 Getting Started

This section describes the minimum computer requirements, the installation of the software, opening a case, and developing and running a model.

2.1 Computer Requirements

The FEDS 8.0 software requires the following minimum computer platform:

- A Windows-based personal computer running Window 7 SP1 or later (Windows 7 SP1, 8, and 10 are compatible with FEDS 8)
- 1.6 GHz or faster processor
- 1+ GB of RAM
- 2 GB of available hard disk space – for installing the FEDS program and storing FEDS input and output files
- Microsoft Excel is needed to display the Summary Results and create the Compliance Tracking System (CTS) output report but is otherwise not required to run FEDS.

2.2 Installing FEDS

1. Run the FEDS setup file provided by download or CD
2. Follow the prompts to complete installation

Note: to reduce hard drive space requirements the setup process allows for the installation of a subset of the available weather files (select the regions that are applicable for your building(s)). If weather stations for regions or time periods beyond those offered by the setup process are desired, use the Import EPW Weather File option from within the FEDS application as described in Section 3.7.2.

2.3 Developing a FEDS Model

The basic steps for developing a FEDS model include creating a new case or opening an existing case, specifying site and building parameters, and updating inferences. Figure 2.1 shows the opening page of the FEDS application, from where a new case can be created, or an existing case opened.

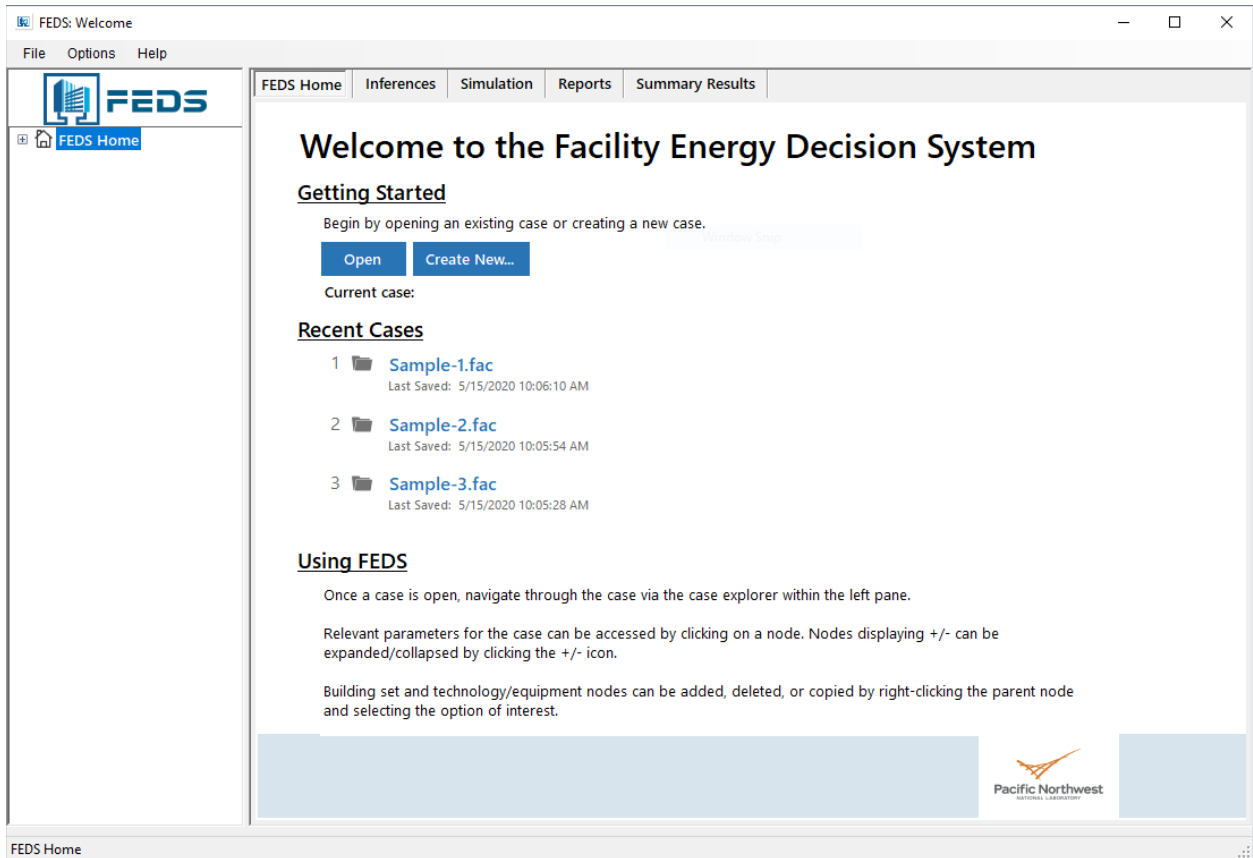


Figure 2.1 FEDS Home Screen

2.3.1 Create New Case

To create a new case, press the **Create New** button from the Getting Started section of the FEDS Home page OR select the **New case...** option from the *File* menu. The *New Case Selection* screen will appear and prompt for a case name and path, as illustrated in Figure 2.2.

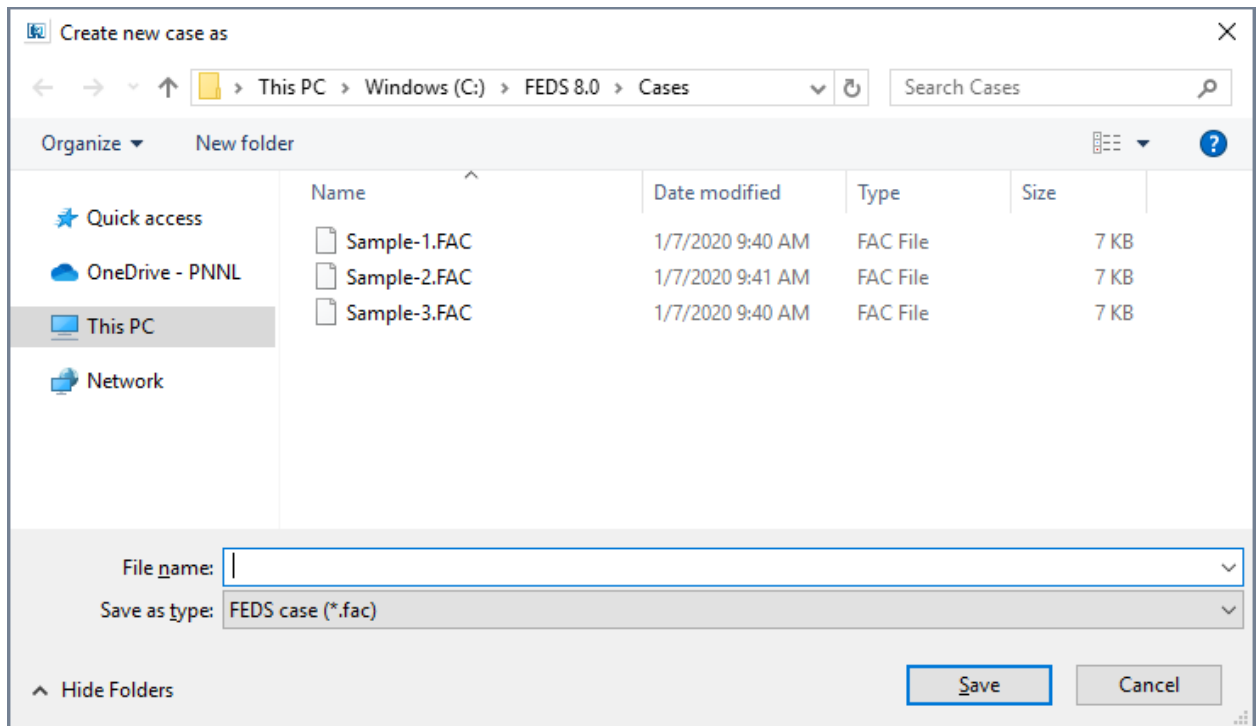


Figure 2.2 New Case Selection Screen

For each case, FEDS creates 17 input files (where {casename} represents the name you have given your model):

| | |
|----------------|----------------|
| {casename}.fac | {casename}.flk |
| {casename}.bld | {casename}.llk |
| {casename}.blk | {casename}.lop |
| {casename}.dbp | {casename}.nep |
| {casename}.ecn | {casename}.plk |
| {casename}.elk | {casename}.plt |
| {casename}.elp | {casename}.rcf |
| {casename}.emi | {casename}.rrs |
| {casename}.eng | |

These files are needed to create, view, edit, and run a case. A number of additional files are created during optimization and are needed for generating output reports. Adding the various report options, as many as 43 files are possible for each case. When transferring a FEDS case from one location on your computer to another, it is important to be sure to transfer ALL of the files having the same case name.

2.3.2 Open Existing Case

To open a previously created case, select **Open** from FEDS Home OR select the **Open case...** option from the *File* menu. The *Existing Case Selection* screen will appear and prompt you for the location and name of the case (see Figure 2.3). Select a case name by clicking on one of the choices followed by the **<Open>** button. A double-click on the selected case will also open it.

Three cases are included with the FEDS software named “Sample-1”, “Sample-2”, and “Sample-3.” These appear in the case name list with a file extension of “.fac.” If not, check to ensure that the directory specified during the software installation is selected (default is C:\FEDS 8.0\Cases). For more information about the sample cases, see Description of Sample Cases in Section 2.5.

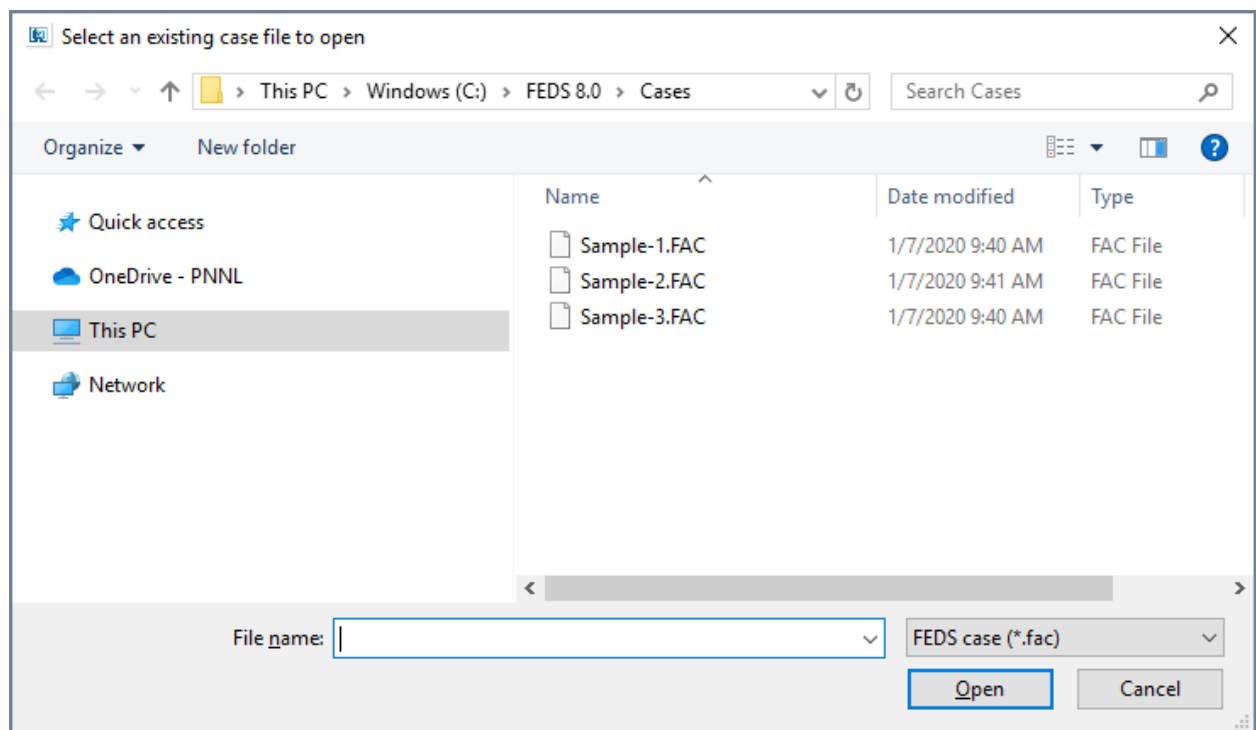


Figure 2.3 Existing Case Selection Screen

2.3.3 Converting Older FEDS Case Files

In order to run FEDS 8.0 using files created with an earlier version of FEDS, the files must be converted into the appropriate format. The following sections explain how to convert older FEDS input files for use with the latest version.

Convert case files (“*.fac”) created with FEDS 7.1 or a previous version to FEDS 8.0 format as follows:

1. Follow procedure for Open Existing Case in Section 2.3.2.

2. Select an existing case file ("*.fac") from any existing directory
3. If FEDS does not recognize this case to be in the current FEDS format, it will inform you that it is attempting to translate the case
4. If successful, a screen will appear prompting you for a name and destination directory for the translated case. The directory where the original case is stored will be the default destination. However, it is recommended that you place the case in a different location (e.g., your FEDS 8.0\Cases directory), by selecting the desired directory from the file structure list. If you choose not to save the translated case to a different directory, it is recommended that you give the case a new name rather than overwriting the original set of files. To do so, edit the name before pressing <Save>.

NOTE: When running a converted model in a newer version of the FEDS application, expect to see changes to both inferred inputs and resulting output values due to model and data updates and improvements.

2.3.4 Building a Model

Once you have started FEDS and have opened or created a case, an outline for developing and refining the model (which can represent a single building or large multi-building campus) is as follows (refer to the listed sections for more information):

1. Specify facility information, such as location, weather station, energy prices (see Section 4.1).
2. Define parameters for any central plans and thermal distribution loops (see Section 4.2).
3. Enter or modify input data for each building or group of similar buildings (see Section 4.3).
4. Update inferences (see FEDS Home functions in Section 3.1).
5. Examine resulting inferences, make appropriate changes, update inferences again, and repeat process until satisfied with the model input data.

For more detailed information on these steps, see FEDS Process in Section 5.

2.4 Running FEDS Simulation

Once you have started FEDS and have opened or created a case, an outline for running the model is as follows (refer to the individual sections for more information):

1. Select the Calibration analysis type or exclude all building sets from optimization (see the discussion of this in Sections 3.1 and 6).
2. Run FEDS (see FEDS Home overview in Section 3.1).
3. Open and examine the reports that are created including the calibration output report (*.Calib.xls) and the *.txs output, comparing consumption estimates to actual metered data. Review and reconcile model inputs based on calibration results and uncover any input errors or omissions (see FEDS Output discussion in Section 8).
4. Correct any input errors and continue to calibrate the model until satisfied that it reasonably represents reality.
5. Set simulation parameters as appropriate (as described in Section 6).
6. Change analysis type to 'Optimization' (or remove building set exclusions) and run FEDS.
7. Open and review output reports to examine FEDS recommendations (see FEDS Output in Section 8).

For more detailed information on these steps, see FEDS Process in Section 5.

2.5 Sample Cases

When FEDS is installed onto your hard drive, the software will automatically create three sample input files for your use, "Sample-1.fac", "Sample-2.fac" and "Sample-3.fac". These files can be used for several purposes, including the following:

- They may be accessed using the **Open case** option to review on a screen-by-screen basis how data files are constructed.
- They may be run through FEDS inference, simulation, and optimization engines to check whether your FEDS software is operating correctly. This can be especially useful if files that you have developed do not run, or if you get error messages that lead you to believe that your software may not be performing as designed. In rare cases, the program may not have installed properly, or it may not have the necessary user rights. In such cases, uninstalling and reinstalling FEDS may be advisable.
- The sample cases can serve as a starting point for developing your own models. Use the **Open case** followed by **Save case as...** option from the *File* menu to create a copy of the sample case with a new name to avoid overwriting the sample case data. The newly copied case can then be edited and modified as needed to develop your own case. This method provides a potential shortcut when compared to creating a new case from scratch. However, it is important to pay close attention to the inputs that require changes.

2.5.1 Sample-1

This case file contains the example of a single 40,000 ft² office building in San Francisco, California. The office was built in 1978. It is heated by electric resistance heaters and cooled by electric packaged single zone units. Service hot water is heated with electric resistance. The building has 30% incandescent lighting, 50% conventional fluorescent lighting, and 20% high-efficiency fluorescent lighting. On weekdays, the building is occupied from 7 am to 6 pm; on Saturdays from 10 am to 4 pm; on Sundays the building is unoccupied.

2.5.2 Sample-2

The example in this case file is a complex consisting of two 50,000 ft² office buildings, six 50,000 ft² warehouses, ten 2,000 ft² single family (detached) residences, and three multi-family (five or more unit) buildings with an average floor area of 26,667 ft². All of these buildings are located in Seattle, Washington.

The two office buildings were constructed in 1977. One office is heated and cooled with an electric air-source heat pump; it has an electric water heater. The other office is heated with natural gas and cooled with packaged single zone units; it has natural gas water-heating. For both offices, the lighting is 20% incandescent and 80% conventional fluorescent. On weekdays, the buildings are occupied from 7 am to 6 pm; on Saturdays from 10 am to 4 pm; on Sundays the buildings are unoccupied.

The warehouses were all built in 1979. Three of the warehouses are heated with distillate oil; three are not heated at all. None of the warehouses has cooling. All six warehouses have distillate oil water heaters, and all have 100% high-pressure sodium lighting. The warehouses are occupied from 6 am to 8 pm on weekdays, 8 am to 6 pm on Saturdays, and 10 am to 4 pm on Sundays.

The single-family residences were built in 1981. Five of the homes are heated and cooled by electric air-source heat pumps; the other five are heated by natural gas and not cooled at all. All of the homes have electric water heaters and 100% incandescent lighting. They are occupied from 5 pm to 7 am on the weekdays and continuously occupied during the weekends.

The multi-family buildings were constructed in 1984. One of the buildings (24,000 ft²) is all electric, with electric resistance heating and electric water heaters. The other two buildings (28,000 ft² each) are heated with natural gas and have gas water heaters. All three buildings cool with window air conditioners. The lighting is 10% fluorescent and 90% incandescent. The buildings are occupied from 5 pm to 7 am on the weekdays and continuously occupied during the weekends.

2.5.3 Sample-3

This sample case file contains three administration buildings and four warehouses located in Cincinnati, Ohio.

The first administration building set consists of a single L-shaped building and is modeled using the Advanced Geometry capability (see Section 4.3.5). The building's heating and hot water service are supplied by a central energy plant—Central Hot Water Plant. The thermal loop supplying central hot water to this building (Loop #1) has recently been upgraded and will not be considered for abandonment even if cost effective, and has thus been marked “No abandonment”. Chilled water from the district chilled water plant provides all of the cooling.

The second administration building set has two nearly identical WWII-vintage buildings that have old leaky windows that are going to be replaced regardless of cost effectiveness (so the “Replacement required” box is checked for the windows—see Section 5.8). Heating for these buildings is all supplied by Central Hot Water Plant Loop #2 which is in very poor repair and is scheduled for abandonment; thus the loads supplied by this loop will be forced to retrofit to distributed building level technologies (e.g., building-level boilers). Chilled water from the district chilled water plant provides 80% of the cooling to each building and the other 20% is supplied by window air conditioners. The heating and cooling technology records are paired so that heat pumps (including ground-coupled systems) and gas packs may be evaluated as replacements. These buildings are utilized only every other weekend during the year except in the summer when they are operated daily (and are modeled using Seasonal/Variable Operation—see Section 4.3.4).

The first warehouse building set is a single fairly new insulated metal building with gas infrared heating, no cooling, and gas water heating. It has high output T5 fluorescent lighting inside, LED exit signs, and 250W high pressure sodium security lights on the exterior that operate at night.

The second warehouse building set represents three older buildings which receive their heat from either Central Hot Water Plant Loop #2 (scheduled for abandonment) or Loop #3. All have electric water heating, and none have cooling.

3 FEDS Application Overview

This section provides a brief overview of and orientation to the FEDS application, including structure, case and screen navigation, special buttons and indicators, menu items, and program functions. Information is available within the FEDS application for all inputs via Help on the *Help* menu and via the context-sensitive help key <F1>. For additional information on how to conduct a FEDS analysis, see FEDS Process in Section 5.

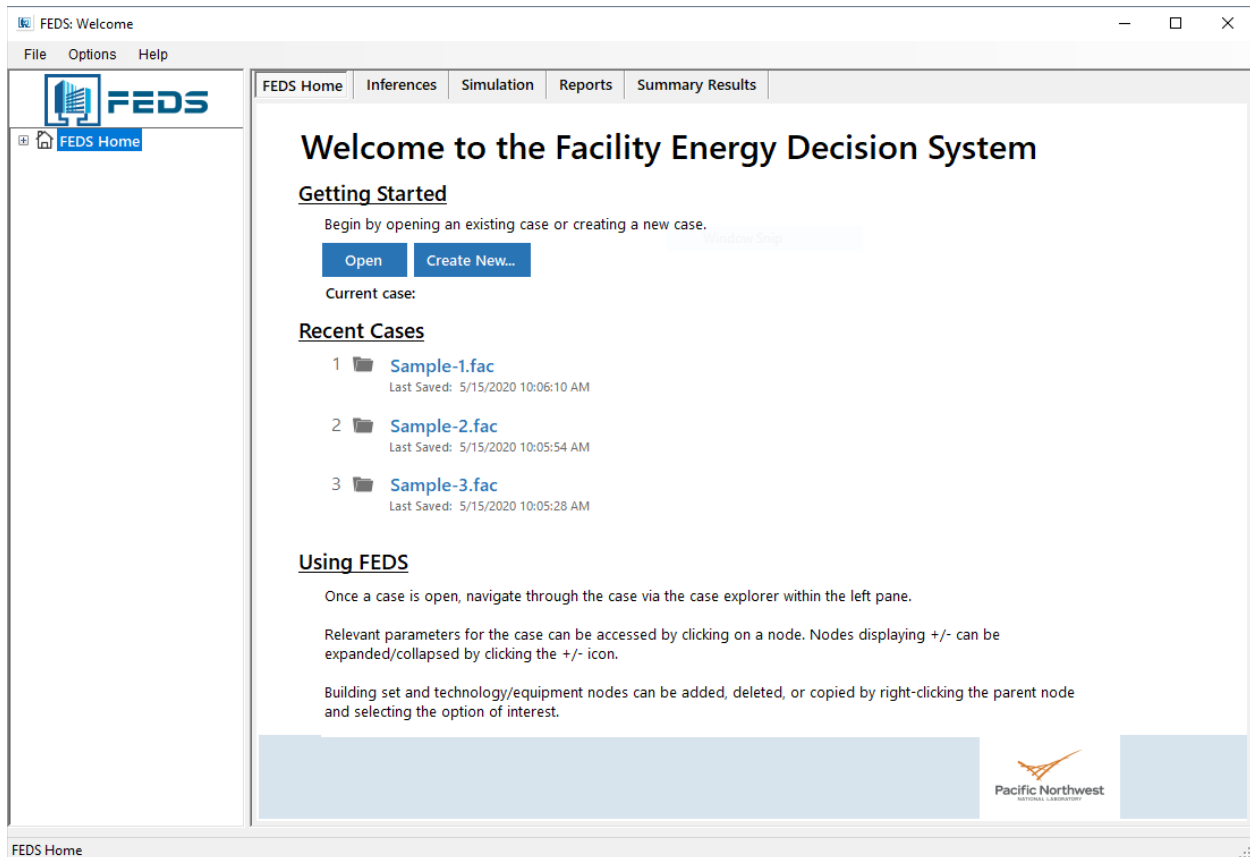


Figure 3.1 FEDS Home Screen

3.1 FEDS Home

After launching FEDS, you will see the *FEDS Welcome or Home* screen as shown in Figure 3.1. From this screen, you may Open an existing case or Create a new case. Once a case has been loaded or created, you can access the case navigation pane to explore the range of possible inputs and settings. In addition, a number of case and program functions can also be accessed using the menu bar or options under the FEDS Home node. For instance, the following options are accessible from within the FEDS Home (either via the navigation pane on the left or from the tabs at the top of the FEDS Home window): Inferences, Simulation, Reports, and Summary Results.

3.1.1 Inferences

Generate inferences for all or select buildings in the case, along with central plant and thermal loops, and the inferable facility inputs (Figure 3.2). Updating inferences also performs checks on inputs to trap any errors and report any required inputs that have not been specified. Inferences may also be run for individual building sets from the menu accessed by right-clicking the desired building set's top node within the navigation window.

| Building Sets | Inferences Status |
|--|-------------------|
| <input type="checkbox"/> [1] L-Shaped Admin | |
| <input type="checkbox"/> [2] Var Occ Admin New Windows | |
| <input type="checkbox"/> [3] Warehouse with IR Heating | |
| <input type="checkbox"/> [4] Warehouses on CEPs | |
| | |
| | |
| | |
| | |
| | |
| | |

< [Progress Bar] >

Select All Unselect All Update Inferences Clear Results

Facility and central plant inference results:

Figure 3.2 Inferences Screen

3.1.2 Simulation

Specify simulation parameters (e.g., calibration or optimization analysis type), exclude building sets, restrict retrofits, and run FEDS (Figure 3.3). Running FEDS initiates the baseline energy simulation to estimate current energy use and the optimization engine to evaluate energy efficiency measures and simulate their performance. A calibration analysis can also be performed in order to help compare FEDS energy simulation results with actual metered energy use. For more information on the simulation settings and options, visit Section 6.

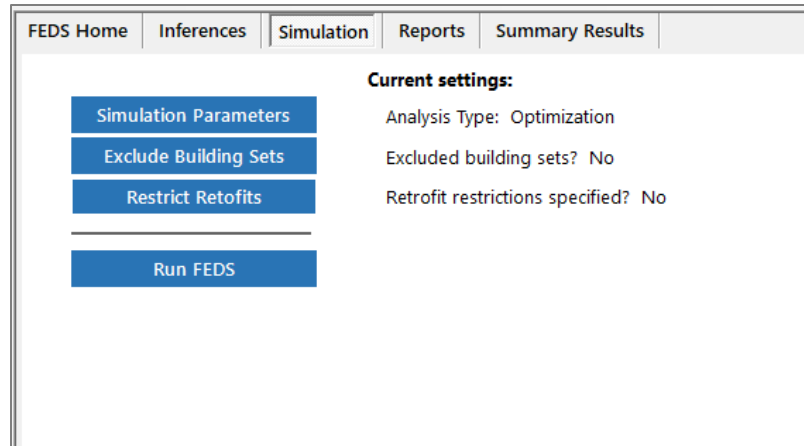


Figure 3.3 Simulation Settings

3.1.3 Reports

Access, create, and open a variety of FEDS report options (Figure 3.4). For more information, see FEDS Output in Section 8.

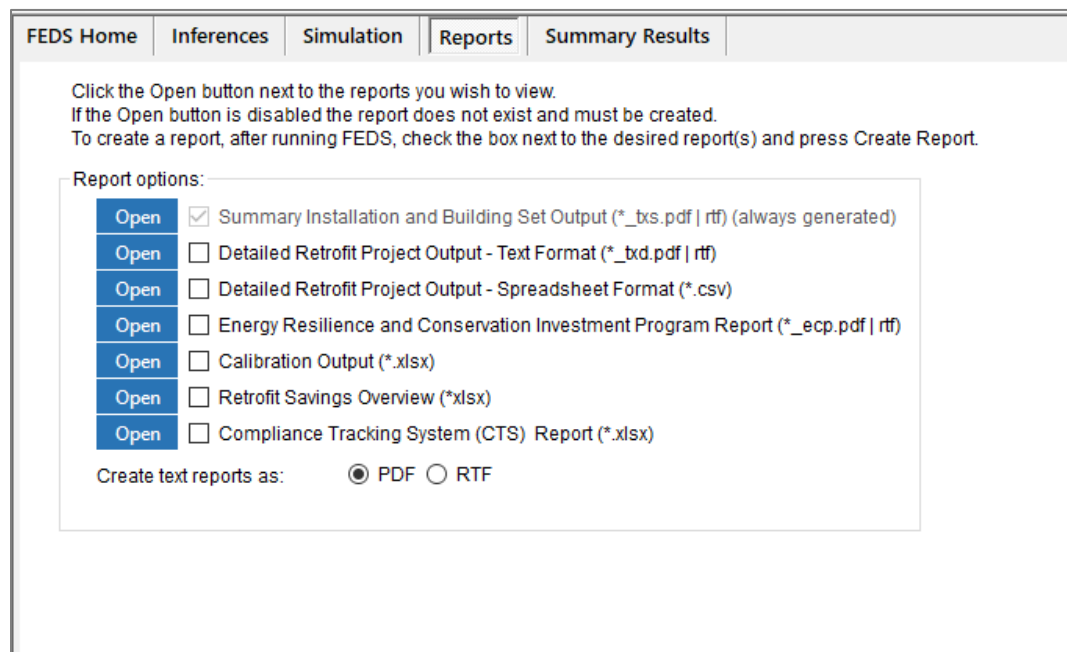


Figure 3.4 Report Options

3.1.4 Summary Results

View high level results of the latest FEDS simulation, showing annual and monthly energy use and electric peak demand, in tabular or graphical format, as shown in Figure 3.5. Note: Microsoft Excel is required in order to view the Summary Results.

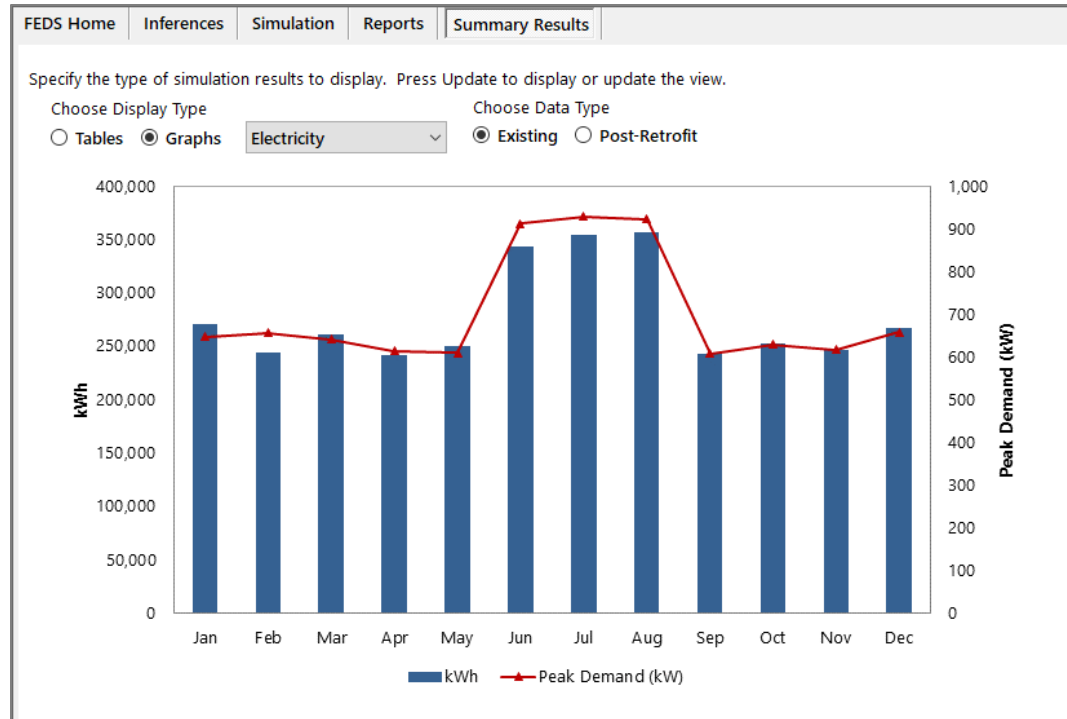


Figure 3.5 Summary Results

3.2 Case Navigation

A new feature of FEDS 8.0 is the case navigation pane at the left of the FEDS application window. As shown in Figure 3.6, the navigation pane offers direct access to each component of a FEDS case. The navigation pane presents a standard hierarchical structure that allows the sub-elements under each heading to be expanded or collapsed as desired. The number of available sub-elements varies according to the content. Right-clicking select elements with the mouse will bring up a menu of possible options for expanding or collapsing the navigation tree, and adding, copying, and deleting model components.

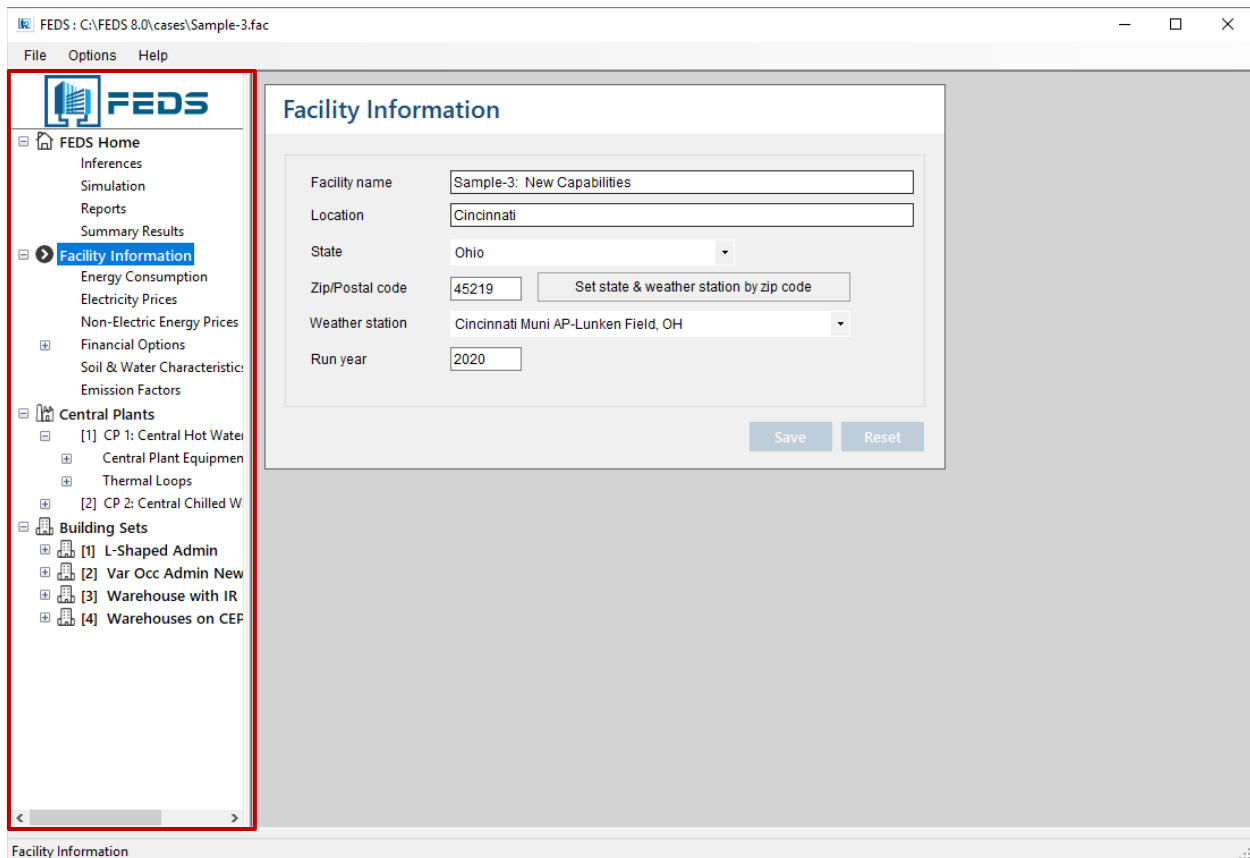


Figure 3.6 FEDS Navigation Pane

Each main component is highlighted here:

- **FEDS Home:** The FEDS Home page, where a new case can be opened or created. Additionally, access to the following capabilities is provided:
 - **Inferences:** Generate inferences for all or select buildings in the case, along with central plant and thermal loops, and the inferable facility inputs.
 - **Simulation:** Specify simulation parameters (e.g., calibration or optimization analysis type), exclude building sets, restrict retrofits, and run FEDS.
 - **Reports:** Access, create, and open a variety of FEDS report options.
 - **Summary Results:** View high level results of the latest FEDS simulation, showing annual and monthly energy use and electric peak demand, in tabular or graphical format.
- **Facility Information:** Specify information on the site, such as name, location, zip code, weather station. Additional screens of inputs at this level include:

- **Energy Consumption:** record actual energy consumption by fuel type (not required).
- **Electricity Prices:** specify electricity rate details.
- **Non-Electric Energy Prices:** input prices for all other fuel types used.
- **Financial Options:** funding source, discount rate, fuel price escalation rates, and any screening thresholds for projects.
 - **Regional Costs:** view and update labor rates, materials cost multipliers, taxes and overheads that apply to project costs in your location.
 - **Retrofit Cost Multipliers:** set cost multipliers as needed, to adjust the project costs estimated by FEDS, for specific end uses and technologies.
- **Soil & Water Characteristics:** soil type and other characteristics relevant to the performance of ground-coupled heat pump systems, plus groundwater temperature which is also used to calculate water heating energy.
- **Emissions Factors:** emissions factors for 6 pollutant types.
- **Central Plants:** Define information for any central plants and thermal distribution loops serving the site being modeled. There will be a central plant node for each central plant defined within the case (and none if no central plants are modeled). For each central plant there may be one or more Central Plant Equipment records defined, as well as multiple Thermal Loop records.

New central plant records can be created by right-clicking on the main Central Plants node, and selecting 'Add Plant'. The same can also be done for central plant equipment and thermal loop records. Records of each type may also be copied or deleted by right-clicking the mouse on the specific record you wish to copy or delete.¹
- **Building Sets:** A FEDS case can contain any number of building sets. There are a number of input screens associated with each building set that enable the specification of pertinent information from building type, size, and vintage to the characterization of use, occupancy, geometry, construction and envelope, lighting, heating, cooling, ventilation, hot water, motor, and miscellaneous equipment.

New building sets can be added by right-clicking the mouse on the main Building Sets node and selecting 'Add Building Set'. Existing building sets can be copied or deleted by right-clicking on the desired building set and selecting 'Copy' or

¹ Central plant records can also be added in two other ways: 1) a default central plant is created when inferences are updated on buildings using a central fuel (steam, hot water, chilled water) with no source loop identified, and 2) a 'purchased fuel central plant' is automatically created when a fuel price is saved for a purchased central fuel.

‘Delete’. Building sets can also be imported from other FEDS cases using the Import Building Sets option (see Section 3.7.1). For building technology records (e.g., lighting, heating, cooling, hot water, motors, miscellaneous equipment), right-clicking will also allow you to add, copy, and delete. The right-click menu also provides the option to update inferences for the current building set.

Remember: Right-click select navigation pane nodes to Add, Copy, or Delete a record or Update Inferences for a specific building set.

3.3 Screen Navigation and Operation

FEDS 8.0 is a menu-driven Windows application and is designed to be operated with a mouse and keyboard (as well as just a keyboard). Its features include the following:

- **Tab and shift-tab:** Tab moves the cursor forward from one data field to the next. Shift-Tab moves the cursor backward from field to field.
- **Buttons:** Buttons control many operations and often open a new window, e.g., selecting lighting technology records. A single click of the left mouse button (or SPACEBAR) will activate any button.
- **Check boxes:** A left mouse (or SPACEBAR) click in a check box will select a function. Clicking the box again will turn off the function. Some check boxes are mutually exclusive, that is, selecting one item will deselect a previously selected item.
- **Radio buttons:** Radio buttons are selected in a similar manner as check boxes (using the mouse or arrow keys); however, only one option may (and must) be specified.
- **Data fields:** On many screens, data fields are used to enter information. A label describing the function of the box is located next to the data field. When the cursor is in the desired data field, enter the requested information. A tab will move you to the next field.
- **Drop-down lists:** For several data screens, you will need to access a drop-down list to select from a list of choices. A left mouse-click or pressing ALT+DOWNARROW will display the list. The slide bar and arrows will move you to the desired item. A single left mouse-click (or ENTER) will select the item.


3.4 Save, Reset, Close Buttons

Each of the FEDS input screens has a Save and Reset button. These buttons will remain disabled as long as no edits or changes are detected to the inputs on that screen (or underlying screens). When a change is detected, both buttons will become enabled.


<Save> will save the information have entered. **<Reset>** will revert the changes back to their previous state from the last save.


Some input screens will also have Apply, Cancel, and Close buttons. **<Apply>** saves the changes and returns to the parent screen. **<Cancel>** returns to the parent screen without saving, and **<Close>** will close the current window and return you to the parent screen.


3.5 Special Indicators and Input Locking

 Inputs that have a blue arrow pointing at them are required inputs and have not yet been satisfied. For a new building set or technology record, required inputs must be provided in order to successfully determine the inferences and run the model. These must be provided by the user and are not inferable by FEDS and, thus, do not have the locking feature associated with them. Once a valid input is provided for a required input and saved successfully, the blue arrow will disappear, indicating that the requirement has been met.

> From the case navigation pane, a red symbol next to a given input screen node indicates that one or more required inputs remain that must be specified before FEDS can update inferences or perform a simulation.

 Inputs that have this open lock symbol next to them are inferable by FEDS meaning that FEDS will update the value when you select **<Update Inferences>**. In the unlocked state, these values are subject to change each time inferences are updated depending upon which other values may have been changed by the user.

 This closed lock symbol next to an input indicates that its value is locked, and will not be changed by FEDS. All values entered by the user are automatically locked. To unlock a value, click on the lock icon to change it to an open lock. Once unlocked, this value will then be inferred the next time inferences are updated. Inputs can also be locked to the current value by clicking directly on the lock icon.

 This standard Windows Help icon offers additional context for select inputs and related concepts. Press this button to access guidance about the input or help in understanding how to specify the information.

Recommended Inputs: Inputs without the blue required input arrow or lock icons are highly recommended but not required for FEDS to run. These include user-defined labels for the installation, building set, and technology equipment descriptions as well as most facility level information and economic parameters. Except as noted for particular inputs (e.g., energy consumption inputs), many of these values affect optimization and are essential for legitimate results. If, for example, the energy price input screens are not visited, all fuels will be valued at \$0.00/unit and no fuels will be inferred as available to the building sets. Similarly, if building occupancy hours are not specified, FEDS will

assume that the building set is never occupied. Therefore, it is important to review and provide this information.

3.6 Help Options

FEDS Help is available via a number of sources:

- The FEDS User's Guide may be accessed from the *Help* menu or by pressing <Ctrl+F1>.
- Context-sensitive help for each input is also available. To access help for a particular input, activate the input cell or box by clicking on it with the mouse (or tabbing to it) and hit <F1>. OR simply hover the mouse pointer over the input text. A brief explanation of what input FEDS is requesting, along with information on how FEDS uses that data may be given. Whenever you are unclear about a certain input first check the help text - your questions will likely be answered.
- On some screens additional context is provided by a blue question mark help icon. Clicking on this will open a window containing information relevant to the current input screen or concept.

3.7 Application Menu Options

The FEDS application currently includes the following menu bar items: File, Options, and Help.

3.7.1 File Menu

Each of the following case options is accessible from the *File* menu:

- **New case [Ctrl+N]:** Allows you to create a new case. See Create New Case in Section 2.3.1.
- **Open case [Ctrl+O]:** Opens an existing binary (*.fac) case file to be viewed, edited, or run. Will also open and convert previous version FEDS cases. See Open Existing Case in Section 2.3.2 and Converting Older FEDS Case Files in Section 2.3.3.
- **Save case [Ctrl+S]:** Saves the current case input data.
- **Save case as:** Enables you to save the current case to a new filename. You will be asked to specify a case name and path. If you just want to look at a case and not change any values, <Save case as...> is the best way to ensure that the original case will not be altered. It also provides a time-saving tool for creating a new case that has similarities to an existing case. Just save a current case as a new name and modify the parameters necessary to define the new installation and building data, rather than entering it all from scratch.
- **Import Building Sets [Ctrl+I]:** An import tool to allow building sets from other existing cases to be merged into the current case. This feature allows the

combining of data for integration of multi-user input sessions, from separate case files. When this function is selected, a case navigation window will open in order to identify the case containing the building sets to be imported into the current FEDS case. Note that all of the building sets from the selected case will be imported and appended at the end of any building sets in the current case. This process will only import the building set data, and no facility data (energy prices, financial parameters) or central plant and loop inputs will be imported.

- **Recent:** Lists as many as ten most recently opened FEDS cases, for ease in opening them.
- **Exit [Alt+F4]:** Closes the current FEDS case and shuts down the FEDS application. This can also be accomplished via the close application X at the top right of the application window.

3.7.2 Options Menu

Each of the following case options is accessible from the *Options* menu:

- **Input Profiles:** Provides access to the hourly profiles for more detailed specification of select parameters (e.g., electric rates, building occupancy, heat/cool setpoints, light and equipment utilization rates, water temperature).
 - View/Modify Profiles (Export): writes the select facility and building input profiles to disk (in CSV format) for viewing and editing. Any changes made to the input profiles must be saved by changing the Apply Profile Type for the edited profiles from “FEDS” to “User”. The edited CSV files must then be saved and imported back into FEDS.
 - Save Profiles (Import): reads the facility and building input profiles back into FEDS for use in subsequent simulations.
- **Import EPW Weather File:** This option allows users to apply weather data for other locations or time periods to their FEDS simulations and analyses. The weather station data must be in standard EPW file format. Review the additional help provided from the import screen when selecting this option.
- **Autosize Nav Menu:** This user option, when turned on, will automatically size the width of the navigation pane to show the full length of description text. Auto-sizing can also be accomplished manually by double-clicking the right border of the navigation pane.
- **Highlight Selected Input Label:** Selecting this option will highlight the text label of the current selected (active) input cell in a **combination of blue text and grey background**. The purpose is to aid in tracking the current input. Unchecking this option will turn off this feature.

3.7.3 Help Menu

Each of the following case options is accessible from the *Help* menu:

- **User's Guide [Ctrl+F1]:** An electronic pdf version of the FEDS User's Guide can be accessed by selecting this option.
- **About FEDS:** The About FEDS page lists information about the current FEDS version, sponsors, copyright notice, and a link to the FEDS website.

3.8 Display Modes

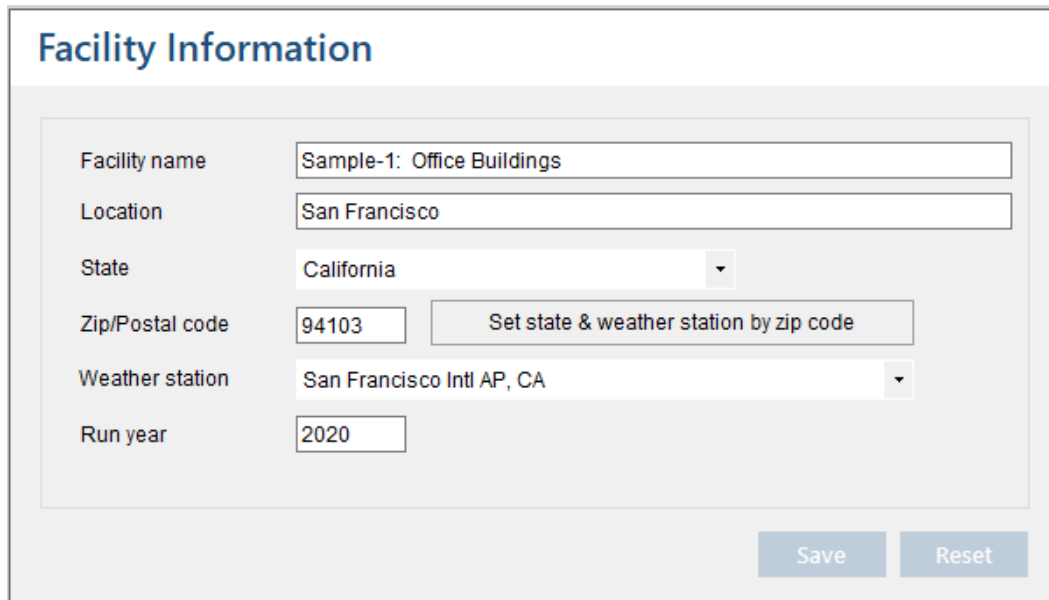
In previous versions of FEDS (e.g., FEDS 7.1 and earlier) there were two modes available for displaying available model inputs: Minimum Set and Maximum Detail display. As of FEDS 8.0, the minimum set display option has been removed and all inputs are viewable. However, keep in mind that **only the required inputs** (designated by the blue arrow - see Section 3.5) must be specified and any of the other inputs can be left for FEDS to infer. Thus, only the display option has changed and not the behavior or performance of the FEDS Inferences.

4 FEDS Inputs

This section highlights the input options that define a FEDS case. These are grouped according to facility, central plant and thermal distribution loop, and building inputs.

4.1 Facility Information

After launching FEDS, you will see the *FEDS Welcome or Home* screen. From here, the Facility Information screen (shown in Figure 4.1) may be accessed by clicking on the appropriate node from the navigation pane on the left side of the FEDS application window. This screen prompts you for general descriptive information about the site, such as its name, location, zip code, and weather station.



The screenshot shows the 'Facility Information' screen in the FEDS application. The title 'Facility Information' is at the top left in a blue font. Below it is a light gray form area containing several input fields. The 'Facility name' field contains 'Sample-1: Office Buildings'. The 'Location' field contains 'San Francisco'. The 'State' field is a dropdown menu currently showing 'California'. The 'Zip/Postal code' field contains '94103', and next to it is a button labeled 'Set state & weather station by zip code'. The 'Weather station' field is a dropdown menu showing 'San Francisco Intl AP, CA'. The 'Run year' field contains '2020'. At the bottom right of the form area are two buttons: 'Save' and 'Reset'.

Figure 4.1 FEDS Facility Information Screen

The following additional facility level input screens can be accessed beneath the Facility Information node in the navigation pane.

4.1.1 Energy Consumption

Provides information on the energy consumption at the site for a typical year. These values are currently not used in FEDS calculations but are valuable as a measure of the input data accuracy when compared to consumption values generated in FEDS output.

4.1.2 Electricity Prices

These data include detailed electric rate structure information for flat and time-of-day rates, demand ratchets, and minimum demand, as applicable. The electric rate schedule for the buildings being modeled should be analyzed to determine the

appropriate marginal rate inputs. Typically, the buildings modeled together in a single FEDS case should all be served by the same billing meter (especially if there are demand charges), and the same rate structure.

4.1.3 *Non-Electric Energy Prices*

Fuel price information for all non-electric fuels available at the installation, including oil (distillate and residual), natural gas, coal, purchased steam, purchased hot water, purchased chilled water, and other fuels. Building set fuel availability is defaulted based on these inputs. Note that if a price is entered for any energy type, then the program will assume (unless changed for a building set in "Fuel Type" inputs) that the energy source is available to all buildings being modeled and will optimize the life-cycle economics for all buildings using technologies that employ that energy source. Conversely, if a price is not entered for a particular fuel, then no technologies that use that fuel will be evaluated as possible retrofits. The value of any site-generated fuels (e.g., self-generated steam, hot water, chilled water) are determined by the model based on information provided in the central plants and thermal loops inputs.

4.1.4 *Financial Options*

This edit group provides the model information on financial parameters necessary for life-cycle cost analysis and system optimization. These parameters include discount rate, energy escalation rates, and screening on simple payback and savings-to-investment ratio. Specifications for alternative financing arrangements can also be accessed [here](#).

Two additional financial input screens are accessible as sub-nodes. These are the Regional Costs and Retrofit Cost Multipliers inputs. These provide the user access to FEDS' internal project cost assumptions used in calculating the cost of retrofit equipment. The FEDS default cost data considers important intra-state variations to construction labor rates and construction costs, based on the state and zip code inputs. Further altering these values allows users the ability to further adjust additional variation or local anomalies that may be important for project cost estimation and to more accurately model the cost of retrofit projects in specific locales.

Regional Costs

This screen (see Figure 4.2) displays relevant project cost data for the site including fully burdened labor rates, materials cost multipliers (fractions of national average costs), sales tax rate, contractor overhead & profit, design cost, and site SIOH rates for that location. The FEDS regional default data is displayed in the cells, and values may be changed by entering new data and saving. These changes apply globally to all cost data for all end-uses in a particular case.

The "Other (global multiplier)" input is a value applied to the total cost of all retrofit projects considered during optimization. It can be used to account for any general costs associated with completing retrofit projects at your site that are not captured by any of the other cost values. As always, for more detailed information about specific inputs,

refer to the on-line help for that input cell by pressing the <F1> key when the cell is active.

Regional Cost Data

| Fully burdened labor rates (\$/hr): | | Regional materials cost multipliers (U.S. average = 1.0): | |
|-------------------------------------|--------|---|-------|
| Carpenter | 85.28 | Envelope insulation | 1.016 |
| Common laborer | 70.31 | Windows | 1.046 |
| Electrician | 102.28 | Electrical equipment | 1.042 |
| Equipment operator | 90.76 | HVAC equipment | 1.0 |
| Glazier | 91.95 | Service hot water equipment | 1.0 |
| Plumber | 123.64 | Sales tax rate (%) | 10.1 |
| Insulator | 95.44 | Contractor overhead & profit | 15.0 |
| Sheet metal worker | 105.54 | Design cost (%) | 10.0 |
| Steamfitter | 123.64 | Site SIOH (%) | 6.0 |
| | | Other (global multiplier) | 1.0 |

Save Reset

Figure 4.2 Regional Cost Data

Retrofit Cost Multipliers

A separate overall cost multiplier is available for each end-use (heating, cooling, lighting, etc.) and sub-end-use (boilers, package units, fluorescent fixtures, etc.) to allow for further adjustments to the cost of particular systems. Using these multipliers, the user is able to adjust the total lumped cost (including all labor, materials, design, overhead, etc.) of specific types of systems or technologies. See Figure 4.3.

These multipliers are intended to be used only after adjusting the Regional Cost Data and running FEDS. At that point if the specified cost for a particular retrofit is different than the known cost, an adjustment may be made by entering a multiplier for that technology to replace the default 1.0. If the costs of all technologies within a given end-use technology (e.g., all lighting fixtures) are off by a certain factor, then an end-use multiplier may be applied. For example, if the cost output by FEDS = \$100 and the actual cost = \$95, 0.95 should be entered as a multiplier for that particular technology type for the next model run.

End Use / Technology Cost Multipliers

Use the following multipliers, as appropriate, to adjust FEDS project costs according to a reliable basis such as bid detail (1.0 represents the unadjusted FEDS cost for your location). Be sure to review and update the Regional Cost Data first.

| | | | | | |
|-----------------------------------|----------------------------------|--|----------------------------------|----------------------------------|--|
| Envelope | <input type="text" value="1.0"/> | | HVAC Controls | <input type="text" value="1.0"/> | |
| Roof/ceiling insulation | <input type="text" value="1.0"/> | | Heating | <input type="text" value="1.0"/> | |
| Wall insulation | <input type="text" value="1.0"/> | | Boilers | <input type="text" value="1.0"/> | |
| Floor insulation | <input type="text" value="1.0"/> | | Furnaces | <input type="text" value="1.0"/> | |
| Windows | <input type="text" value="1.0"/> | | Infrared | <input type="text" value="1.0"/> | |
| Lighting | <input type="text" value="1.0"/> | | Cooling | <input type="text" value="1.0"/> | |
| Controls | <input type="text" value="1.0"/> | | Package units | <input type="text" value="1.0"/> | |
| Incandescent | <input type="text" value="1.0"/> | | Conventional chillers | <input type="text" value="1.0"/> | |
| Halogen | <input type="text" value="1.0"/> | | Absorption chillers | <input type="text" value="1.0"/> | |
| Compact fluorescent | <input type="text" value="1.0"/> | | Gas engine-driven chillers | <input type="text" value="1.0"/> | |
| Fluorescent | <input type="text" value="1.0"/> | | Air source heat pumps | <input type="text" value="1.0"/> | |
| Mercury vapor | <input type="text" value="1.0"/> | | Dual-fuel heat pumps | <input type="text" value="1.0"/> | |
| Metal halide | <input type="text" value="1.0"/> | | Ground-coupled heat pump systems | <input type="text" value="1.0"/> | |
| High pressure sodium | <input type="text" value="1.0"/> | | Water source heat pumps | <input type="text" value="1.0"/> | |
| Low pressure sodium | <input type="text" value="1.0"/> | | Horizontal ground loops | <input type="text" value="1.0"/> | |
| LED | <input type="text" value="1.0"/> | | Vertical ground loops | <input type="text" value="1.0"/> | |
| Induction | <input type="text" value="1.0"/> | | Wells | <input type="text" value="1.0"/> | |
| Exit | <input type="text" value="1.0"/> | | Pumps | <input type="text" value="1.0"/> | |
| Service hot water | <input type="text" value="1.0"/> | | Motors | <input type="text" value="1.0"/> | |
| Distributed system tanks | <input type="text" value="1.0"/> | | | | |
| Distributed system heat pumps | <input type="text" value="1.0"/> | | | | |
| Loop system boilers | <input type="text" value="1.0"/> | | | | |
| Loop system heat pumps | <input type="text" value="1.0"/> | | | | |
| Other (wraps, flow reducers, etc) | <input type="text" value="1.0"/> | | | | |

Save

Reset

Figure 4.3 End Use/Technology Multipliers

4.1.5 Soil & Water Characteristics

This screen provides access to the hydrogeologic characteristics for the site. Such information is used in analyzing the cost and performance of various ground-coupled heat pump systems. The ground water temperature is also used in the service hot water calculations.

4.1.6 Emissions Factors

Along with energy consumption and costs, FEDS also tracks and reports the estimated emissions impacts of selected retrofits and upgrade packages. FEDS provides the ability to view and modify the emissions factors for 6 pollutant types (carbon dioxide, sulfur oxides, nitrogen oxides, methane, nitrous oxide, and total greenhouse gases in carbon dioxide equivalent) for each purchased fuel type available in FEDS. These represent full fuel-cycle factors and are inferred based on the state or province in which the facility is located.² For most locations outside of the United States and Canada, FEDS infers emissions factors based on the U.S. average values. However, in order to provide greater flexibility and accuracy in modeling site specific emissions and variations in electricity source fuel mix, the option to override these inferred factors is provided (see Figure 4.4). This is useful in instances where you know the specific emissions profile for the electricity used on-site, as well as perhaps for other fuels.

Regional Emissions Factors

Enter emissions factors (if known) for the following pollutants and fuel types, in pounds per unit of fuel consumed.

Carbon Dioxide | Sulfur Oxides | Nitrogen Oxides | Nitrous Oxide | Methane | CO2 Equivalent

| | | Carbon Dioxide (CO2) | |
|----------------|--------------|----------------------|--|
| Electricity | (lbs/kWh) | 0.21306 | |
| Distillate oil | (lbs/gallon) | 26.63036 | |
| Residual oil | (lbs/gallon) | 29.63869 | |
| Natural gas | (lbs/therm) | 13.0 | |
| Coal | (lbs/ton) | 4821.968 | |
| Other fuels | (lbs/MBtu) | 163.0 | |

Save Reset

Figure 4.4 Regional Emissions Factors

4.2 Central Plants

The central plant inputs are optional and allow users with central energy plants to appropriately model the energy required to generate and transmit the fuels to their

² The state-level source emissions factors were derived from the sum of pre-combustion and combustion emissions factors associated with the electricity generation mix for each state presented by: N. Leslie. 2019. *Full-Fuel-Cycle Energy and Emission Factors for Building Energy Consumption – 2018 Update*. American Gas Association.

buildings. FEDS will calculate the input energy requirements and also evaluate opportunities for trimming loops or abandoning entire plants in favor of in-building boilers and chillers. The Central Plant input screens allow the creation of multiple central plant records, each with multiple thermal loops that distribute the central fuels to the buildings. The plant type, equipment and thermal loop parameters, and operating costs can be specified. All of this information will be used by the model to determine the value of the central fuels at each building and for use in retrofit optimization.

Central plants can be added, copied, or deleted via the central plant node menu, accessed by right-clicking on the appropriate central plant node.

The screenshot shows the FEDS software interface. The left sidebar contains a tree view with the following structure:

- FEDS Home
- Facility Information
- Central Plants
 - [1] CP 1: Central Hot Water Plant - Selfgen (selected)
 - Central Plant Equipment
 - CP 1: Central Hot Water Plant Equipment
 - Thermal Loops
 - Central Hot Water Plant Loop #1
 - Central Hot Water Plant Loop #2
 - Central Hot Water Plant Loop #3
- [2] CP 2: Central Chilled Water Plant - Selfgen
 - Central Plant Equipment
 - CP 2: Central Chilled Water Plant Equipme
 - Thermal Loops
 - Central Chilled Water Plant Loop #1
- Building Sets
 - [1] L-Shaped Admin
 - [2] Var Occ Admin New Windows
 - [3] Warehouse with IR Heating
 - [4] Warehouses on CEPs

The main panel displays the 'Central Plant Information' form. The 'General Plant Information' tab is active. The form contains the following fields and values:

- Plant ID: CP 1: Central Hot Water Plant - Selfgen
- Description: (empty)
- Type: Central hot water
- Temp/Pressure: ☐ High ☐ Medium ☒ Low
- General Plant Information tab:
 - Total plant capacity (Million Btu/hr): 23.466
 - Predominant source fuel: Coal
 - Value of thermal output (\$/Million Btu):

| Marginal | Average |
|----------|----------|
| 6.077988 | 6.349708 |
 - Plant operating season:

| Month | Day |
|---------------------|-----|
| Start date: January | 1 |
| End date: December | 31 |
 - Number of equipment types defined: 1
 - Number of distribution loops this plant serves: 3
 - Average supply temperature (°F): 225
 - Average return temperature (°F): 175

Buttons for 'Save' and 'Reset' are located at the bottom right of the form.

Figure 4.5 Central Plant Inputs

4.2.1 Central Plant Equipment

The central plant equipment inputs allow users to specify the characteristics of the equipment in the central plant for generating the steam, hot water, or chilled water produced by the plant. Boilers or heat exchangers can be specified for steam or hot water plants, while a variety of chillers can be specified for chilled water plants.

Multiple equipment records can be created to represent a mix of different equipment and/or fuel types combining to provide the total output. Central plant equipment records can be added, copied, or deleted by right-clicking on the appropriate node in the navigation pane and selecting the preferred option.

4.2.2 Thermal Distribution Loops

The distribution lines that deliver the central fuels to the buildings are defined here, with several parameters related to the size, length, temperature, and insulation of both supply and return runs. Multiple distribution loops may be defined for each central plant, and the Loop ID is used to identify (via the 'source loop' inputs at the building technology level) the loop that delivers the central fuel to specific buildings and loads. Loops may be added, copied, or deleted via the menu that appears when right-clicking on the appropriate thermal loop node in the navigation pane.

4.3 Building Sets

A building set is a group of buildings of similar type that can be modeled together, ideally of similar size, age, fuel availability, occupancy hours, and construction. A building set will often consist of a single building but can represent a group of buildings with similar characteristics. See Section 5.3 for more information.

Clicking on a building set node (beneath the main Building Sets node) on the navigation pane will open the *Building Set: General Information* screen for the selected building set. If no building sets are currently defined in the case, they can be added by right-clicking on the Building Sets node and selecting 'Add Building Set'. Each building set has its own *General Information* screen so while there will only be one *Facility Information* screen per case, the number of Building Set records is essentially unlimited.

Tip: Screening assessments of sites with many buildings will often use building sets to model common building types together. As more data is gathered and more detailed analysis is performed, the number of buildings modeled together in a building set is often reduced, to better model the differences and develop more accurate and actionable results.

Building Set: General Information

Building set identification

Description

Building 'Type' classification

Number of buildings in this set

Total floor area for this building set (sq. ft.)

Average construction year for buildings in this set

How many Use-Areas are in this building set?

Aspect ratio (north facing length / east facing length)

Solar gain method

Linked building set: None

1

2

Calculate solar gains by facing directions

Normalize solar gains

Link

Unlink

Options

Save

Reset

Figure 4.6 FEDS Building Set Inputs Screen

4.3.1 Required Building Inputs

The following are required inputs for each building set:

- Building Type:** These include 16 civilian (commercial and residential), and 26 military types, which are listed in Table 4.1. You create building sets, which are logical groupings of buildings of one type that have similar characteristics. An unlimited number of building sets can be created of each building type.
- Building Set Physical Data:** These data include the average vintage (construction year), size, and number of buildings in that particular building set.
- Building Operating/Occupancy Hours:** These include occupancy starting and ending hours for weekdays, Saturdays, and Sundays (or weekdays, Fri/Sat, and Sundays if a 4-day week schedule is selected). If no start and end time is specified FEDS will assume the building is unoccupied.
- End-use Inputs:** These include the percentage of building set end-use service provided by each lighting technology, heating fuel type, cooling technology, and service hot water fuel type.

Table 4.1 FEDS Building Types

| FEDS Civilian Building Types | |
|------------------------------|---------------------------------|
| Assembly | Public Order/Safety |
| Education | Warehouse & Storage |
| Food Sales | Other |
| Food Service | Single Family Detached |
| Health Care | Single Family Attached |
| Lodging | 2 to 4 Unit Buildings |
| Mercantile and Service | 5 or More Unit Buildings |
| Office | Mobile Homes |
| FEDS Military Building Types | |
| Administration | Morale, Welfare, and Recreation |
| Barracks | Military Other |
| Chapel | Production and/or Process |
| Clinic | Recreation |
| Clubs | Schools and/or Training |
| Commissaries | Security |
| Dining Halls | Shops |
| Electronics | Storage |
| Exchange Facilities | Warehouse |
| Guest Houses | Single Family Detached House |
| Hangar | Single Family Attached House |
| Hospital | Duplex |
| Labs | Multifamily 3 or More Units |

4.3.2 Inferable Building Inputs

Any input that has a lock icon beside it is inferable by FEDS (see Section 3.5 for an example and description of the locks). That means that if the user does not input a value, FEDS will automatically generate and populate the input with the most likely value considering all of the other related parameters. Therefore, the inability to collect or confirm a detailed building system parameter will not impede a user from developing and simulating a model. The inferred values will appear on the screens where they can be evaluated and changed if necessary. Given the very small number of required inputs, the bulk of inputs in FEDS are inferable, and cover the full range of building characteristics, from occupancy, geometry, construction and envelope, lighting, HVAC, water heating, and miscellaneous equipment. The following are examples of select inferable FEDS inputs:

- **Building Occupancy:** The number of occupants present during occupied and unoccupied periods, plus sensible and latent occupant heat gains, are inferable by FEDS. Seasonal and variable operation can also be specified for each use area. More information on the Occupancy inputs is found in Section 4.3.4.
- **Building Geometry:** The number of thermal zones, floors, percentage of wall area that is glass, and floor-to-ceiling and floor-to-floor heights. Additionally, an *Advanced Geometry* option allows users the ability to specify detailed building geometry parameters at the specific zone and/or orientation level (see Section 4.3.5 for more information).
- **Envelope Inputs:** Construction materials and thermal characteristics of roof, floor, walls, and windows. Detailed descriptions of FEDS floor, wall, roof, and window types are available in [Appendix F](#).
- **Lighting:** fixture type, configuration, utilization, heat to space, presence of controls. Comprehensive listing of fixture configurations in Appendix H.
- **Heating and Cooling:** set points, equipment types, efficiencies, etc.
- **Ventilation System:** Control mode and specific system parameters, including design supply air, outdoor ventilation air, plus economizer, demand-controlled ventilation, reheat, and dehumidification system specification and control options.
- **Service Hot Water:** Daily consumption, distributed and loop system types and associated parameters.
- **Motors:** Electric motor parameters and operating characteristics.
- **Miscellaneous Equipment:** Equipment capacity densities and utilization factors for all other miscellaneous loads (of any specified fuel type). Miscellaneous equipment records are automatically generated for each FEDS building set (by use area) and inferred according to the specific use area type. Categories include refrigeration, food preparation, and other (which includes computer/office equipment, etc.).

4.3.3 Use Areas

FEDS allows the modeling of buildings with up to two distinct uses and occupancy patterns within each building set. For single use buildings sets, FEDS will infer the use area type to be the same as the building type. However, the user can change this. A reason to select a use area type that is different from the building type would be if the building is currently being used for a purpose other than it was originally built for. In general, the building type describes the construction of the building and helps to define construction and geometry characteristics while the use area impacts the operational characteristics of the space, such as occupancy, equipment utilization, and HVAC space temperature setpoints. As an example, barring a major renovation, a building

constructed as a warehouse, but now serving primarily as an office space may best be modeled as a warehouse building type and office use area type.

An example of a dual-use building is a barracks renovated with administrative offices on the first floor. If this set were modeled as one use-area, the entire building would be assumed to be barracks and all operating and energy consumption characteristics would be driven by the barracks use area type. As a dual-use set, however, the use-area parameters are inferred and set distinctly for each area based on the area types and percentages. Following is a list of use-area-specific parameters:

- Use-area type: selected from existing list of use-area types; must specify the percentage of each building under this use type
- Occupancy: operating schedules, number of occupants during the different occupancy periods, and seasonal and variable operation
- Lighting technology configurations and fixture densities
- Distributed service hot water systems: Distributed systems are the only type that may be selected for Use-Area 2. *Loop systems are only specified in Use-Area 1 and are modeled to serve the entire building set.*
- Motor types, size, utilization and load factors
- Miscellaneous equipment types, fuel types, capacity densities and utilization factors.

4.3.4 Occupancy

Standard Occupancy

The standard occupancy inputs (Figure 4.7) consist of occupancy hours (typical occupancy start and end hours) for each standard day type (weekday, Saturday, Sunday). The option to specify whether the standard work week consists of 5 days or 4 days is also possible. Within a 4-day work week, weekdays are defined as Monday-Thursday, and Friday/Saturday hours are specified together.

Seasonal/Variable Operation

These inputs can be used to specify the months and days of each type that the building set is occupied according to the standard occupancy schedule. This can be useful when modeling school or other buildings that are shut down for part of the year, as well as buildings that experience highly variable use throughout the year (e.g., seasonal camp or retreat facilities, extended retail hours, training periods at National Guard facilities). Two options are available for specifying the non-operating periods; these are 'Non-operating (no occupancy)' which is the default setting and 'Low occupancy'. Under the Non-operating (no occupancy) definition, the building is modeled as if it is temporarily shut down with no occupants and only minimal energy use (e.g., only exit lighting and heating set at Unoccupied Season thermostat setpoint for freeze protection). Under the

Low occupancy setting, the non-operating periods are modeled the same as the unoccupied periods of the standard operating schedule (e.g., with reduced occupants, thermostat setback if defined, and reduced lighting and equipment utilization).

Figure 4.8 highlights the seasonal and variable operation inputs. This example shows the inputs for a building that is shut down for two and a half months during the summer. If the shut-down begins on Saturday June 20th and runs through the end of August, the inputs could be specified as shown. Sixty-eight percent (15 of the 22) of June weekdays follow the standard operating schedule, along with half of the four Saturdays and four Sundays. As all days in July and August are non-operating, zeros can be input for each day type or the 'Non-operating?' box can be checked next to those months.

Occupancy

Standard Occupancy

Seasonal/Variable Operation

Occupancy schedule type ☒ 5-day work week ☐ 4-day work week

Occupancy hours:
Enter hours in 24 hour format without the colon; e.g., 1800 represents 6pm. Midnight can be specified as either 0 or 2400. For continuous occupancy, enter the same start and end times (but not 0 or 2400). For unoccupied day types, enter 0 for both the start and end times.

| | Start | End | Set Start/End for: | |
|----------|-------|------|--------------------|------------|
| Weekday | 700 | 1800 | Continuous | Unoccupied |
| Saturday | 1000 | 1600 | Continuous | Unoccupied |
| Sunday | 0 | 0 | Continuous | Unoccupied |

Number of occupants (during operating months):

Occupied periods

Unoccupied periods

Sensible heat gain per occupant

☐ Btu/hr ☒ Watts

Latent heat gain per occupant

☐ Btu/hr ☒ Watts

Save

Reset

Figure 4.7 FEDS Standard Occupancy Inputs

Occupancy

Standard Occupancy

Seasonal/Variable Operation

Does building operation vary by week or month? ☒ Yes ☐ No

Select non-operating period status type: ☒ Non-operating (no occupancy) ☐ Low occupancy

Percent of days within each month that follow the operating schedule defined by the General Occupancy inputs. Check the 'Non-operating' box for months that are completely

| | Weekday | Saturday | Sunday | Non-operating? |
|-----------|---------|----------|--------|-------------------------------------|
| January | 100 | 100 | 100 | <input type="checkbox"/> |
| February | 100 | 100 | 100 | <input type="checkbox"/> |
| March | 100 | 100 | 100 | <input type="checkbox"/> |
| April | 100 | 100 | 100 | <input type="checkbox"/> |
| May | 100 | 100 | 100 | <input type="checkbox"/> |
| June | 68 | 50 | 50 | <input type="checkbox"/> |
| July | 0 | 0 | 0 | <input checked="" type="checkbox"/> |
| August | 0 | 0 | 0 | <input checked="" type="checkbox"/> |
| September | 100 | 100 | 100 | <input type="checkbox"/> |
| October | 100 | 100 | 100 | <input type="checkbox"/> |
| November | 100 | 100 | 100 | <input type="checkbox"/> |
| December | 100 | 100 | 100 | <input type="checkbox"/> |

Save

Reset

Figure 4.8 FEDS Seasonal/Variable Operation Inputs

4.3.5 Geometry

There are several approaches for defining the geometry of a building in FEDS, each providing successively greater detail.

Standard Geometry

The standard assumption for building geometry in FEDS is of a rectangular prism. The footprint of the prism is defined by the combination of building floor area and the aspect ratio (ratio of north/south facing length to east/west length). Additional geometric details are There provided via the Geometry inputs, such as number of thermal zones, number of floors, and floor-to-floor and floor-to-ceiling height.

Linked Building Sets

Linked Building Sets (see Figure 4.9) is feature that facilitates added flexibility in modeling unique building geometries. This allows you to model L- or T-shaped buildings that are adjacent to one another, sharing common wall space (such as a warehouse with a small office built onto one side). Buildings that are stacked on top of one another can also be easily modeled, sharing common roof and floor area. The difference between linked building sets and dual-use sets is that linked sets consist of two distinct building sets not only having unique uses and occupancy/operating schedules, but each also potentially having their own separate HVAC systems.

Linked Building Set Inputs

Linked building sets must each contain the same number of buildings, each must calculate solar gains by facing directions (solar normalization flag = 0), and each must have calculated inferences at least one

Current building set [1] Office Position relative to linked building set East

Linked building set [2] Retail Position relative to current building set West

Apply Cancel

Figure 4.9 Linked Building Set Inputs

How to link buildings sets:

1. Select "Link" from within the *Building Set Inputs: General Information* screen of one of the sets you wish to link.
2. This will bring up the *Linked Building Set Inputs* screen. Select the building set to link to and the relative positions, and click **<Apply>**.
3. If the link was accepted, the name of the set linked to will appear in the "Linked Building Set" box.

You may link any combination of building sets, including combinations of single and dual use, as well as any size, type, vintage, aspect ratio, etc. The only requirements are:

- Each set must contain the same number of buildings.
- Solar normalization must be set to calculate solar gains by facing directions.
- When you select to link with a top/bottom orientation, the footprint area (total floor area / number of floors) of the top set must not be greater than that of the bottom set (FEDS does not model cantilevered buildings).

There are two ways to unlink a pair of building sets:

- Click on **<Unlink>** from the *Building Sets Inputs: General Information* screen of one of the sets you wish to unlink.
- Delete one of the linked building sets - this will sever the link to the remaining set.

Advanced Geometry

Beyond both the Standard Geometry and Linked Building Set features, an Advanced Geometry option allows users the ability to specify detailed building geometry parameters at the specific zone and/or orientation level. This enables more detailed and accurate modeling of unique and difficult-to-model buildings, such as those with non-uniform geometries (that may impact a zone's wall or roof area, or volume) or envelope characteristics (e.g., different window areas on each side of the building). Parameters that are available by zone for advanced specification include the following: exterior wall area, exterior window area, roof area, floor area (both total and ground floor), exterior perimeter length, and conditioned air volume.

Figure 4.10 shows an example Advanced Geometry input screen from the Sample-3 case. The following parameters may be specified for each zone:

- Gross exterior wall area (by facing direction)
- Exterior window area (by facing direction)
- Roof area
- Total floor area
- Ground-level floor area
- Exterior perimeter length
- Conditioned air volume
- Zone conditioning status

The zone conditioning status options allow users to specify whether each individual zone is heated, cooled, and ventilated. An option to specify a season for heating and cooling is also possible. For buildings with two use areas defined, another input allows you to identify specific zones as serving a given use area.

In order to use Advanced Geometry, the following steps are recommended:

1. Define and verify all standard geometry inputs first, including building size, aspect ratio, number of thermal zones, number of floors, glass area fraction, floor-to-floor and floor-to-ceiling height, to the best of your ability.
2. Update inferences for the building to check for errors and to populate current geometry settings.
3. Select the Use Advanced Geometry setting from the Geometry input screen.

Advanced Geometry

Advanced Geometry

Important: Data input within this screen will supersede many of the standard geometry inputs on the previous screens. Additionally, FEDS will NOT infer any of these values, therefore if you choose to use the Advanced Geometry inputs, ALL values must be defined and verified for all zones.

Current zone
1: Zone 1

Zone ID
Zone 1

For this zone, enter the gross wall and window areas for the following representative facing directions. For core zones with no exposed wall or window area, all values should be 0.

| | North | East | South | West | Zone Total | Building Total |
|------------------------------------|-------|------|-------|------|------------|----------------|
| Gross exterior wall area (sq. ft.) | 7920 | 0 | 0 | 0 | 7920.0 | 27720.0 |
| Exterior window area (sq. ft.) | 792 | 0 | 0 | 0 | 792.0 | 8316.0 |

| | This Zone | Building Total |
|--|-----------|----------------|
| Roof area (sq. ft.) | 9900 | 28800.0 |
| Total floor area (all levels)(sq. ft.) | 18900 | 64800.0 |
| Ground-level floor area (sq. ft.) | 9900 | 28800.0 |
| Exterior perimeter length (ft.) | 360 | 1080.0 |
| Conditioned air volume (cu. ft.) | 189000 | 648000.0 |

Zone conditioning status:

Start Date:
Month
Day
January
1

End Date:
Month
Day
December
31

Heated?
☒ Yes
☐ No
☐ Seasonal

Cooled?
☒ Yes
☐ No
☐ Seasonal

Ventilated?
Yes - as Specified for Building

Save
Reset
Close

Figure 4.10 FEDS Advanced Geometry Inputs Screen

None of the Advanced Geometry inputs are inferable. All parameters will be defined initially based on standard geometry settings and the updating of inferences. Any changes made to the Advanced Geometry inputs will be final for as long as the 'Use Advanced Geometry' setting is selected. Therefore, it is strongly recommended to input all basic geometry inputs and update inferences first before entering Advanced Geometry. If mistakes are made, all Advanced Geometry settings can be cleared by deselecting the Use Advanced Geometry option and updating inferences. That will reset all Advanced Geometry inputs back to the values calculated based on the basic building specifications and assumed rectangular geometry.

Tip: Input all basic geometry inputs and update inferences first before entering Advanced Geometry.

4.3.6 Building Envelope

The Building Envelope Characteristics input screen is shown in Figure 4.11. Here, inferred parameters for roof, floor, wall, and window types and thermal performance can be viewed and adjusted. Each can be accessed from the appropriate tab at the top of the screen.

The screenshot shows the 'Envelope Characteristics' window with the 'Roof' tab selected. The inputs are as follows:

| Parameter | Value | Lock Icon | |
|---|---|-----------|----------|
| Roof construction type | Built up | Unlocked | |
| If built-up roof, roof deck type | Wood | Unlocked | |
| Roof color | Dark | Unlocked | |
| Total U-value for this roof (Btu/hr-sqft-°F) | 0.06789225 | Unlocked | |
| Is the roof insulated? | <input checked="" type="radio"/> Yes <input type="radio"/> No | Unlocked | |
| If yes, | Insulation R-value (hr-sqft-°F/Btu) | 8.9 | Unlocked |
| | Insulation thickness (inches) | 2.78125 | Unlocked |
| Does the building have a suspended ceiling? | <input checked="" type="radio"/> Yes <input type="radio"/> No | Unlocked | |
| Space available for additional internal insulation (inches) | 21.21875 | Unlocked | |

Buttons: Save, Reset

Figure 4.11 FEDS Building Envelope Inputs

4.4 Technology Records

A technology record consists of the complete set of information describing a single technology serving an end use in a particular building set. There are limits on the number of technology records for a particular end use, within each building set.

Table 4.2 contains the maximum number of technology records allowed for each end use per building set. Note that for end uses that are specified separately in dual-use building sets (i.e., lighting, service hot water, and miscellaneous equipment), there is no per use-area limit, only a total per building set limit. In such dual-use scenarios, the maximum number of records applies to the sum of technologies across both use areas. Note that the ventilation end use is somewhat different in that there can only be one common set of control, technology, and operational settings specified for the ventilation system for the buildings in the building set.

Table 4.2 Maximum Technology Records by End Use

| End Use | Maximum Per Building Set |
|-------------------------|--------------------------|
| Lighting | 40 |
| Heating | 10 |
| Cooling | 10 |
| Ventilation | N/A |
| Service Hot Water | 10 |
| Miscellaneous Equipment | 20 |
| Motors | 20 |

4.4.1 Lighting

The Lighting screen (Figure 4.12) contains a number of inputs to model the lighting technology configurations within most buildings. Clicking the ‘Select a light technology’ or clicking within the technology configuration cell will open a lighting technology selection wizard, shown in Figure 4.13. This wizard is designed to aid in the selection of the appropriate lighting configuration based on the specification of relevant characteristics such as lighting technology, number of lamps, lamp size, wattage, fixture size, ballast type, etc. With each selection of criteria, the list of Figure Configurations at the top of the screen narrows to show the configurations matching the selected criteria. Clicking on the desired configuration and pressing **<Continue>** will select the configuration and return to the main lighting record input screen.

Additional lighting inputs of note include fixture location (interior or exterior), fixture density, information on lighting controls, and fixture utilization. The number of lighting fixtures can be specified either as a density (fixtures per square foot of floor area) or a direct count (fixtures per use-area). The presence of lighting controls can be specified, and if automated controls are not currently present, users may select the type of control technology (e.g., occupancy sensors) to be evaluated by FEDS during the automated project optimization and selection process. The space type input helps FEDS to estimate the potential savings associated with the deployment of lighting controls within spaces. This helps to infer the utilization factors which represent the percentage of time (on average) that the lights are on during both the occupied and unoccupied periods. An input of 100% for both occupied and unoccupied utilization factors means that the lights operate all the time (except if some days are defined as non-operational in the Seasonal/Variable Operation inputs). The Existing utilization factors identify current operation while the With Controls factors specify the utilization of the lights when the selected or desired controls are in use. This allows users to adjust the impact of lighting control options to specific lighting configurations based on the actual configuration and expected performance. The ‘Number of sensors required’ input is used by FEDS to estimate the cost of deploying lighting sensors to the modeled lighting specified by this record.

Lighting

| | | | |
|---|--|---------------|--------------------|
| Description | Fluorescent (T8) | | |
| | Code | | |
| Technology configuration | Select a light technology | FL236 | FL 2X4 3F32T8 ELC3 |
| Fixture location | <input checked="" type="radio"/> Interior <input type="radio"/> Exterior | | |
| Space type | Mixed - consistent with use area | | |
| Use-Area fixture density (per building) | 0.0098208 | | |
| OR | <input checked="" type="radio"/> fixtures per Sq. ft. <input type="radio"/> fixtures per Use-Area | | |
| Percentage of Use-Area illumination or percentage of floor area served by this technology configuration (will be ignored if 'Fixture density' has been changed) | 80 | | |
| Technology mounting method | Surface | | |
| Percentage of the lighting heat to the conditioned space | 90 | | |
| Existing lighting controls? | No - evaluate occupancy sensor | | |
| Number of sensors required | 79 | | |
| Utilization factors (during seasonally occupied months): | Existing | With Controls | |
| Occupied periods (%) | 63 | 50.4 | |
| Unoccupied periods (%) | 17 | 13.6 | |
| <input type="checkbox"/> Replacement required | | | |

Save

Reset

Figure 4.12 FEDS Lighting Inputs

Lighting Technologies

Fixture type:

- Incandescent
- Halogen
- Fluorescent**
- Compact fluorescent
- LED
- Mercury vapor
- Metal halide
- High pressure sodium
- Low pressure sodium
- Induction

Fixture configuration:

- FL50 FL 2X4 3F32T8 ELC1,2
- FL56 FL 2X4 3F32T8 ELC1,2 REF
- FL236 FL 2X4 3F32T8 ELC3
- FL237 FL 2X4 3F32T8 ELC3 REF
- FL276 FL 2X4 3F32ST8 ELC3
- FL280 FL 2X4 3F32ST8 ELC3 REF
- FL284 FL 2X4 3F30ST8 ELC3
- FL288 FL 2X4 3F30ST8 ELC3 REF
- FL292 FL 2X4 3F28ST8 ELC3
- FL296 FL 2X4 3F28ST8 ELC3 REF

Continue

Cancel

Fixture filters (select as many as apply)

Show fixtures with codes containing the following text:

Number of lamps

- ☐ 1
- ☐ 2
- ☒ 3
- ☐ 4
- ☐ 6
- ☐ 8

Lamp size

- ☐ Biax
- ☐ T12
- ☐ T5
- ☒ T8

Fixture size

- ☐ 1x4
- ☐ 1x8
- ☐ 2X2
- ☐ 2X3
- ☒ 2X4

Ballast type

- ☒ Electronic
- ☐ Energy Efficient Magnetic
- ☐ Std. Magnetic (Obsolete)

Features

- ☐ 34W T12 Lamps (ES)
- ☐ High Output Lamps (HO)
- ☐ Reflectors (REF)
- ☐ Super T8 (ST8)
- ☐ U-Tubes (U)

Clear

Clear

Clear

Clear

Clear

Figure 4.13 FEDS Lighting Fixture Configuration Selection

4.4.2 HVAC

FEDS HVAC inputs encompass heating and cooling end use and control settings, heating and cooling equipment records, plus ventilation options.

Heating and Cooling End-Use and Control Settings

The end use and control settings for heating and cooling (Figure 4.14) define whether heating or cooling exists in the buildings that comprise the building set, how the zone temperature is controlled, and what the setpoints are. The 'Portion of building in this set that are NOT heated/cooled' are used to specify which buildings or portion of buildings are not conditioned. The 'Whole buildings' option should be selected if entire buildings within the building set are conditioned with the same technologies (different buildings can be conditioned with different technologies. Otherwise, if portions of individual buildings are conditioned by different technologies select the 'Percentage of each building served option'.

Heating End-Use and Control Settings

Within the heating and cooling equipment records, the 'portion of building set served' represents:

Portion of buildings in this set that are NOT heated. Enter a value and its associated units

Heating supply temperature (°F)

HVAC control method

Number of thermostats

Occupied season heating thermostat setting (°F):

 Occupied periods

 Unoccupied periods

Unoccupied season heating thermostat set-point (°F)

Thermostat dead band (°F)

☒ Whole buildings served (default)
☐ Percentage of each building served

0

☐ Sq. ft. ☐ Num. Blds. ☒ Percent of Blds.

110

Building automation system (BAS)

6

70

70

45

0

Equipment Options

Save Reset

Figure 4.14 FEDS Heating End-Use and Control Settings

Heating and Cooling Equipment

Details of the heating and cooling equipment are specified within the equipment records. There can be up to 10 records specified per building set, to represent different technologies serving the different buildings within the set or technologies serving different parts of each building. This option is determined by the setting of the 'Portion of building set served representation' which is accessible from the Heating and Cooling End-Use and Control Settings. Parameters for each heating and cooling record depends on the selected fuel and equipment types. The example for a building chiller is shown in Figure 4.15.

Cooling Equipment

Description

Building Chiller with AHU

Specify the portion of building set served

100

Units for portion served

☐ Sq. ft.
 ☐ Num. Blds.
 ☒ Percent of Blds.

Fuel type

Electric

Equipment type

Air handling unit using single-building conventional ch

Chiller type

Water-cooled screw

Equipment output capacity (total per building, assuming one equipment type per building)

176.4682

☐ kW
 ☒ Tons
 ☐ Million Btu/hr

Number of pieces of equipment (per building)

3

Nominal COP

3.591688

Equipment vintage (year of installation)

2010

Define heat/cool pairing, if applicable

[Central Hot Water AHU (Loop #1)]

Pair

Unpair

☐ Replacement required

Save

Reset

Figure 4.15 FEDS Cooling Equipment Inputs

Ventilation

The ventilation inputs allow specification of characteristics of all force-air conditioning and outdoor air ventilation. As shown in Figure 4.16, this includes system type, control mode, design supply air, design outdoor ventilation air, infiltration rate, plus details on the fan and fan motor. A number of technology options are available from the ‘Operational & Control Technologies’ tab, including terminal reheat, economizers, demand controlled ventilation, and active dehumidification.

Ventilation

Ventilation system type
☒ Constant Volume (CV)
☐ Variable Air Volume (VAV)

Ventilation control mode
Continuous during occupied hours, cycle during unoccupied hours

Air Flow & Fan Details

Operational & Control Technologies

Design supply air (cu. ft. per min.)
59025.49

Design outdoor ventilation air (do not include infiltration here)
4095.464

Outdoor ventilation air units
☒ Cu. ft./min.
☐ Air changes per hour
☐ Percent of total air supply

Outdoor ventilation air damper type
☐ Fixed position
☐ 2-position
☒ Continuously modulated

Damper low temperature limit (°F)
45

Infiltration rate (for perimeter zones)
0.8

Infiltration rate units
☐ Cu. ft./min.
☒ Air changes per hour
☐ Percent of total air supply

Total fan motor capacity
38.86893

Fan Motors

Capacity units
☐ Horsepower
☒ kW

Fan motor efficiency (%)
86.01119

Fan efficiency (%)
80

Fan motor location
☒ Air stream
☐ Not in air stream or conditioned space

Ventilation system static pressure (in. of water)
4.5

Save

Reset

Figure 4.16 FEDS Ventilation Inputs

HVAC System Modeling

FEDS has three different algorithms for the calculation of heating, cooling, and ventilation loads. One algorithm models heating and cooling systems that use forced air for distribution. These are referred to as **linked systems** (the cooling or heating coil is directly linked with a fan). Linked systems include furnaces, fan coil units, air-handling units, rooftop packaged units, window air conditioners, and heat pumps. FEDS is able to model any combination of linked systems together in a building set. It is important to note however, that if heat pumps are selected, FEDS requires that the portion of the building set served by each type (air and water source) be equivalent for both heating and cooling.

A second algorithm models heating systems that do not use forced air for distribution (e.g., radiators). These systems are called **unlinked systems**, and there may or may not be a separate ventilation system in the building. Unlinked heating systems include electric baseboard heaters, radiators, infrared heaters and various other radiant heating technologies. FEDS is able to model unlinked heating systems with any cooling system type (except for air and water source heat pumps which necessitate linked heating).

A third algorithm models the special case of evaporative coolers (which are linked systems), which cool air by adding moisture to it. Evaporative coolers are assumed to only

use ventilation energy, i.e., the cooling is essentially "free." They may be combined with both linked and unlinked heating.

The separate algorithms for linked and unlinked heating were developed because these systems operate so differently and as such cannot be modeled together within the same building set. Similarly, the process of evaporative cooling is so different than conventional cooling technologies that a separate algorithm was developed and evaporative cooling cannot be included in building sets with other cooling technologies.

[Appendix I](#) lists allowable HVAC combinations including unlinked heating types with acceptable cooling types, linked heating types with acceptable cooling types, and evaporative coolers.

FEDS also has the capability to model a number of different ventilation approaches and associated technologies. The ventilation control mode defines the periods during which the supply air fans operate (continuous means that they run all the time over the specified period, cycle indicates that they operate only as needed to help meet conditioning demands). FEDS can also model constant volume or variable volume supply systems, economizers, demand-controlled ventilation, terminal reheat, as well as two active dehumidification approaches (desiccant wheel and sub-cool/reheat, the latter which is also commonly referred to as central reheat).

Paired Heating and Cooling Technologies

In any given building set there can be an unlimited number of buildings and up to 10 heating and 10 cooling records. A heat/cool pair identifies to the model which heating and cooling technologies jointly serve a particular building or group of buildings in the building set. In order to consider heat pumps or any other integrated heating and cooling technology as replacements for existing heating and cooling technologies, the heat/cool pairing must be defined.

Heating and cooling technologies may be paired from the heating or cooling equipment record screens. Corresponding heat pump records are automatically paired upon updating inferences. However, all non-heat pump technologies must be paired manually.

How to pair heating and cooling technologies:

1. Select "Pair" from the *Heating Equipment Inputs* or *Cooling Equipment Inputs* screens for one of the heating or cooling technologies that you wish to pair. This will bring up the *Pair HVAC Technologies* screen.
2. Select the technology to pair with the current equipment record, note whether the equipment is separate (distinct heating and cooling units) or integrated, and click **<Apply>**. Each technology must serve the same portion of the building set to be valid.
3. If the pair was accepted, the name of the paired technology will appear in the heat/cool pairing box.

You may pair any combination of heating and cooling technologies except for heat pumps, which must be paired to another heat pump of the same type (i.e., the same fuel, equipment type, loop types, etc.). Heat pumps are automatically paired when inferences are updated.

4.4.3 Service Hot Water

The service hot water inputs include a combination of end-use inputs and technology inputs. The end-use inputs define the hot water demand in gallons of hot water per day by day type for each use area, as well as the number of faucets and showerheads, and percentage that are water efficient. The service hot water equipment records define the characteristics of the water heaters, boilers, or heat exchangers that supply the hot water. These are defined as either distributed or loop hot water systems. Distributed systems typically consist of a 5- to 80-gallon tank in which the water is heated and stored to serve a small portion of a large building or the entirety of a smaller building. Instantaneous or on-demand water heaters can be modeled as a distributed system with a very small (<1 gallon) storage capacity. Loop systems are designed to heat water which is then typically stored in a separate tank and recirculated throughout the building. Because of this, loop systems are assumed to serve all use areas within a building.

Like heating and cooling, the service hot water inputs include the specification of the portion of the building set served. This is to specify which whole buildings have any hot water service rather than define the specific floor area where hot water is provided. The end use inputs for each use area should be used to define the hot water demand by occupants within each use area.

Tip: FEDS assumes that if a building has hot water it is available to the entire building (i.e., to all occupants within the building).

4.4.4 Motors

FEDS models non-HVAC electric motors based on the inputs specified within the Motor end use. Figure 4.17 shows the parameters available for each motor record.

Motors

Motor identification

10 hp Process Motors

Configuration:

Rated capacity (hp)

10

Synchronous speed (rpm)

1800

Enclosure

Open Drip-Proof

Voltage

460

Nominal efficiency (%)

87.2

Vintage (year of installation)

2013

Number of times rewound

0

Percentage of the motor heat to the conditioned space

100

Number of motors per building (this use-area) with this configuration, vintage, and duty cycle

3

Does the duty cycle vary by month?

☐ Yes
☒ No

If Yes, press the Monthly Duty Cycle button and enter the combined utilization and load factors for each month

Monthly Duty Cycle

If No, enter the combined utilization and load factors below for all months:

Occupied periods (%)

65

Unoccupied periods (%)

33

For improperly sized motors, specify the required motor capacity (hp)

10

☐ Replacement required

Save

Reset

Figure 4.17 FEDS Motor Inputs

4.4.5 Miscellaneous Equipment

An example miscellaneous equipment record is shown in Figure 4.18. FEDS automatically creates a set of three miscellaneous equipment records for each use area, when inferences are first updated. This includes a Refrigeration, Food Preparation, and Other record. Parameters including capacity density and utilization and load factors are inferred to be representative for each use area.

FEDS simulates the energy use and demand from plug and process load equipment to incorporate into the whole building energy simulation. However, no retrofits are currently evaluated. FEDS infers this information to assist with the modeling of whole building energy use without requiring a detailed inventory of this equipment. Where the inferred records do not appear to be representative of the equipment in a building, or where additional plug or process loads exist, the inferred records can be edited or deleted, and new records added.

Miscellaneous Equipment

| | |
|--|--|
| Miscellaneous equipment description | Refrigeration |
| Equipment type | Refrigeration ▼ |
| Fuel type | Electric ▼ |
| Miscellaneous equipment capacity density (per building) | 26.568 🔒 |
| Capacity units | <input checked="" type="radio"/> kW <input type="radio"/> Ton <input type="radio"/> Million Btu/hr |
| Capacity density basis | <input type="radio"/> per Sq. ft. <input checked="" type="radio"/> per Use-Area 1 |
| Percentage of the equipment heat to the conditioned space | 100 🔒 |
| Combined utilization and load factors (during seasonally occupied months): | |
| Occupied periods (%) | 3.31 🔒 |
| Unoccupied periods (%) | 2.94 🔒 |

Save
Reset

Figure 4.18 FEDS Miscellaneous Equipment Inputs

Tip: When auditing, note how the density of plug and process loads compares to what is typical for the building and use area type(s). It is easier to add, edit, or adjust the inferred miscellaneous equipment input than build them from the ground up.

5 FEDS Process

Briefly summarized, the typical FEDS analysis process will usually consist of the following steps. However, due to its flexible design, certain applications may omit or include additional or alternate steps.

1. Collect site and building data
2. Evaluate marginal energy prices
3. Determine building set breakdown
4. Complete an initial opportunity screening
5. Gather additional data about the buildings and central energy plants to be modeled
6. Enter additional building system detail and update and/or modify FEDS inferred data with more detailed building and technology system characteristics
7. Perform QA/Calibration
8. Set desired simulation parameters
9. Run FEDS on validated building models
10. Identify projects

Each of these steps is described in the next sections.

5.1 Step 1: Data Collection

The first step is to gather information about the building(s) to be modeled. This begins with details including location, building type, size, vintage, occupancy, plus basic geometry, construction characteristics, and information on lighting, heating, cooling, hot water. Additionally, electric rates and fuel prices are also important.

Example data collection forms are installed with FEDS and can be found in the FEDS \documents folder (e.g., C:\FEDS 8.0\documents).

5.2 Step 2: Define Energy Rates

Energy rates are important for evaluating energy efficiency measures. Therefore, having a detailed understanding of electricity and other energy prices is critical to properly valuing savings. Rather than applying an average or blended rate of electricity, request a detailed explanation of rates from your utility or search online for the relevant rate schedule. With recent bills in hand, analyze the rates to define the appropriate marginal cost of both energy and demand, including any seasonal and time-of-day rates, demand ratchets, and any minimum or contract demand. For all fuels, identify and exclude any fixed charges that cannot be impacted by reducing energy use. Focus on defining the

marginal value of each fuel – the savings that would accrue by reducing energy use by one unit of measure (e.g., kWh, therm, gallon, MBtu).

5.3 Step 3: Identify Building Sets

FEDS is designed to model sites of all sizes, from single buildings and small sites with a handful of buildings, to very large campuses and installations with hundreds or thousands of buildings. For small sites, a FEDS model will typically be built for each building. However, for larger sites, depending on its size and the goals of the assessment, it may not be practical or necessary to model each building individually. For very large campuses and installations, there are often groups of buildings that are similar in construction and use characteristics that lend themselves to be reasonably modeled together. FEDS therefore supports the grouping of buildings that can be categorized together into sets. This is particularly useful for performing a screening assessment of a larger site. Grouping similar buildings into sets can facilitate the modeling and analysis of such sites without a significant loss of detail at this level.

The following example illustrates how and why building types are broken into building sets. A sample installation contains two groups of administration buildings: a group of approximately 1943-vintage buildings and a group of buildings constructed in the early 1980s. If you were to group these buildings into one set based on type, the average vintage of the administration buildings would be about 1963, a value that is not very representative of either group. To improve the results, the building type may be broken up into two sets, one for each vintage category. Making this one change will greatly improve the applicability of the inferred values to the two building sets.

It may also be appropriate to use other determinants as well, such as common construction characteristics, common HVAC system types or characteristics, to which central energy plants or thermal loops the buildings are attached, similar penetration rates of particular lighting technology configurations, or similar miscellaneous equipment densities.

[Appendix A](#) contains a brief description of the FEDS inference generation. After building type, the major determinants of inference selection are the building vintage, location, and size. A first step for determining building sets could be to break each type into the vintage and size ranges used by FEDS, which are given below in Table 5.1. With 6 size categories and 8 vintage categories, there are potentially 48 building sets for each building type. Moreover, this does not even account for differences in occupancy hours or fuel availability among similar building sets. Obviously, a FEDS case for a large site can grow very large, very quickly. A more reasonable approach may be to break up a particular building type into sets by grouping along common construction characteristics (e.g., wall type, presence or absence of insulation, percentage of wall area that is glazed, etc.), common lighting and/or equipment densities, and common fuel availability.

Table 5.1 FEDS Size and Vintage Categories

| Size Categories (ft ²) | Vintage Categories |
|------------------------------------|--------------------|
| 0 – 4,999 | Before 1946 |
| 5,000 – 9,999 | 1946 – 1960 |
| 10,000 – 24,999 | 1961 – 1973 |
| 25,000 – 49,999 | 1974 – 1979 |
| 50,000 – 99,999 | 1980 - 1986 |
| 100,000 or more | 1987 - 1996 |
| | 1997 - 2005 |
| | 2005+ |

5.4 Step 4: Opportunity Screening

FEDS is designed to be scalable and support a top-level screening as a preliminary indication of what actions should be initiated, with minimal data collection and modeling effort. This enables users to quickly assess the potential return on investment before expending additional resources to collect additional data and refine the analysis as required before a project is designed and implemented. When entering only the required inputs, FEDS draws upon numerous assumptions about the "typical" stock of U.S. buildings, with only minimal energy price and installation configuration information needed as input.

FEDS uses the small set of required inputs that you provide to internally generate descriptions of prototype buildings for each building set that you create. The default values of the parameters used to describe the prototypes are inferred from the input data; for instance, the climate zone is used in conjunction with the building type, vintage, and size to infer parameters relating to the building construction characteristics. This information is also used to infer the most likely heating equipment types for each user-supplied heating fuel type. The resulting building prototype parameter values are statistically the most likely values for a given building type, climate zone, average vintage, size, and fuel/technology mix.

The benefits of high-level screening analysis include:

- accepting input data of a generic and/or aggregated nature – for example, the percentage of a building set that uses a particular heating fuel is entered, but the individual heating technologies are not specified.
- estimating current and post-retrofit energy consumption for all energy systems under consideration.
- determining the optimal retrofits to the current system (considering interactive effects) and estimating the post-retrofit energy consumption, initial installed

cost of the retrofits, recurring costs of the retrofits, value of the change in energy consumption and operation and maintenance (O&M) requirements, and the net present value of the retrofit – the net present value is the difference between the life-cycle cost (LCC) of the existing technology and the LCC of the retrofit technology.

Running FEDS at this level can provide utility, institution, agency, energy, resource, or installation managers with a simple 3- to 4-hour method to:

- estimate resource efficiency potential at a single multi-building installation with limited metered energy-use data
- characterize and prioritize the most promising building and end-use retrofit project opportunities
- estimate capital investment requirements and potential energy and cost savings based upon Federal life-cycle cost economics.

The tool can also be used at the headquarters or agency level to characterize opportunities at all sites, thereby providing a way to prioritize among these sites.

Applicability. The application of the FEDS inferences to the development of the building prototypes via a most likely parameter-value approach allows FEDS to perform detailed modeling and analysis of an installation while requiring only very limited information from a user. The results from a screening analysis are intended to be used as a gross indication of the required investment to achieve the energy and cost savings potential at an installation. The results can indicate which building types and end uses have the greatest savings potential. However, the most likely parameter-value approach also means that when FEDS is used with limited information, it is most appropriately applied to installations with large numbers of buildings.

5.5 Step 5: Gathering Additional Data

Results from the initial screening can be used to direct resources for additional data-gathering. The building types, end uses, and fuels with the largest potential savings (according to the screening) are the building types, end uses, and fuels that should be given the most time and focus for additional data-gathering. This effort may be as minimal as confirming the heating and cooling equipment types and the construction characteristics with a quick walk-through or drive-by, or it may involve such detail as determining actual lighting densities by counting light fixtures and confirming technology configurations and controls.

For most large installations, there will be a limit to how much additional data it is reasonable to gather. As a FEDS user, you must make the trade-off between the cost of gathering additional data and the quality of the output. The screening results can be used to help prioritize the data-gathering effort, and the effort must also be coordinated with a re-examination of the building set breakdown to determine if any of the building

set groupings should change. Sample FEDS data collection forms were installed during software installation to the FEDS \documents folder.

Also, during this step, more detailed information about any central plants and thermal loops located on site should be gathered including seasonal operation, temperatures, pipe lengths, leakage rates, etc.

5.6 Step 6: Build a More Detailed and Robust Model

Modify inferred data. At this point, it is time to modify the FEDS inferred data to more closely model the particular buildings at the site. Additional detailed data collected for the buildings should be entered into the appropriate input fields. Do not worry about modifying all data—modify only those you have easy access to or believe to be most important (as determined in step 3). Unlike other models that require highly detailed and comprehensive inputs, this approach allows *but does not require* you to enter any site-specific information that is not readily available. For instance, you may specify the wall system U-value if known, however, it is not necessary and FEDS will infer a reasonable value based on parameters including construction type, location, presence and thickness or R-value of insulation.

Following is a brief list of commonly suggested areas to evaluate:

- **Solar gain method:** Select “Calculate solar gains by facing directions” if most buildings in the set are oriented similarly. Select “Normalize solar gains” for sets of buildings with different orientations.
- **Occupancy inputs:** You may specify the number of occupants during occupied and unoccupied periods, as well as seasonal/variable occupancy for the ability to model buildings that are used only part of the year.
- **Geometry:** Geometry inputs should be reviewed and updated as appropriate. Thermal zoning, number of floors, window fraction, and floor-to-floor and floor-to-ceiling heights. As needed, linked buildings or advanced geometry specifications could be considered.
- **Fuel availability:** When considering fuel-switching retrofits at, it is assumed that the fuels available to the installation are available to each building on the installation. This assumption to better reflect the actual fuel availability at different parts of an installation. If a fuel is currently not available at a building but you would like to determine whether it would be worthwhile to bring in a fuel, specifying that it is available will enable FEDS to examine the fuel-switching opportunity.
- **Building envelope characteristics:** You may change the inferred construction types and materials used for the walls, roof, floor, and windows. You may also specify different insulation R-values and thicknesses or simply specify the overall U-value for windows, walls, roof, and floor (if known). [Appendix F](#) provides a detailed description of the FEDS wall and roof types.

- **Lighting systems:** You may change the inferences for the lighting technology configuration(s), the lighting fixture density, lighting utilization levels for occupied and unoccupied periods, and lighting heat to space. FEDS provides access to over 900 existing lighting technology configurations. A description of the FEDS lighting fixture codes and technology configurations is provided in [Appendix G](#). The complete listing of all available fixture codes contained within the FEDS model may be found in [Appendix H](#).
- **Heating and cooling equipment:** The inferences for equipment type, number of units, nominal capacity, and efficiency (or coefficient of performance) for heating and cooling equipment may be changed. Heat/Cool pairs can also be specified to identify which equipment serves the same areas.
- **Ventilation system:** Fan and fan-motor capacities and efficiencies, as well as the ventilation system control mode, among many other parameters, may be adjusted. Specific motor, economizer, demand-controlled ventilation, and dehumidification system parameters may also be specified.
- **Service water heating system:** Assumptions regarding the hot water consumption levels, system type, equipment efficiency, and capacity may all be changed.
- **Motors:** You may add records to model a wide range of 3-phase electric motors. The monthly duty cycle (combined utilization and load factor) can also be entered.
- **Miscellaneous equipment:** You may change the inferences for miscellaneous equipment densities, utilization levels, and heat to space, and add records for other equipment types or delete records for equipment that is not present.

Update inferences. Any additional information that you provide is used by FEDS to recalculate (where appropriate) any dependent inferred values. Inferences for a particular building set may be updated by selecting **<Update Inferences>** from the menu accessed by right-clicking on the building set node within the navigation window. You may update all installation and building set inferences for the case from the Inferences screen under FEDS Home.

Repeat. Examine these resulting inferences and, if desired, make further changes to them before running the FEDS model. If you feel that more changes are necessary, modify the inferred data, generate new inferences, and repeat the process until you are satisfied with the input data.

5.7 Step 7: QA & Calibration

Building a more robust FEDS model starts with reviewing inferred parameters, collecting additional building data, and updating relevant inputs. Performing quality assurance (QA) checks follows to be sure that all intended inputs have been specified. This includes reviewing energy rates, occupancy hours, and for dual use buildings ensuring

that occupant, lighting, hot water, motor, and miscellaneous equipment details are provided. The building set input summary (available from the main Building Set node on the navigation window) as well as the first several pages of the TXS report can offer good options for reviewing inputs.

Model calibration is also important to ensure that the model is reasonably accurate. This can be reviewed by performing a calibration run and comparing the resulting energy use metrics against metered energy use for the buildings(s). Set the Analysis Type to 'Calibration' (or exclude all building sets from optimization - see Section 6.1) and then run FEDS to perform a baseline simulation and review resulting consumption estimations. This allows you to quickly get baseline information that you can check against real data and resolve any large discrepancies before doing a full run of the model. It also provides a valuable tool for analyzing various what-if scenarios, which can be modeled manually via changing parameters on the building or installation input screens and comparing resulting *.txs and calibration reports. Lacking metered energy consumption detail, reviewing the energy use intensity for each building (and end use) is a useful way to compare the relative consumption of each building. Based on these results, selected building inputs can be adjusted and the models re-simulated to assess the impact.

Most users will find that FEDS simulates the energy use of many buildings within 10-15% of actual energy use with minimal effort. A difference of 5% or less (even approaching 0%) is possible with additional effort and increased knowledge of the building systems and operation. The goal of calibration is to create a robust model that has a high probability of behaving similarly under simulation as the real building. Any model can be made to match actual energy use; the challenge is to do so without pushing inputs or behavior outside of the bounds of plausibility. This process takes some experience to master, and the objective of the analysis should be kept in sight to guide what level of calibration is warranted.

5.8 Step 8: Set Simulation Parameters

After you are satisfied with your inputs and believe that you have modeled the buildings accurately based on reasonable QA and calibration effort, you should review and set the optimization parameters to best suit your analysis objectives. Review the following optimization parameter options:

- Specify the funding source (e.g., appropriated or alternative financing). See Section 7.
- Set financial screening options as described in Section 4.1.4.
- Exclude building sets that you do not want to consider retrofits for as described in Section 6.2.
- Restrict retrofit technologies or end uses that you do not want to evaluate as described in Section 6.3.

- Alter cost data (labor rates, end use materials multipliers, tax rate, etc.) to match your locale. See Section 4.1.4.
- Review emissions factors for your locale as described in Section 4.1.6.
- Choose whether the spreadsheet output lists the optimal retrofit only or the top 3 retrofits. See Section 6.1.2.
- Set any “Replacement required” (i.e., force retrofit) flags for those technologies that must be replaced. This gives the user the ability to specify that a particular piece of equipment or component **must** be replaced, and therefore require that FEDS select the best, most life-cycle cost effective replacement. Replace on failure economics-allows the user to specify that a piece of equipment must be replaced due to failure, renovation, or new construction. This is extremely useful in design and renovation. For example, if you know that all of the windows are going to be replaced, which type of window should be installed? Because the user is requiring the technology to be replaced there is no longer a requirement that the retrofit be life-cycle cost effective. Hence, some retrofits may have negative net present values.
- Review thermal loops and set force abandon/do not abandon settings as may be appropriate. If the user requires that a loop be abandoned, then the model will select the most life-cycle cost effective retrofit technology to replace the existing technology. There is no requirement that the retrofit have a positive NPV; hence, some retrofits may have negative net present values. In fact, even if a loop is not set for forced abandonment, retrofits with negative NPVs may appear on the TXD and CSV reports if the loop (and plant) savings gained from abandoning the loop (and possibly plant) are greater than the resulting costs (negative savings) associated with all of the connected technologies.

5.9 Step 9: Run FEDS

Once you have performed reasonable QA and calibration of your model, and reviewed and set appropriate simulation parameters, it is time to run FEDS to evaluate savings measures. Return Analysis Type to ‘Optimization’ (or remove the building set exclusions) and select "Run FEDS" from the *Simulation screen within the FEDS Home*. You will be informed that all inferences will automatically be updated and asked if you are sure you want to proceed. Click on <Yes> to continue.

At this point, FEDS begins by loading the input information and calculating the baseline (existing) energy consumption. The iterative optimization process follows, in which numerous candidate energy efficiency measures are successively evaluated for each end use technology and envelope component, by performing an annual hourly energy simulation to estimate the savings from each individual option and identify the package of measures offering the lowest life-cycle cost. The energy price data that you supplied are used in conjunction with the estimates of full building set energy consumption (to account for the interactive effects) and your specified or selected real energy cost

escalation rates to determine the energy costs of the existing and the potential retrofit technologies.

The retrofit modifications to existing equipment that FEDS analyzes include complete replacement with similar but more efficient equipment (e.g., replacing existing fluorescent lamps or fixtures with new high-efficiency LED lamps or fixtures), changes to different equipment types that provide equivalent service more efficiently (e.g., replacing an electric forced-air furnace with a heat pump), and changes to more efficient equipment using different fuel (fuel-switching). A complete list of retrofit options appears in [Appendix B](#).

For technologies served by central plants, FEDS considers replacing the existing equipment with new single-building technologies (e.g., in-building boilers, chillers, etc.). Additionally, FEDS examines the cost effectiveness of abandoning loops and plants, comparing the savings associated with reduced transmission losses and maintenance requirements with the costs of installing and maintaining equipment at the building level.

The FEDS model then uses the federally-mandated life-cycle cost methodology, as specified in 10 CFR Part 436, to combine the retrofit project capital cost, operation and maintenance cost changes, and changes in the energy costs to determine the cost-effectiveness of potential measures. For more information on FEDS optimization and retrofit modeling, see [Appendix A](#).

Once FEDS has successfully completed its optimization, relevant output reports will be generated automatically, and you are ready to open them from the *Reports* screen accessed from the *FEDS Home* as described in Section 8.

5.10 Step 10: Identify Projects

The results of the FEDS simulation and optimization process can be used to identify and justify prospective energy efficiency projects. A number of projects will likely be identified by FEDS, based on the opportunity to improve building construction, system efficiency, and/or operation. The Summary Installation and Building Set Output (TXS) provides the high-level view of results, costs, and savings potential – at the individual building and end use level as well as for the total site. The identified cost-effective projects that together represent the lowest life-cycle cost are detailed on the TXD and CSV reports.

In addition to the projects identified by the automated FEDS optimization process, additional measures can be evaluated via parametric analysis. In this more manual process, two versions of a building model can be created. One will represent the baseline building as it currently exists (the model evaluated in Step 9). In addition to running this model through an optimization analysis, the model can also be copied (using the Save case as function) for implementing selective changes to represent a potential measure. These two models can then be simulated; comparing their resulting baseline energy consumption and costs will provide an estimate of savings. This would

then need to be compared against estimated implementation costs to determine cost-effectiveness.

More information on the output from FEDS simulations is presented in Section 8.

6 FEDS Simulation Settings

This section provides an overview of the operation and effective use of the features accessible within the Simulation Settings. These are accessed from the Simulation area of the FEDS Home.

6.1 Simulation Parameters

The Simulation Parameters (Figure 6.1) provides access to inputs that define key parameters of the FEDS simulation process. This includes the Analysis Type (Optimization vs. Calibration) as well as options that help specify the simulation year.

The screenshot shows a window titled "Simulation Parameters" with a standard Windows-style title bar (minimize, maximize, close buttons). The window content is organized into sections:

- Analysis type:** Features two radio buttons: "Optimization" (selected) and "Calibration". A lock icon is present to the right.
- Simulation Settings:** A group box containing several parameters:
 - Analysis year:** A text input field containing "2019".
 - Simulation start day of week (January 1):** A dropdown menu showing "Sunday".
 - Is this a leap year?:** Two radio buttons, "Yes" and "No", with "No" selected.
 - Apply daylight saving time?:** Two radio buttons, "Yes" and "No", with "Yes" selected.
 - Daylight saving peirod:** A section with two date pickers:
 - Start Date:** A text input field containing "3/12/2019".
 - End Date:** A text input field containing "11/ 5/2019".
- Retrofit Options:** A group box containing two radio buttons: "Generate Optimal Retrofits Only" (selected) and "Generate Top Three Retrofits".
- Notes on the top three retrofits:** A text area containing two bullet points:
 - The top three retrofits (where available) will appear in the spreadsheet (*.CSV) output only.
 - The 2nd and 3rd best retrofits are determined with all other measures at minimum LCC.

At the bottom of the window, there are three buttons: "Save", "Reset", and "Close".

Figure 6.1 Simulation Parameters Screen

6.1.1 *Simulation Settings*

Analysis type – ‘Optimization’ will run the FEDS retrofit optimization engine to evaluate and recommend energy efficiency projects. The ‘Calibration’ option on the other hand focuses on the FEDS baseline modeling to estimate current building and central plant energy consumption by fuel type in order to help calibrate the model (to check for input errors and compare resulting energy consumption from FEDS to actual metered consumption data). This further supports the calibration process by automatically turning off the optimization engine, so that the Calibration analysis is completed very quickly. Finally, at the end the Calibration run, FEDS will automatically generate not only the *.txs report but also a calibration spreadsheet output report containing many of the commonly reviewed energy consumption metrics for the base building model, to facilitate comparison with available metered data.

Analysis year – for a ‘Calibration’ run, the Analysis Year may be specified by the user in order to help set up the calibration to match the characteristics and calendar of the year of the metered consumption data which is being calibrated to. For ‘Optimization’ runs, this is automatically set to the Run Year input on the main FEDS screen.

Simulation start day of week (January 1) – This day type input sets the day of the week the current simulation will begin on. In other words, it is the day that January 1 fell on for a particular analysis year. For ‘Calibration’ runs, this is inferred to the actual start day for the Analysis Year specified. For ‘Optimization’ runs, which attempt to run a non-specific year representative of the future, it is defaulted to Sunday (but can be changed).

Is this a leap year? – This Yes/No option allows you to specify whether the current simulation (for each Analysis Type) will model 365 or 366 days for the year.

Apply daylight saving time? – Similarly, this option allows you dictate whether the simulation considers daylight saving time or not.

Daylight saving period – For simulations that include a daylight saving time adjustment, this set of inputs defines the range of dates for which daylight saving is applicable.

6.1.2 *Retrofit Options*

This feature gives users the option of generating not only the optimal (minimum life-cycle cost) retrofit, but the second and third best as well.

"Generate Optimal Retrofits Only" is the default selection and will generate the one most life-cycle cost-effective retrofit for each technology and building system being evaluated. Choosing "Generate Top Three Retrofits" will instruct FEDS to determine the top three retrofit options for each existing piece of equipment or envelope component.

When the "Generate Top 3 Retrofits" option is enabled, the second and third best retrofits will be listed in the "{casename}.csv" output report. When the "{casename}.csv" report is generated, the top three retrofits will be listed (if available) on successive rows in the spreadsheet. The ranking of each retrofit technology will be

identified on the "Rank" column to the right of the "Retrofit Technology" field. A maximum of three retrofits will be output for each existing technology or envelope component; this number can be less, however, as only those retrofit options that are cost-effective will be printed. For more information about the "{casename}.csv" output report, see Description of {Casename}.csv Output.

Note: The second and third best retrofits are determined with all other retrofits at the minimum LCC. If you decide to choose a second or third best retrofit for a project, it is recommended that you restrict the top retrofit technology (if possible) and re-run the case, as the selection of the other optimal retrofit technology selections may change.

6.2 Exclude Building Sets from Optimization

This option allows the user to specify that a certain portion of building sets be excluded from optimization. FEDS still uses these sets to determine the installation electric demand profiles but will not consider any retrofits for them, saving valuable run time. There are three choices available for the exclusion of building sets, each chosen from the *Exclude Building Sets from Optimization* screen (Figure 6.2).

User Selects Building Sets to Exclude:

This method allows the user to choose specific sets to exclude from optimization. To access this option, mark the "Pick building sets" box in the top section of the screen. On the left portion of the screen there is a list of all building sets in the case. Simply select the sets to exclude from optimization by clicking on the set name with the mouse (or tabbing through the list and marking sets with the SPACEBAR). Those building sets picked for exclusion will then be shaded. Clicking on a highlighted set again will deselect it. Pressing the <Select all> button will mark all building sets for exclusion and <Clear all> deselects all sets.

Tip: Excluding all building sets provides a helpful technique to run through the baseline calculations only, providing output that is helpful in verifying the input data, and to catch errors before spending the time to run the model with optimization.

Exclude Building Sets from Optimization

Select method for excluding building sets from optimization:

- ☒ Pick building sets
- ☐ Electric consumption
- ☐ Exclude none

Pick building sets

Select the building set(s) that you wish to exclude from optimization:

- ☐ [1] Building Set 1
- ☒ [2] Building Set 2
- ☐ [3] Building Set 3
- ☒ [4] Building Set 4
- ☒ [5] Building Set 5
- ☐ [6] Building Set 6
- ☐ [7] Building Set 7
- ☐ [8] Building Set 8
- ☐ [9] Building Set 9
- ☐ [10] Building Set 10

Select all Clear all

Electric consumption

Consider for retrofit only those building sets representing the top X% of the total electric consumption:

Cutoff percentage (%)

Save Reset Close

Figure 6.2 Exclude Building Sets from Optimization Screen

FEDS Selects Sets Based on Electric Consumption:

The second option for excluding building sets from optimization is a method that instructs FEDS to automatically eliminate a certain fraction of building sets. This determination is based on considering for retrofit only those building sets responsible for the top X% of the total baseline electric consumption, where X is a user-entered value. With this method, the number of sets excluded from optimization is variable, completely dependent on the entered percentage and the relative electric energy consumption among sets within the case. It enables the user to automatically target those building sets likely to offer the largest energy savings opportunities (i.e., those with the largest current electric consumption) without having to optimize all sets.

Optimize All Sets:

The final choice in this category is "Exclude none". Selecting this instructs FEDS to ignore all selections under the "Pick Building sets" method as well as the cutoff percentage of the "Electric consumption" method. This allows the user to optimize all building sets without losing the settings defined for either method of exclusion.

6.3 Restrict Retrofits from Optimization

This option enables the user to specify certain classes of retrofits that FEDS will not consider retrofitting to during optimization. For example, if you do not want FEDS to evaluate any window retrofits, select "Windows" from within the Envelope end-use category. Retrofits can be restricted at a variety of levels to meet a range of requirements: entire end-uses (e.g., lighting retrofits), individual technologies (e.g., fluorescent fixtures), or specific configurations (e.g., fluorescent reflectors). They can be selected for individual building sets, groups of sets, or for all sets in a case.

The procedure for restricting retrofits is as follows:

1. Select a building set (or group of sets) from the list on the left by clicking on it with the mouse. The **<Select all>** and **<Unselect all>** buttons can aid in this process. Symbols to the right of the building set name identify sets that have been excluded from optimization ("[X]") and sets with existing retrofit restrictions defined ("[R]"). In Figure 6.3, sets 2, 3, and 8 have been excluded while sets 1, 5, and 9 each have at least one retrofit restriction currently defined.
2. On the right half of the screen is an expandable list of retrofit options, grouped by end use. Select the end use category or specific retrofit technologies to eliminate from evaluation during optimization.
3. Select the retrofit(s) to restrict for the chosen building set(s). Note that the options are hierarchical in that selecting high-level categories automatically restricts all underlying retrofits (i.e., choosing "Wall insulation" will mark "Interior masonry surface insulation" and clicking on "Envelope" will select all envelope retrofits). The **<Collapse all>** and **<Expand all>** buttons can aid in accessing the desired list elements. Click on the boxes next to the end use, technology, and measure to restrict it for the selected building set(s). **<Unselect all>** will remove all selected items.
4. Pressing **<Save>** at this point will save the specified restrictions. **<Reset>** will revert any changes made since the last save.
5. At this point you may choose another end-use to specify more retrofit restrictions for the current building set(s), select a new building set or group of sets for which to specify restrictions, or exit the *Restrict Retrofits from Optimization* screen with **<Close>**.

Note: Copying a building set will copy any existing retrofit restrictions of the original set to the new building set.

Since each building set in a group of sets may have different retrofit restrictions defined, the complete set of restrictions cannot be viewed for any group. When retrofits are selected for a group of building sets, they are added to the current list of restrictions for each building set in that group. *In order to view the restricted retrofits or to delete specific restrictions for a building set, you must make sure that only one building is selected on the building set list.*

<Clear all restrictions> will remove the entire set of retrofit restrictions for the highlighted building set(s). To clear all retrofit restrictions for a given case, select all building sets with the **<Select all>** button beneath the building set list and then hit the **<Clear all restrictions>** button.

7 Alternative Financing

The desired result of the alternative financing analysis is to provide the user with the appropriate data that leads them to the correct decisions regarding alternative financing and also allows for easy comparison to calculations done assuming government appropriations or site financing. Alternative financing includes utility or third-party loans, leases, and energy savings performance contracts (ESPC).

When an alternative financing case is run, the comparison being made is between:

- having the site continue to operate the baseline equipment and when it fails to replace it with the minimum life-cycle cost equipment, and
- having an alternative financier replace the equipment immediately with the minimum life-cycle cost equipment and then continue to have minimum LCC equipment throughout the life of the contract.

In a site financing run the comparison is the same except the site makes the retrofits. Hence the output of an alternative financing run and a site financing/appropriated funding run can be directly compared to determine which is the more favorable situation.

7.1 Alternative Financing Inputs

The alternative financing inputs may be accessed by selecting "Financial Options" under the *Facility Information*. The following screen (Figure 7.1) will appear:

Financial Options

Do you want to use the 3% real discount rate currently specified by the federal government? ☒ Yes ☐ No

If no, enter your real discount rate (%):

Select the source of funding for the selected projects ☒ Appropriated funding ☐ Alternative financing

Energy rate sector

Apply the DOE/EIA real energy escalation rates for your area, for all fuel types? ☒ Yes ☐ No

Screen out projects that are life-cycle cost effective but do not meet a maximum simple payback or a minimum savings-to-investment ratio (SIR)? ☐ Yes ☒ No

If yes, specify which values of maximum simple payback and minimum savings-to-investment ratio to use:

Energy Resilience and Conservation Investment Program (ERCIP) criteria ☐ Yes ☐ No

OR

User defined:

Figure 7.1 Financial Parameters and Screening Options Screen

At this point a decision is made between appropriated funding and alternative financing. Checking the "Alternative Financing" box will enable the "Alternative financing inputs" button and clicking on that button will take you to the following screen (Figure 7.2):

Alternative Financing Inputs

Alternative Financing

Select the type of alternative financing

☐ Utility or third-party loan
☐ Lease
☒ Energy savings performance contract (ESPC)

Life of the agreement (years)

Third-party (financier) real interest or discount rate (%)

Site contract development cost (\$)

Annual contract administration cost (\$)

Buy-out or balloon payment required at end of contract (% of installed cost)

Should current O&M costs be included in savings calculations? ☒ Yes ☐ No

Party responsible for O&M requirements during contract ☐ Site ☒ Alternative financier

Save Reset Close

Figure 7.2 Alternative Financing Screen

The alternative financing inputs are briefly explained below.

- **Type of alternative financing** – this is the source of funding with choices of low interest rate utility/third-party loans, lease, or energy savings performance contracting (ESPC)
- **Life of the agreement** – this is the loan period, lease period, or ESPC contract duration
- **Third-party interest or discount rate**
 - Leases: lessor pre-tax real discount rate
 - Utility/third party loans: loan interest rate
 - ESPC: ESCO's real required rate of return
- **Site contract development cost** – this is the amount by which the total cost of developing and entering into an alternative financing agreement exceeds the cost of securing budgeted funding to accomplish the same work (this generally consists of contract development, evaluation, negotiating, etc.)
- **Annual contract administration cost over the life of the agreement** – the first year cost which is assumed to escalate at the inflation rate over the contract life
- **Buy-out or balloon payment percentage**
 - Leases: fraction of installed cost required to take possession of the equipment at the end of the lease

- Utility/third party loans: fraction of installed cost required at the end of the loan in the form of a balloon payment
- ESPC: fraction of installed cost required at the normal end of the ESPC contract that goes its full duration
- **Should current O&M costs be included in savings calculations?** – this input is used to designate whether baseline O&M costs are to be considered in the savings calculations. (Generally the answer will be yes – without considering these savings many projects will not be cost effective.)
- **Party responsible for O&M requirements during contract** – designates who is responsible for the O&M costs during the period of the agreement. (This is generally the alternative financier – if the alternative financier is responsible, they are better able to assure that savings occur and persist.)


7.2 Alternative Financing Output

Alternative financing output is identical to the output under appropriated funding except that the *.ecp output is not available for cases run with alternative financing because alternative financing and Energy Resilience Conservation Investment Program (ERCIP) funding represent different and incompatible funding mechanisms.

8 FEDS Output

Upon completion of a successful FEDS run, a number of relevant reports will be generated automatically. Additional output reports may be generated at any time, or refreshed as needed. From the FEDS Home, select **Reports**. The following report types are available (as shown in Figure 8.1):

- Summary Installation and Building Set Output (txs) – *always generated*
- Detailed Retrofit Output – Text Format (txd)
- Detailed Retrofit Output – Spreadsheet Format (*.csv)
- ERCIP Format Output (ecp)
- Calibration Output (*.Calib.xlsx)
- Retrofit Savings Overview (*.Retrofit.Savings.xlsx)
- Compliance Tracking System (CTS) Report (*.CTS.xlsx)

FEDS provides direct access to the report files from the Report screen. To open a report, simply click the  button next to the report you wish to view and FEDS will open it within the application you have established to open files of that type. When opening a report, if the report file type is not yet associated with a viewing application (e.g., a word processing program, spreadsheet program, or PDF reader), you will be prompted to select the application you wish to use to open and view the report.

To create or refresh a report manually, check the box next to the report(s) you wish to generate and hit the “Create Report” button. And then the report(s) may be opened.

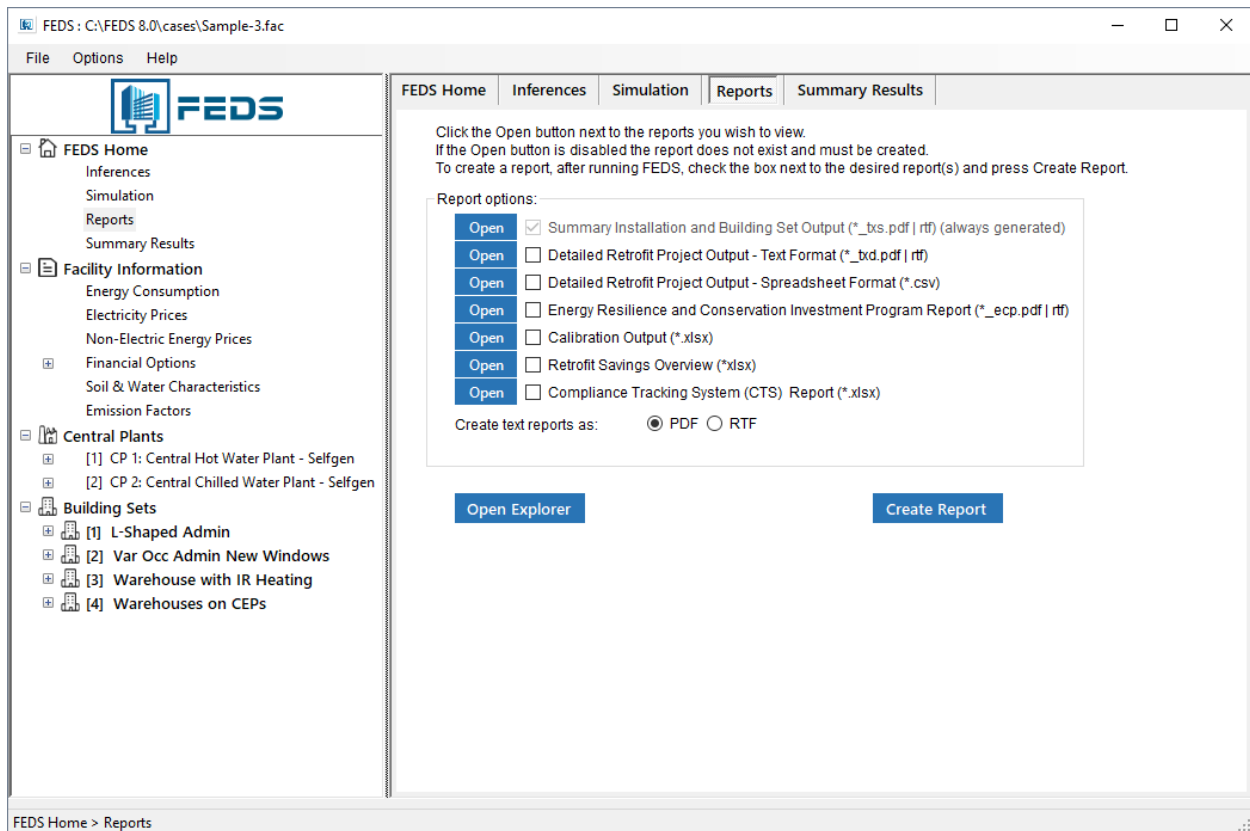


Figure 8.1 Report Options Screen

8.1 Summary Installation and Building Set Output (TXS Report)

The text-based summary (“txs”) report presents a summary of the installation and building set energy, demand, dollar, and air pollution emissions impacts. This report is automatically generated by FEDS at the end of each FEDS run and any time any report format is created. It can be created in either portable document format (PDF) or rich text format (RTF) according to the setting specified on the reports screen. The output file is structured as follows:

Page 1: A summary of the **site energy-use characterization** provided in the input file.

Page 2: A summary of the **electricity price and schedule information** specified in the input file.

Page 3+: A summary of the **site building characteristics** specified in the input file. This includes the number of buildings, floor area, construction date, space heating technology, space cooling technology, and service water heating technology.

Page 4+: A summary of **additional site building characteristics** including indoor lighting technology and building operating hours. In addition to start and end time for each day type within each building and use area, identifiers for 5- or 4-day workweeks and the use of variable occupancy are presented, plus the number of calculated annual operating hours.

Page 5+: A summary of the **site economic data** specified in the input file, including financial analysis parameters (discount rate, energy cost escalation rates, etc.) and utility cost-sharing. Also, basic information regarding the status of the Simulation Options such as whether any cost data have been altered, and which building sets have been excluded from optimization or have retrofit restrictions defined. See FEDS Simulation Settings (Section 6).

Page 6: Reports the **highest level of identified resource savings potential**, as shown in Figure 8.2. A description of each line of output follows.

| Summary of Retrofit Resource Potentials | |
|--|---------|
| ----- | |
| First year energy and demand dollar savings due to retrofits (\$)..... | xxx,xxx |
| Present value of life-cycle energy, demand, and O&M savings (\$)..... | xxx,xxx |
| Total estimated investment required for retrofits (\$)..... | xxx,xxx |
| Present value of capital investments (\$)..... | xxx,xxx |
| Total net present value (\$)..... | xxx,xxx |
| First year energy, demand, and O&M savings: | |
| Retrofits not due to plant/loop abandonment (\$)..... | xxx,xxx |
| Retrofits due to plant/loop abandonment (\$)..... | xxx,xxx |
| Net present value: | |
| Retrofits not due to plant/loop abandonment (\$)..... | xxx,xxx |
| Retrofits due to plant/loop abandonment (\$)..... | xxx,xxx |
| Estimated current installation energy use (MBtu)..... | xxx,xxx |
| Estimated post-retrofit installation energy use (MBtu)..... | xxx,xxx |
| Estimated installation annual energy savings (MBtu)..... | xxx,xxx |

Figure 8.2 Example TXS Output Report

First year energy and demand dollar savings due to retrofits. This is the sum of the energy savings for each fuel across the entire installation (all buildings, central plants, and thermal loops) plus the electric demand savings. The value of savings is the product of the energy savings and the user-entered price. Electric energy savings are based on hourly changes when time-of-day rates are used. Electric demand savings reflect changes in hourly demand and demand ratchets.

Present value of life-cycle energy, demand, and O&M savings. This is the sum of the present values of all energy, demand, and O&M savings over the investment lifetime across the entire installation. The investment lifetime for equipment is the shorter of 25 years or the remaining life of the existing equipment; for other improvements (e.g., envelope measures), the investment lifetime is 25 years. The "present value of life-cycle energy, demand, and O&M savings" is also the sum of the "net present value of retrofits" and the "present value of capital investments."

Total estimated investment required for retrofits. This is the sum of all the retrofit installed costs across the entire installation.

Present value of capital investments. This is the sum of all the present values of annualized installed costs. NOTE: The "present value of capital investments" can be greater than, less than, or equal to the "total estimated investment required for retrofits."

- It will be more than the investment cost if an improvement is being made to the existing equipment and if the life of the improvement is less than the life of the existing equipment. This is because there are interim capital charges due to continual replacement of the improvement over the remaining life of the existing equipment.
- It will be less than the investment cost if the existing equipment is being replaced and if the life of the new equipment is longer than the remaining life of the existing equipment. This is because only those equipment capital costs that are amortized during the remaining life of the existing equipment are included in the calculation of the present value of capital investments.

Net present value of retrofits. This is the present value of life-cycle energy, demand, and O&M savings less the present value of capital investments (also called the net savings) across the entire installation.

First year energy, demand, and O&M savings: (Note: This output is provided only when central energy plants are present.)

- **Retrofits not due to plant/loop abandonment.** This is the sum of the energy, demand, and O&M savings for each optimal retrofit that is not due to plant abandonment. Hence these retrofits would be selected based on their own cost effectiveness even if the plant or loop was not recommended for abandonment.
- **Retrofits due to plant/loop abandonment.** This is the sum of the energy, demand, and O&M savings for each optimal retrofit that has been selected as a direct result of its serving central plant or thermal loop being recommended for abandonment. Hence these retrofits would not be selected if the plant or loop was not being abandoned; on their own they are not cost effective, but the savings from abandoning the plant and/or loop are sufficient to drive the retrofit and result in a positive net savings. Or conversely, the thermal loop may have been marked for required abandonment, in which case the net savings may not be positive.

Net present value: (Note: This output is provided only when central energy plants are present.)

- **Retrofits not due to plant/loop abandonment.** This is the present value of life-cycle energy, demand, and O&M savings less the present value of capital investments (also called the net savings) for each optimal retrofit that is not due to plant abandonment. Hence these retrofits would be selected even if the plant was not recommended for abandonment.
- **Retrofits due to plant/loop abandonment.** This is the present value of life-cycle energy, demand, and O&M savings less the present value of capital investments (also called the net savings) for each optimal retrofit that is due to plant abandonment. Hence these retrofits would not be selected if the plant was not recommended for abandonment.

Estimated current installation energy use (MBtu). This is the estimated total annual site energy use in million Btu prior to retrofit for the entire installation that is modeled in FEDS. This does not include process energy not accounted for in buildings, electric distribution system losses, outdoor lighting that is not modeled, and other energy consumption that has not been explicitly modeled. This value will not equal the annual energy consumption that you have entered but should be relatively close to indicate a well-calibrated model. The difference is due to excluded uses described above and the difference between the actual weather for the site during the time period for which consumption data were provided and the typical year weather data used by the model.

Estimated post-retrofit installation energy use (MBtu). This is the estimated total annual site energy use in MBtu for the entire installation that is modeled in FEDS, with the recommended package of energy efficiency measures in place.

Estimated installation annual energy savings (MBtu). This is the difference between the "estimated current installation energy use (MBtu)" and "estimated post-retrofit installation energy use (MBtu)."

Page 7: Annual installation energy use and cost by fuel type (before and after retrofit), the difference, and the percentage change.

Page 8: Annual installation electric peak demand and cost (before and after retrofit), the difference, and the percentage change. The time of the installation peak demand (month, day type, and hour) is also provided. Additionally, a listing of simulated site peak demand, billing demand, and demand cost, by month, for both existing and post-retrofit scenario, is presented.

Page 9: Annual installation emissions by pollutant type (SO_x, NO_x, N₂O, CH₄, CO₂, CO_{2e}). Values are provided for existing, post-retrofit, the difference, and the percentage change.

Page 10: Annual energy use by fuel type and end use for all buildings (heating, cooling, ventilation, lights, motors and miscellaneous loads, and hot water). Values are provided for existing, post-retrofit, the difference, and the percentage change.

Page 11+: Central plant and thermal loop annual energy and cost. For each central plant, information is printed on existing and post-retrofit source energy consumption, plant output, annual O&M cost, and marginal and average value of output. Also, a section is printed for each loop connected to the plant, listing the connected loads by building set or downstream plant, total delivered energy, loop loss, energy input, loop efficiency, annual O&M cost, and marginal and average value of delivered fuel. If the plant and/or loops are abandoned during optimization, a first year and present value of abandonment are also reported. This page (one per central plant) is only created for cases that have central plants and thermal loops defined.

Page 12+: Annual energy use and cost by building set similar to that provided on page 7 for the installation. Electric costs on this page are based on the overall installation cost and, thus, will not necessarily precisely match the values reported on the TXD

report, which are calculated at the margin based on the impact from each retrofit. There is one page of results per building set.

Page 13+: Annual electric peak demand by building set (before and after retrofit), the difference, and the percentage change. The time of the building set peak electric demand (month, day type, and hour). The contribution to the installation peak demand (coincident demand) and cost (before and after retrofit), the difference, and the percentage change. There will be one page per building set.

Page 14+: Annual emissions by building set and pollutant type, similar to that provided on page 9 for the installation. There will be one page per building set.

Page 15+: Annual building set energy use, by fuel type and end use, similar to that provided on page 10 for the installation. There will be one page per building set.

Page 16+: Energy intensity by building set and fuel type, expressed in user units per 1,000 ft² of floor area. Both existing and post-retrofit values are printed.

Page 17+: Energy intensity by building set and fuel type, expressed in MBtu per 1,000 ft² of floor area. Both existing and post-retrofit values are printed.

8.2 Text-Based Detailed (TXD) Retrofit Project Report

This text report format contains detailed information on each retrofit selected for each building set in the case:

Page 1+: Summary building set information, including building set description, number of buildings in set, total floor area in set. Existing, post-retrofit, and the change in the building set energy and demand costs are also provided. Lastly, summary life-cycle cost savings and installed capital costs for building set retrofits are included.

Page 2+: Detailed information on each optimal retrofit selected. Figure 8.3 shows an example. The output is broken down into 8 sections with a blank line separating each:

Section 1: A description of the existing and retrofit technology and where the technology is located on the installation. This includes a description of the building set, building type, and use area; the technology end use; the type of existing and retrofit technology; and the portion of the building set served by this technology.

Section 2: Retrofit Technology -- Technical information about the existing and retrofit technologies, including information on capacity, number of units, performance, vintage and remaining life.

Section 3: Technology Energy Use/Demand (this technology) -- The direct energy usage and demand information for the existing and retrofit technologies in this building set (no interactive effects included) and the change due to the retrofit.

Section 4: Building Set Energy Use/Demand (All technologies at minimum LCC except technology being retrofit) -- Building set energy consumption by end use,

total building set energy use, and peak electric demand. The “Existing” column shows the energy use and demand assuming all technologies in the building set are at the minimum life-cycle cost, as determined in the FEDS run, except the technology being retrofit (the existing technology). The “Retrofit” column shows the energy use and demand with all technologies at the minimum life-cycle cost - this column is the same for all retrofits within a building set as it represents the optimized building set consumption, as determined in this FEDS run. The “Difference” column shows the energy change, by end use, including interactive effects, as a result of this retrofit and the overall building set peak demand change.

Section 5: Air Pollution Emissions (All technologies at minimum LCC except technology being retrofit) -- Existing, retrofit, and difference in the air pollution emissions for six pollutant types. These values are derived from the changes in fuel consumption associated with the retrofit's Building Set Energy Use/Demand impact described above.

Section 6: Building Set Energy/Demand Cost--First Year (All technologies at minimum LCC except technology being retrofit) -- The value of the energy and demand for:

- This technology -- The energy and demand costs, and savings, directly associated with the existing and retrofit technology energy usage and demand
- Balance of Building Set -- The energy and demand costs, and savings, associated with the entire building set excluding those directly tied to the technology being retrofit. Thus, the energy and demand savings displayed here represent the value of the interactive effects.

Section 7: Life-Cycle Costs Savings -- The present and annualized values of the installed cost, annual maintenance costs, non-annual maintenance costs, energy/demand costs, and total LCC savings (NPV). Also provided are the simple payback (years), AIRR (percent/year), and SIR (savings-to-investment ratio). There are several reasons that some retrofits can have negative net present values (NPVs) as explained in Section 5.8 and Section A.6. If a negative NPV retrofit occurs there will be a note on that page to indicate the reason (e.g., marked for required replacement, loop abandoned, or plant abandoned).

Section 8: Installed Capital Cost -- The estimated installed cost of the retrofit.

| | | | |
|--|-----------------------|-----------------------|-----------------|
| Technology Retrofit Information for Building Set #3: (B) Office (C) | | | |
| Sample-2 Building Set 3: Office (D) | | | |
| End Use: Lights (E) | | | |
| Use Area: Office (F) | | | |
| Equipment Description: Main Office Lights (G) | | | |
| Existing Technology: FL236: FL 2X4 3F32T8 ELC3 (H) | | | |
| Percent of Building Set Served by this Technology: 80.00% | | | |
| Retrofit Technology: LD301: LED 59W 2x4 Retrofit Panel (6227 Lumens) plus occupancy controls (J) | | | |
| | Existing | Retrofit | Difference |
| Retrofit Technology | | | |
| Watts/fixture | 96.0 (P) | 59.0 (Q) | -37.0 |
| Operating hours/Year | 2,948 (R) | 2,359 (S) | -590 |
| Fixtures in this Bldg. Set | 982 (N) | 982 (O) | 0 |
| Vintage | 1977 (M) | New | |
| Remaining Life (years) | 25 | 25 | |
| Technology Energy Use/Demand (This technology) | | | |
| Energy (user units) | 277,967 (T) (kWh) (U) | 136,667 (V) (kWh) (W) | -141,300 |
| Energy (MBtu) | 949 | 466 | -482 (X) |
| Electric Peak Demand (kW) | 59 | 29 | -30 (Y) |
| Coincident Peak Demand (kW) | 59 | 29 | -30 |
| Building Set Energy Use/Demand (All technologies at minimum LCC except those being retrofit) | | | |
| Heating (MBtu) | 758 | 836 | 78 |
| Cooling (MBtu) | 390 | 338 | -52 |
| Ventilation (MBtu) | 901 | 901 | 0 |
| Lighting (MBtu) | 1,194 | 712 | -482 |
| Misc. Equip. (MBtu) | 1,793 | 1,793 | 0 |
| Motors (MBtu) | 0 | 0 | 0 |
| Service Water Heating (MBtu) | 42 | 42 | 0 |
| Total (MBtu) | 5,078 | 4,622 | -455 (Z) |
| Peak Electric Demand (kW) | 366 | 328 | -38 (AA) |
| Air Pollution Emissions (All technologies at minimum LCC except those being retrofit) | | | |
| Carbon Dioxide (tons) | 179.9 | 167.8 | -12.1 (AF) |
| Sulfur Oxides (lb) | 136.3 | 124.5 | -11.8 (AG) |
| Nitrogen Oxides (lb) | 407.1 | 382.8 | -24.3 (AH) |
| Nitrous Oxide (lb) | 5.9 | 5.6 | -0.3 (AI) |
| Methane (lb) | 1,127.5 | 1,084.8 | -42.7 (AJ) |
| CO2 Equivalent (tons) | 196.9 | 184.1 | -12.8 (AK) |
| Building Set Energy/Demand Cost--First Year | | | |
| (All technologies at minimum LCC except those being retrofit) | | | |
| This technology | | | |
| Energy | \$ 27,797 | \$ 13,667 | \$ -14,130 (AB) |
| Annual Electric Demand | \$ 3,148 | \$ 1,548 | \$ -1,600 (AC) |
| Balance of Building Set | | | |
| (All technologies other than those being retrofit--includes systems and retrofit interactions) | | | |
| Energy | \$ 107,205 | \$ 106,619 | \$ -586 (AD) |
| Annual Electric Demand | \$ 15,454 | \$ 15,073 | \$ -381 (AE) |
| Life-Cycle Costs Savings | | | |
| | Present Values | Annualized Values | |
| Installed Cost | \$ -279,023 (AL) | \$ -16,024 (AM) | |
| Annual Maintenance | \$ 0 (AN) | \$ 0 (AO) | |
| Non-Annual Maintenance | \$ 149,658 (AP) | \$ 8,595 (AQ) | |
| Energy/Demand | \$ 291,039 (AR) | \$ 16,714 (AS) | |
| Total LCC Savings (NPV) | \$ 161,674 (AT) | \$ 9,285 (AU) | |
| Simple Payback (years) | 11.0 (AV) | | |
| AIRR (percent/year) | 4.9 (AW) | | |
| SIR | 1.6 (AX) | | |
| Installed Capital Cost: | \$ 279,023 (AY) | | |

Figure 8.3 Example Output of the TXD Report (The characters in parentheses represent the spreadsheet column indicator where the data will reside once opened in a spreadsheet program.)

8.3 Detailed Retrofit Project Report – Spreadsheet (CSV) Format

The “Detailed Retrofit Output - Spreadsheet (*.csv)” option from the *Reports* screen represents a comma-separated variable format report that can be opened by most any spreadsheet program. This file will be named “{casename}.csv.” Selected quantities from the “{casename}.txd” output report are included in this file as indicated by the mapping shown in parentheses in Figure 8.3. The colored characters (e.g., “(J)”) correspond to the column in which that information will appear in the spreadsheet. Each page of the “*.txd” output is represented as a single row of data on the “*.csv” report. This information is included for each existing technology considered in each end use, regardless whether a retrofit was selected or not. In cases where a retrofit project was not chosen (either because it was not cost-effective or due to retrofit restrictions) the “Retrofit Technology” will be listed simply as “none.”

In addition to the data from the “{casename}.txd” reports shown in Figure 8.3, the “{casename}.csv” output will display the following additional columns of information:

- Installation Name (Column A) – The installation name entered on the *FEDS Installation Inputs* screen will appear in the first column.
- Required Replacement (Column I) – Indicates whether the user selected the technology for required replacement (or forced retrofit); note that this can result in retrofits with negative NPVs as explained in Section 5.8.
- Rank (Column K) – This field lists the ranking of the current retrofit technology. If the “Generate Top 3 Retrofits” option has been enabled, up to three retrofits may be listed for each existing technology and ranked according to lowest life-cycle cost. If this option was disabled during the FEDS run, all retrofits listed will be the optimal retrofits. For more information see Generate Top 3 Retrofits in Section 6.1.2.
- End-use Retrofit Restrictions (Column L) – This field displays information pertaining to the Exclude Building Sets and Restrict Retrofits from Optimization portions of the Advanced Options. It displays whether the current building set has been excluded from optimization or whether any end-use retrofit restrictions exist for that building set. If neither applies “none” will be printed.
- Additional Installed Cost Detail (Columns AZ - BB) – These additional fields detail the makeup of the total installed capital cost presented in Column AY. These include the Materials Cost (AZ), Labor Cost (BA), and Indirect Cost (BB) consisting of overheads.
- Fuel Savings (MBtu/Yr) and Value of First Year Fuel Savings (\$) (Columns BC - BT) – These 18 columns present the annual energy savings and first year dollar savings for each fuel type. This provides another layer of detail for the overall energy and dollar savings, to identify the savings for each fuel used in the building.

Notes:

- *Some fields of data on the *.csv output list results in units of measure that vary according to the type of retrofit project. For example, the #Units fields present the number of pieces of equipment or lighting fixtures for most types of projects, but for most envelope projects it represents the area in square feet of roof, wall, window, or floor area impacted. For slab floor insulation projects, the #Units identifies the perimeter floor length in feet. The Performance fields generally list the equipment efficiency, insulation R-value, window U-value, or lighting wattage. The Rated Size fields also report data in varying units, as identified in the header (“Rated Size: (kBtu/hr); Light(hrs/yr); Motor(hp); Envel(thickness); Glass(SC)”).*
- *Values of “NA” appearing in the *.csv output represent values that are not applicable for the current retrofit technology. Examples of this are the fuel/units for the existing and retrofit technology energy consumption associated with an envelope measure (e.g., wall insulation).*

8.4 ERCIP Report

Selecting the “ERCIP report” option will generate a life cycle cost analysis summary in the format and calculation method prescribed for the Energy Resilience and Conservation Investment Program (ERCIP). This file contains three pages of information for each retrofit project identified by FEDS. Figure 8.4 shows examples of output for the three pages of an ERCIP report.

Page 1: Header information listing the building set, end use, and existing and retrofit technologies.

Page 2: The Energy Project Summary Sheet, containing general project description, location, and savings information.

Page 3: The Energy Life Cycle Cost Analysis Summary listing the specific energy and cost savings associated with the particular project.

Technology Retrofit Information for Building Set #3: Office
Sample-2 Building Set 3: Office
End Use: Lights
Use Area: Office
Equipment Description: Main Office Lights
Existing Technology: FL236: FL 2X4 3F32T8 ELC3
Percent of Building Set Served by this Technology: 80.00%
Retrofit Technology: LD301: LED 59W 2x4 Retrofit Panel (6227 Lumens) plus occupancy controls

Energy Project Summary Sheet

| | |
|--------------------------------------|---|
| Installation: | Sample-2: Four Building Sets |
| Location: | Seattle, WA |
| Project Title: | Lighting Systems |
| Project Description: | Sample-2 Building Set 3: Office |
| | LD301: LED 59W 2x4 Retrofit Panel (6227 Lumens) plus occupancy controls |
| Project Number: | |
| Total Investment: | \$ 279,023 |
| MBtu/Yr Saved: | 455 |
| Discounted MBtu Savings: | \$ 176,884 |
| Discounted Demand Savings: | \$ 23,646 |
| Discounted Total Energy Savings: | \$ 200,530 |
| Discounted Total Non-Energy Savings: | \$ 122,084 |
| First Year Dollar Savings: | \$ 27,577 |
| Simple Payback in Years: | 10.12 |
| Discounted Total Net Savings: | \$ 322,614 |
| Savings To Investment Ratio (SIR): | 1.16 |
| Point Of Contact: | I.M. Somebody |
| Phone Number: | (123) 456-7890 |

ERCIP Page 1 and Page 2 Output

Figure 8.4 Example Output of {Casename}.ecp Report

Energy Life Cycle Cost Analysis Summary

Location: Seattle Region: 4 Project No:
Category: 6 Economic Life: 15 Project Title: Lighting
Systems
FY: 2008 Date: 20-May-2020

Prepared By: I.M. Somebody
State: WA

| | | | | |
|--|----|---------|----|----------------|
| 1. Investment Costs | | | | |
| A. Construction Cost | \$ | 240,537 | | |
| B. SIOH (6.00%) | \$ | 14,432 | | |
| C. Design Cost (10.00%) | \$ | 24,054 | | |
| D. Energy Credit Calc (1A+1B+1C) | | | \$ | 279,023 |
| E. Salvage Value of Existing Equipment | | | \$ | 0 |
| F. Public Utility Company Rebate | | | \$ | 0 |
| G. Total Investment (1D-(1E+1F)) | | | \$ | 279,023 |
| | | | | Funding Amount |
| | | | | \$ 279,023 |

2. Energy Savings(+) or Cost(-) Analysis Date Savings, Unit Costs & Discounted Savings

| Fuel | Cost \$/MBtu(1) | Savings MBtu/Yr(2) | Annual \$ Savings(3) | Discount Factor(4) | Discounted Savings(5) |
|-------------------|--------------------|-----------------------|-------------------------|-----------------------|--------------------------|
| A. Electricity | \$ 29.30 | 518 | \$ 15,187 | 12.01 | \$ 182,370 |
| B. Distillate Oil | \$ 21.27 | 0 | \$ 0 | 11.64 | \$ 0 |
| C. Residual Oil | \$ 0.00 | 0 | \$ 0 | 13.59 | \$ 0 |
| D. Natural Gas | \$ 7.50 | -63 | \$ -471 | 11.64 | \$ -5,486 |
| E. Coal | \$ 0.00 | 0 | \$ 0 | 11.98 | \$ 0 |
| F. Steam | \$ 0.00 | 0 | \$ 0 | 0.00 | \$ 0 |
| G. Hot Water | \$ 0.00 | 0 | \$ 0 | 0.00 | \$ 0 |
| H. Chilled Water | \$ 0.00 | 0 | \$ 0 | 0.00 | \$ 0 |
| I. Other Fuels | \$ 0.00 | 0 | \$ 0 | 0.00 | \$ 0 |
| J. Demand Savings | | | \$ 1,981 | 11.94 | \$ 23,646 |
| K. Subtotal | | 455 | \$ 16,696 | | \$ 200,530 |

| | Cost \$/Mgal(1) | Savings Mgal/Yr(2) | Annual \$ Savings(3) | Discount Factor(4) | Discounted Savings(5) |
|----------|--------------------|-----------------------|-------------------------|-----------------------|--------------------------|
| L. Water | | | \$ 0 | 11.94 | \$ 0 |
| M. Total | | | \$ 16,696 | | \$ 200,530 |

3. Non-Energy Savings(+) or Cost(-)

| | | |
|--------------------------------------|-------|------|
| A. Annual Recurring(+/-) | | |
| (1) Discount Factor | 11.94 | \$ 0 |
| (2) Discounted Savings/Cost (3Ax3A1) | | \$ 0 |

B. Non-Recurring Savings(+) or Cost(-)

| Item | Savings \$ Cost(1) | Year of Occurrence(2) | Discount Factor(3) | Discounted Savings (+) or Cost(-) (4) |
|----------|-----------------------|--------------------------|-----------------------|--|
| d. Total | \$ 163,214 | | | \$ 122,084 |

| | |
|--|------------|
| C. Total Non-Energy Discounted Savings/Cost (3A2+3Bd4) | \$ 122,084 |
|--|------------|

| | |
|--|-----------|
| 4. First Year \$ Savings (2P3+3A+(3Bd1/Yrs Econ Life)) | \$ 27,577 |
|--|-----------|

| | |
|--------------------------|-------|
| 5. Simple Payback (1G/4) | 10.12 |
|--------------------------|-------|

| | |
|--|------------|
| 6. Total Net Discounted Savings (2P5+3C) | \$ 322,614 |
|--|------------|

| | |
|---|------|
| 7. SIR (If < 1.25 Project Does Not Qualify) | |
| SIR = (6/1G) | 1.16 |

ERCIP Page 3 Output

Figure 8.4 Example Output of {Casename}.ecp Report (cont'd)

8.4.1 Differences Between ERCIP Output and Other FEDS Output

There are at least two reasons why the ERCIP results can differ from the results in the FEDS "*.txd" and "*.csv" output. You should be aware of these reasons if you try to reconcile the ERCIP results with the "*.txd" and "*.csv" results. The differences arise because the ERCIP specification directs that some LCC computations be performed in a manner that is different from that used in computing the "*.txd" and "*.csv" output.

- The analysis period used by the LCC model in FEDS is usually different from that dictated by the guidelines for ERCIP reporting. This affects the discounted savings computed for the five ERCIP fuels and for the non-recurring maintenance savings.
- In the ERCIP output, the average for nonrecurring maintenance cost is used in computing total first-year savings, which is then used to compute the simple payback. The FEDS "*.txd" results for the simple payback are based upon an annualized value for the nonrecurring maintenance costs.

Note: prior to FEDS 7.0, the site SIOH and Design costs were factored into the ERCIP cost analysis only. Now, these costs are fully reflected in all FEDS analyses and report types, to include overhead and design costs related to the project beyond those paid to the contractor.

8.5 Calibration Output Report

The purpose of the Calibration Output report is to assist in calibrating FEDS building and site energy models to available metered consumption data for a particular year. The report contains many of the same results as the Summary Installation and Building Set Output (*.txs) report, but formatted as a spreadsheet file (*.Calib.xls) for easier comparison to a table of metered consumption data by building set. Results are presented across three worksheets (four when the case contains central energy plants and thermal distribution loops) within the spreadsheet file, as follows:

- FEDS Summary:
 - Overview of the run including Case Name and date and time of the analysis
 - Total Installation Energy Use By Fuel Type – listing total combined annual energy consumption, EUI, and Cost over all fuel types
 - A counter to report the number of building sets, central plants, and thermal loops present in the case
- FEDS Building Summary:
 - FEDS Summary of building set characteristics including identification, description, number of buildings, floor area, vintage
 - Energy Use By Building and Fuel Type – lists energy use and EUI for each fuel type as well as overall

- Energy Use By Building, End Use and Fuel Type – lists total consumption by end use, for each fuel type
- Energy Intensity By Building and Fuel Type – lists in MBtu/ksf, the EUIs for each fuel type
- Energy Intensity By Building and End Use – lists in MBtu/ksf, the EUIs for each end use as well as overall
- FEDS CEP Summary: *(only present for cases containing central energy plants and/or thermal loops)*
 - Central Energy Plant Energy Use – lists the equipment level energy consumption for each central plant, auxiliary equipment electricity, total energy consumption, and annual plant output in either MBtu (for steam or hot water plants) or ton-hr (for chilled water plants)
 - Central Energy Plant Loop Losses – lists for each modeled thermal distribution loop, the total delivered energy, thermal loss, leakage loss, total loss, total energy input, loop efficiency, annual O&M cost, and both marginal and average values of delivered energy
- Full Summary: this table presents all of the data contained on the preceding tables but in a single worksheet, which may be preferred for certain calibration processes

The Calibration Output report will be automatically generated at the end of each Calibration analysis (in which the Analysis type is set to “Calibration” from within the *Simulation Parameters* screen which is accessed from the Advanced Options.

8.6 Retrofit Savings Overview Report

The Retrofit Savings Overview report provides a high-level summary of a site’s energy and cost savings potential identified by FEDS during an Optimization analysis. The report is output in a spreadsheet table including the following results for each building, as well as the total over all buildings:

- Current Annual Energy Use (MBtu)
- Energy Savings (MBtu/yr)
- Energy Savings (%)
- Energy / Demand Savings (\$/yr)
- Estimated Investment (\$)
- Simple Payback (yrs)
- SIR
- Carbon Reduction (tons CO_{2e})

An example of the Retrofit Savings Overview report is shown below in Figure 8.5, based on the Sample-3 case. It is important to note however, that the data presented on the Retrofit Savings Overview table reflect energy and dollar savings compiled at the individual building level only, and do not include any savings that may have been identified within the central plants or thermal loops. Consult the *.txs report to review the savings attributable to recommendations specific to the central plants and/or thermal loops.

| Sample-3: New Capabilities - Retrofit Savings Overview | | | | | | | | |
|--|----------------------------------|--------------------------|--------------------|---------------------------------|---------------------------|------------------------|-------------|---|
| Building Set | Current Annual Energy Use (MBtu) | Energy Savings (MBtu/yr) | Energy Savings (%) | Energy / Demand Savings (\$/yr) | Estimated Investment (\$) | Simple Payback (Years) | SIR | Carbon Reduction (tons CO ₂ e) |
| L-Shaped Admin | 5,957.61 | 1,554.85 | 26.10 | 28,460.66 | 175,786.05 | 6.56 | 1.76 | 216.98 |
| Var Occ Admin New Windows | 4,405.00 | 1,116.06 | 25.34 | -3,643.27 | 455,716.97 | 19.28 | 0.74 | 220.36 |
| Warehouse with IR Heating | 7,457.74 | 129.93 | 1.74 | 9,143.23 | 6,631.74 | 1.20 | 13.67 | 41.54 |
| Warehouses on CEPs | 15,615.90 | 3,788.99 | 24.26 | 108,129.52 | 397,325.03 | 2.99 | 5.48 | 1,025.48 |
| Site Total | 33,436.25 | 6,589.82 | 19.71 | 142,090.15 | 1,035,459.79 | 5.49 | 2.81 | 1,504.36 |

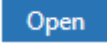
Figure 8.5 Example Output of {Casename}.Retrofit.Savings.xls Report

8.7 Compliance Tracking System (CTS) Report

A CTS format report has been developed to assist federal agencies in meeting EISA 2007 Section 432 auditing requirements. This new spreadsheet output summarizes the results of an EISA-compliant assessment, to facilitate reporting to the Compliance Tracking System (CTS). The report automatically compiles the details from the assessment to assist in the reporting of assessed floor area and identified energy savings potential. Retrofit measures identified by FEDS are categorized and compiled within the CTS format, across all buildings evaluated, to provide a summary of the number of measures and impact from each group. The report can assist agencies in submitting required documentation into the CTS. Note: Microsoft Excel is required for FEDS to generate the CTS report.

8.8 Formatting and Printing Reports

Once the FEDS run has completed and the reports have been generated (see FEDS Output), the report files can be opened from the *Report Options* screen. The report files themselves are created and stored within the FEDS\Cases subdirectory with all the other files that make up a FEDS case.

To open a report simply click the  button next to the report you wish to view and FEDS will open the report in the application you have assigned to view the report type. For example, if you have selected to create the text-based report files (e.g., *.txs, *.txd, *.ecp) in PDF format, the application you have designated to read PDF files will

launch to allow report viewing, editing, and printing. The spreadsheet files (e.g., *.xlsx, *.csv) should open within a spreadsheet application.

Text-Based Reports

The *.txs, *.txd, and *.ecp reports will open in an application appropriate for the format selected (either PDF or RTF).

Spreadsheet Reports

The spreadsheet-based reports (e.g., *.csv, *.Calib.xls, *.Retrofit.Savings.xls) may only be opened and examined inside of a spreadsheet application. To view or print the spreadsheet report:

1. select to open the desired report from the FEDS *Report Options* window (the report will open in your spreadsheet application)
2. format the report as desired (adjust column widths to accommodate column headings, sort/filter data, add sums or subtotals, hide fields, etc.)

8.9 Hourly Energy Profile Output

Additional advanced output offered by FEDS includes hourly profiles of energy use based on the FEDS simulation. These profiles are output in CSV format and available at the site, building, and technology aggregation levels, for both baseline and post-retrofit simulations. This detailed output can be extremely valuable for more detailed assessments and analyses, and is used for sizing loads for renewable energy systems as well as resilience planning, among other applications. The capability goes beyond that of the typical FEDS user and therefore a detailed description is not offered here at this time. For more information please contact FEDS Support at FEDS.Support@pnnl.gov.

Appendices

Appendix A – FEDS Technical Approach

FEDS contains complex energy and economic modeling capabilities, which are utilized by a sophisticated optimization algorithm in the determination of the most cost-effective life-cycle energy resource/utilization configuration for facilities ranging from a single building to a multi-building campus or large Federal installation. The FEDS approach allows estimation of the installation-wide energy and peak demand, which is used in conjunction with complex electric rate schedules to determine installation electric costs.

A.1 Design Goals

FEDS was designed with two primary purposes in mind:

- Estimating current energy consumption for all energy systems under consideration – currently, FEDS models only building systems; it is intended that future FEDS releases will capture all energy-consuming systems.
- Determining the minimum life-cycle-cost retrofits to systems within a facility and on an installation (considering all interactive effects) – this includes estimating the pre- and post-retrofit consumption, first cost of the retrofits, recurring O&M costs for the retrofits, the value of the change in annual energy consumption and annual O&M requirements, and the net present value of the retrofits.

A.1.1 *Opportunity Screening*

FEDS provides a user-friendly tool for analyzing energy use and the potential for energy-efficiency retrofit projects at large multi-building campuses or installations. A major feature of its design is that only a minimal amount of energy-system information is required to perform a first-level screening. FEDS uses user-supplied information to infer the appropriate values needed to determine the amount of installation energy consumption and the potential cost-effectiveness of energy retrofits.

A.1.2 *Detailed Analysis and Project Assessment*

FEDS is also designed to allow a user to identify specific projects that are cost-effective and appropriate to a single building or a multiple building site. This is done by allowing a user to override FEDS inferences, specify seasonal occupancy and fuel availability for

each building set, and describe linked building sets. This approach allows **but does not require** a user to enter any site-specific information that is readily available.

A.2 Inference Generation

FEDS uses user-supplied information to internally generate descriptions of prototypes for each building type selected. The default values of the parameters used to describe the prototypes are inferred from the input data; for instance, the climate zone is used in conjunction with the building type, vintage, and size to infer parameters relating to the building construction characteristics. This information is also used to infer the most likely heating equipment types for user-supplied heating fuel type. The resulting building parameter values are statistically the most likely values for a given building type, climate zone, vintage, size, and fuel/technology mix. The FEDS building model (described in the next section) uses these parameters to estimate the energy consumption of each building prototype.

The most likely parameter-value approach to the development of the building prototype allows FEDS to perform detailed modeling of an installation while requiring only very limited information from a user. The results from the FEDS analysis are intended to be used as a gross indication of the required investment, and the energy- and cost-savings potential at an installation. The results can indicate which building types and end uses have the greatest savings potential. However, the most likely parameter-value approach also means that FEDS is most appropriately applied to installations with large numbers of buildings. This approach makes the application of the FEDS screening capability less appropriate for single buildings than when it is used to model multi-building installations. Of course, accuracy is improved if actual parameter values are specified to override the inferred values.

Sources for the inferences about the building characteristics are mostly from the following:

- CBECS and RECS building characteristics data
- ELCAP commercial and residential end-use load and building characteristics data
- ASHRAE standard design and construction practices.

A.3 Central Energy Plant Modeling

The FEDS central plants and thermal loops model estimates energy consumption for any central energy plants located on site as well as any purchased steam, hot water, and chilled water that is piped in. At the building level, central fuels may be defined to provide any combination of heating, cooling, service hot water, desiccant regeneration, and miscellaneous equipment service. For heating, cooling, and service hot water records, once a central fuel type is selected the serving loop will also need to be identified to specify the plant and thermal loop that serves the building technology. Desiccant and miscellaneous equipment will apportion energy to loops and plants

according to the energy delivered by loop for heat, cool, and service hot water for that building set.

Energy losses are added to the energy consumed at the building level for each loop, and summed for each central plant. From this FEDS can determine:

- The total load from all connected buildings and other central plant equipment, both at baseline and throughout the retrofit optimization process
- The value of steam, hot water, or chilled water delivered to each building, considering central plant equipment types and efficiencies, source fuel costs, auxiliary power requirements, O&M costs, loop losses, and other parameters
- The cost effectiveness of various decentralization options including:
 - Which individual technologies served centrally should be replaced with distributed technologies,
 - Which thermal loops of a central energy plant should be abandoned with all attached technologies becoming decentralized, and
 - Which central energy plants should be abandoned with all attached loops becoming abandoned and all attached technologies becoming decentralized

Some things to bear in mind regarding central plant and thermal loop modeling are:

- The "loop season" controls only the heat loss in the loop and not the delivery of energy. For example, if the loop operates only for November through March there will be 5 months of loop loss; however, if a building connected to the loop needs heat in October or hot water in the summer it will be supplied and the delivered energy considered.
- Leakage loss values are expressed in terms of the amount of heat energy being transferred out of the thermal loop. Therefore, they are positive numbers for energy loss from steam and hot water lines and typically negative for heat gain through loss from chilled water lines as heat energy is transferred to the loop. However, during cold times of the year chilled water lines can also lose heat to the surroundings.
- There is only ONE fuel price escalation rate associated with Steam (and one for hot water and one for chilled water) per building set; it is based on the predominate fuel source across all plants and purchased fuels of the same kind that are serving that building set.

A.4 Building Energy Modeling

The FEDS building model estimates energy consumption for the following end uses:

- Lighting
- Heating
- Cooling

- Ventilation
- Service hot water
- Electric motors
- Miscellaneous equipment.

Lighting, motor, and miscellaneous equipment consumptions are calculated according to the user-supplied occupancy schedule, based on capacity and load/utilization factors. Heating, cooling, and service hot water consumption estimates are calculated using estimated loads and system efficiencies. Ventilation energy consumption is also modeled using a number of possible operating scenarios.

A.5 Retrofit Modeling

After modeling the current energy consumption using the existing equipment, the replacement or modification of the equipment is considered. These modifications include complete replacement with similar, but more efficient equipment (e.g., replacing existing fluorescent fixtures with new high-efficiency fluorescent fixtures); changes to different types of equipment which provide equivalent service more efficiently (e.g., replacing a forced air electric furnace with a heat pump); and changes to more efficient equipment using a different fuel (fuel-switching). Additionally, equipment served by central fuels will be considered for replacement with more cost-effective equipment and fuels. Thermal loops and entire central plants are also evaluated for abandonment if each of the technologies served can be replaced and each loop may be abandoned. In such cases, the value of the loop losses and plant and loop fixed operations and maintenance costs will be included in the overall economic evaluation to determine the cost effectiveness of shutting down an entire loop and perhaps a plant.

When considering any equipment changes, the total effect on the building's energy consumption is considered. For example, the model determines the full impact of a lighting system retrofit by determining not only the change in lighting electrical consumption but also the change in the heating, cooling, and ventilation system consumption due to the change in the internal gains.

The impact of any difference in electric consumption is assessed by determining the change in the installation electric energy consumption and demand profiles. These profiles are used in conjunction with the detailed electric rate structures and demand ratchets to calculate the cost or benefit of the change.

A.6 Optimization

Optimization of the building and central plant energy systems is accomplished by an iterative process, as illustrated in Figures A.1 and A.2. The first end use is evaluated (e.g., lights) and the minimum life-cycle cost configuration for that end use is determined. When the second end use is evaluated, the model assumes that the first end use has already been changed. Once all end uses have been evaluated, the model

reconsiders the first end use to see if the minimum life-cycle cost configuration for that end use has changed due to changes in other end uses; this is driven by interactive effects. This process continues until the model has converged to the minimum life-cycle cost configuration for each end use in the entire building set. The model then considers the next building set.

Next, FEDS evaluates the central plants and thermal loops to determine whether it is cost effective to abandon any loops and plants. Any heating, cooling, or service hot water technology that remains connected at this point to a central fuel is optimized and forced to select its most cost effective non-central fueled replacement technology (even if it has a negative life-cycle cost savings). Then, each loop is evaluated to compare the savings associated with shutting down the loop (due to eliminating maintenance and loop loss costs) with the extra life-cycle cost of the new building technologies. If the net savings (known as the loop abandonment value) are positive, then the loop will be abandoned. Otherwise, the abandonment values for all of the loops on a plant are combined, and added to the savings associated with shutting down the plant to determine if it is cost effective to abandon the plant and all of its loops. If this plant abandonment value is positive, the plant and each of its loops are abandoned, and the building technology replacements are kept.³ Otherwise, they are set back to previous state.

The process then repeats to optimize all building sets again. Building technologies that are served by loops now marked for abandonment will be forced to retrofit to their most life-cycle cost effective replacement.

³ In this case, the central fuel technologies that were replaced with in-building technologies may report a negative NPV on the TXD and CSV technology output along with a note that the retrofit was due to plant or loop abandonment. The savings associated with abandoning the loop and possibly plant will not be shown on these reports but on the TXS report where the overall savings will be shown to be positive.

FEDS ENGINE : Baseline

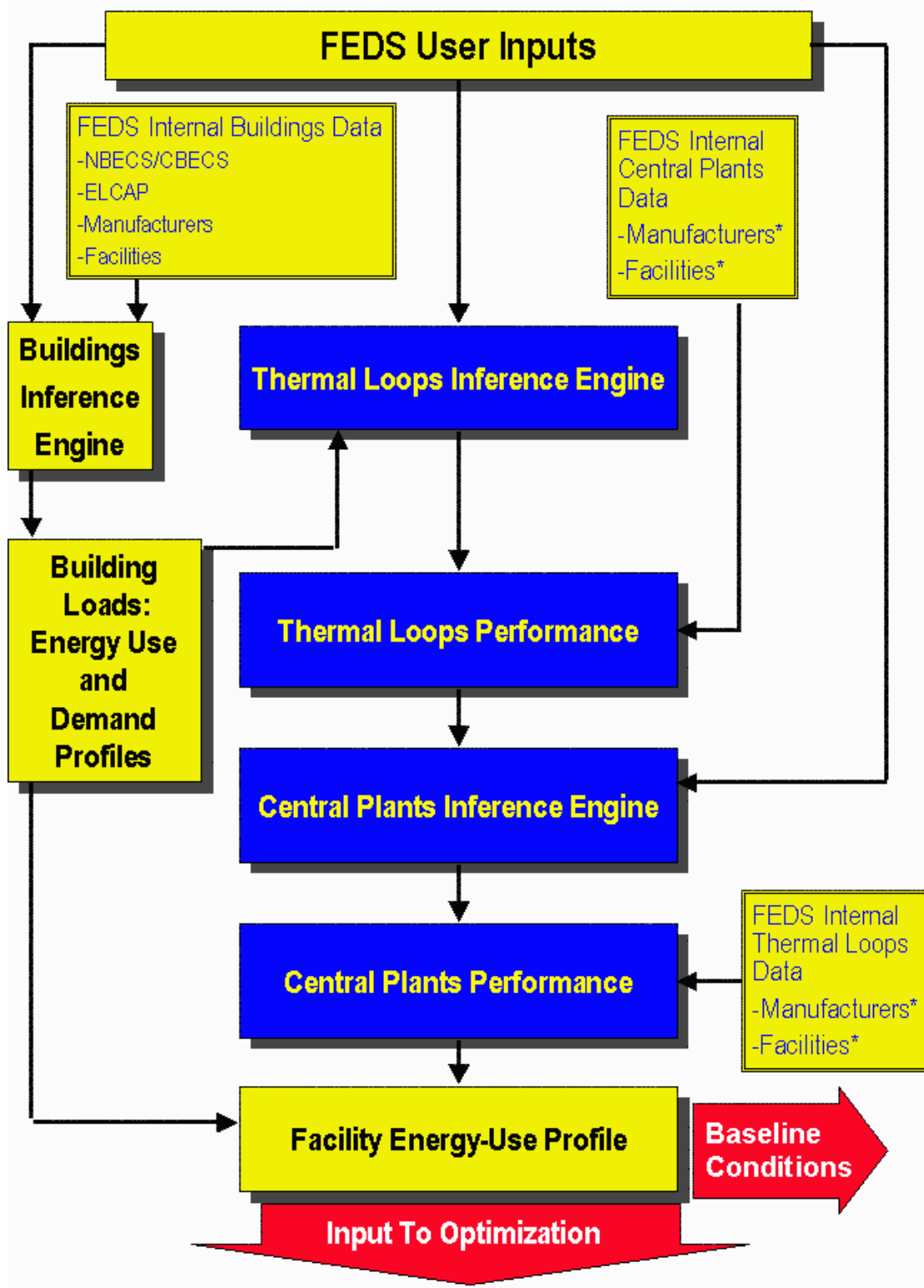


Figure A.1 FEDS Baseline Process

```
graph TD; A[INPUT FROM BASELINE] --> B[Select Building Type (N + 1)]; B --> C[Individual Building Systems Retrofit Optimization Loop  
(Based upon minimum LCC)]; C --> D[Thermal Loops Retrofit Optimization]; D --> E[Central Plants Retrofit Optimization]; E --> F[Estimate of Facility Energy Use and Potential Energy Savings, Including Investment Requirements]; F --> A; F --> B;
```

The flowchart illustrates the optimization process of the FEDS ENGINE. It begins with 'INPUT FROM BASELINE', which leads to 'Select Building Type (N + 1)'. This step feeds into the 'Individual Building Systems Retrofit Optimization Loop (Based upon minimum LCC)'. This loop contains a sequence of components: Service Hot Water, Lighting, Motors, Envelope, Heating Equipment, and Cooling Equipment. The output of this loop goes to 'Thermal Loops Retrofit Optimization', then to 'Central Plants Retrofit Optimization', and finally to 'Estimate of Facility Energy Use and Potential Energy Savings, Including Investment Requirements'. A feedback loop returns from the final estimate to the 'INPUT FROM BASELINE' and also to 'Select Building Type (N + 1)'.

Figure A.2 FEDS Retrofit Optimization Process

Appendix B – FEDS Retrofit Options

The retrofit options for the FEDS software are listed below. This list is continually expanded and refined as new functionality is added to the software. Notes on specific end uses are presented below under each category.

B.1 HVAC Control Retrofits

The following HVAC control options are now available for evaluation by FEDS where viable (depending on current control technology, settings, and building types).

- Thermostat setback: decreasing the unoccupied period heating temperature set point and increasing the unoccupied period cooling temperature set point up to the specified value as compared to the occupied period settings.
- Ventilation scheduling: schedule ventilation system operation based on building occupancy, where applicable.

B.2 Heating Retrofits

The available heating retrofit options are listed below. Both equipment replacements and add-on technologies are considered for building-level heating systems. Retrofit options are dependent on a number of factors including existing equipment type, whether the existing technology has a paired cooling technology defined, the fuel types available to the building, and the required heating capacity. For central district heating systems, the only retrofit options involve conversion to a building-level centralized system (typically involving a boiler or infrared heating system as applicable).

Replacement Heating Retrofit Technology Options Include:

- Conventional forced air furnaces using fuels including electricity, distillate oil, natural gas, and lpg
- Condensing natural gas or lpg furnaces
- Conventional boilers using fuels including electricity, distillate or residual oil, natural gas, and lpg
- Condensing natural gas or lpg boilers
- Infrared heating systems using fuels including electricity, natural gas, and lpg
- Electric air source heat pumps*
- Dual-fuel air source heat pumps (with integrated or separate types of backup heat)*
- Electric ground-coupled heat pump systems (in open-loop, and horizontal or vertical close-loop configurations)*
- Replace water source heat pump units of an existing ground-coupled heat pump system
- Packaged DX A/C unit with integral natural gas or lpg heat (e.g., a gas pack)*

*These heating retrofit options are considered only when the existing heating technology is identified as a pair with a specific cooling technology.

Add-On Retrofit Heating Technology Options Include:

- Boiler feedwater economizers
- Boiler automatic electric dampers
- Adding a forced air furnace to an existing air source heat pump plus controls for dual-fuel operation
- Adding an electric air source heat pump plus controls to an existing furnace for dual-fuel operation
- Adjusting the crossover temperature of an existing dual-fuel heat pump

B.3 Cooling Retrofits

The available cooling retrofit options are listed below. Replacement technologies are considered for both building-level and district cooling systems. Retrofit options are dependent on a number of factors including existing equipment type, whether the existing technology has a paired heating technology defined, the fuel types available to the building, and the required cooling capacity. For central district heating systems, the only retrofit options involve conversion to a building-level centralized system (typically involving a chiller or similar equipment).

Replacement Cooling Retrofit Technology Options Include:

- Packaged DX AC units
 - Window/through wall (<1.5 tons cooling)
 - Residential split system (1.5 - 5.4 tons cooling)
 - Commercial single zone rooftop (1.5 - 20 tons cooling)
 - Commercial multi-zone rooftop (20 - 150 tons cooling)
- Conventional electric chillers (reciprocating, scroll, screw, or centrifugal compressors; in air- and water-cooled configurations)
- Gas engine driven chillers (reciprocating, scroll, screw, or centrifugal compressors; in air- and water-cooled configurations)
- Absorption chillers (single or double effect, direct or indirect fired; in air- and water-cooled configurations)
- Electric air source heat pumps*
- Dual-fuel air source heat pumps (with integrated or separate types of backup heat)*
- Electric ground-coupled heat pump systems (in open-loop, and horizontal or vertical close-loop configurations)*

- Replace water source heat pump units of an existing ground-coupled heat pump system
- Packaged DX A/C unit with integral natural gas or lpg heat (e.g., a gas pack)*

*These cooling retrofit options are considered only when the existing cooling technology is identified as a pair with a specific heating technology.

B.4 Envelope Retrofits

The following retrofits are available for building envelope (roof, walls, floor, and windows) depending on building construction type, existing insulation and window characteristics, and space available for additional insulation.

Roof/Ceiling Insulation:

- Attic ceiling insulation
- Suspended ceiling insulation
- Insulate built-up roof surface and re-roof
- Insulate interior surface of metal roof with fiberglass, bubble pack, or foam

Wall Insulation:

- Blow-in insulation to fill available space
- Interior masonry surface insulation
- Interior metal wall surface insulation (fiberglass, bubble pack, or foam)

Floor Insulation:

- Insulate above crawlspace
- Insulate pier floor
- Insulate perimeter of slab on grade

Window Retrofits:

- Add retrofit film
- Add regular or low-e storm windows (to window exterior or interior)
- Install new windows with a combination of the following characteristics:
 - Number of panes: two or three
 - Frame types: vinyl, aluminum, aluminum with thermal break, or high performance aluminum
 - Films/tint: tinted glass, reflective, low-e, super low-e high gain low-e, low-gain-low-e, heat mirror (with 1, 2, or 3 films)
 - Gas fill: none, argon, krypton, or xenon

B.5 Service Hot Water Retrofits

The following retrofits are available distributed and loop hot water systems.

Replacement Hot Water Retrofit Technology Options Include:

- Residential and commercial storage tank water heaters using fuels including electricity, distillate oil, natural gas, and lpg
- Electric heat pump water heaters
- Conventional boilers using fuels including distillate oil, residual oil, natural gas, and lpg
- Condensing natural gas or lpg boilers

Add-On Hot Water Retrofit Options Include Combinations of the Following:

- Insulate existing storage tank
- Insulate pipe near water heater
- Low-flow (high efficiency) shower heads
- Faucet aerators
- Decrease service hot water temperature (only possible for certain building types and only recommended in conjunction with flow reducers)

B.6 Lighting Retrofits

The Pacific Northwest National Laboratory has developed a large database of over 900 lighting technology configurations that are included in FEDS. These lighting technologies are available to be modeled as existing lighting technologies and considered as retrofit technologies. FEDS considers cross-technology substitution only where it is appropriate (e.g., HPS for fluorescent in warehouses). Additionally, FEDS only considers retrofit alternatives that provide at least 90% of the light output of the existing lighting technology configuration. All possible existing and retrofit lighting technology configurations are listed in [Appendix G](#) and [Appendix H](#).

Lighting controls may also be evaluated as a retrofit technology, where applicable. Occupancy-based controls can be considered for select baseline lighting technology configurations as specified within the lighting technology input screens. For lighting that is noted to not have existing controls but should be evaluated, FEDS will estimate the cost to install the specified number of sensors and apply savings consistent with the difference between the existing and “With Controls” utilization factors from the lighting technology record inputs.

B.7 Ventilation Retrofits

Currently, the only automated ventilation system retrofit is for ventilation system scheduling, which is included in the HVAC control retrofits described in Section B.1. Additional measures can be evaluated manually via parametric analysis (i.e., by making the expected change to the FEDS inputs and comparing the resulting energy use and costs for the baseline and modified scenarios).

B.8 Miscellaneous Equipment Retrofits

Currently, automated miscellaneous equipment (plug-load) retrofits are not available. Savings estimates for select plug load management options can be modeled parametrically by making the expected change to the FEDS inputs and comparing the resulting energy use and costs for the baseline and modified scenarios.

B.9 Motor Retrofits

FEDS provides the capability to analyze the cost-effectiveness of replacing old, inefficient three-phase asynchronous electric motors with new energy-efficient motors. The list of possible motor retrofits (nearly 1000) were derived from the database of motors meeting current standards contained within the *MotorMaster+* software program developed under the U.S. Department of Energy's Motor Challenge Program. The motors were sorted according to key characteristics (size, speed, voltage, enclosure, etc.) and grouped based on efficiency and cost. For a more detailed (and manufacturer-specific) motor analysis it is suggested that a FEDS run be augmented with *MotorMaster+*.

Appendix C – Sample Output

Actual text- and spreadsheet-based report files for the sample cases have been installed to your FEDS\Documents\Sample Case Output directory (default location is C:\FEDS 8.0\Documents\Sample Case Output). These files are:

- sample-1_txs.pdf
- sample-1_txd.pdf
- sample-1_csv.xls
- sample-1.Calib.xls
- sample-1.Retrofit.Savings.xls
- sample-2_txs.pdf
- sample-2_txd.pdf
- sample-2_csv.xls
- sample-2.Calib.xls
- sample-2.Retrofit.Savings.xls
- sample-3_txs.pdf
- sample-3_txd.pdf
- sample-3_csv.xls
- sample-3.Calib.xls
- sample-3.Retrofit.Savings.xls

The spreadsheet output files can be opened with Excel and the text-based output files are in pdf format and may be viewed by opening them with the Adobe Acrobat Reader. If you need to download Adobe Acrobat Reader, visit <http://get.adobe.com/reader/>.

Appendix D – Weather Stations

There are 1,116 weather files that are included with FEDS 8.0 (1,036 for the U.S. and locations in the Caribbean and Pacific Islands, and 80 in Canada). FEDS uses data in the EnergyPlus Weather (EPW) format. Figure D.1 presents a map of the locations of TMY3 weather stations across the United States, published by NREL. The complete set of weather station file names and locations as included with FEDS is listed in Table D.1. These weather data for building energy simulation are intended to represent a typical meteorological year rather than a specific year's weather.

Additional weather files for other locations or time periods are available from a variety of sources. These data files can be added for use by FEDS with the **Import EPW Weather File** option, described in Section 2.7.2. Note that only files in standard EPW format are compatible with FEDS.

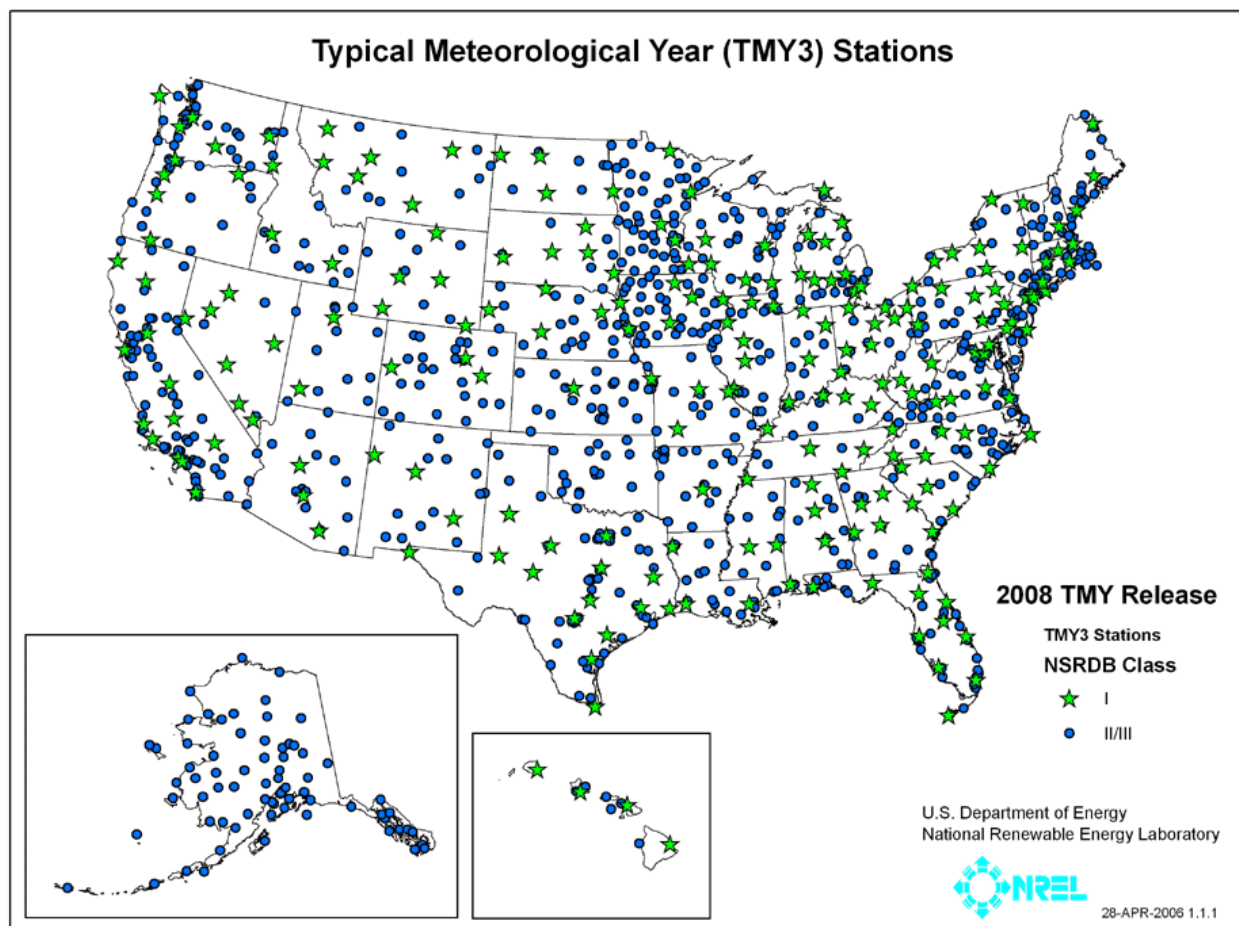


Figure D.1 Locations of Typical Meteorological Year weather stations across the United States (from http://redc.nrel.gov/solar/old_data/nsrdb/1991-2005/tmy3/usTMYmaps3medium.gif)

Table D.1 Weather Stations Included with FEDS 8.0

| State | Locations | | |
|---------|-----------------------------------|--------------------------------|-----------------------------|
| Alabama | Anniston Metro AP | Gadsden Muni AWOS | Montgomery-Dannelly Field |
| | Auburn-Opelika AP | Huntsville Intl AP-Jones Field | Muscle Shoals Rgnl AP |
| | Birmingham Muni AP | Maxwell AFB | Troy Air Field |
| | Dothan Muni AP | Mobile-Downtown AP | Tuscaloosa Muni AP |
| | Fort Rucker-Cairns Field | Mobile-Rgnl AP | |
| Alaska | Adak NAS | Gulkana | Point Hope AWOS |
| | Ambler | Gustavus | Port Heiden |
| | Anaktuvuk Pass | Hayes River | Saint Marys AWOS |
| | Anchorage Intl AP | Healy River AP | Sand Point |
| | Anchorage-Elmendorf AFB | Homer AP | Savoonga |
| | Anchorage-Lake Hood Seaplane Base | Hoonah | Selawik |
| | Anchorage-Merrill Field | Hooper Bay | Seward |
| | Aniak AP | Huslia | Shemya AFB |
| | Annette Island AP | Hydaburg Seaplane Base | Shishmaref AWOS |
| | Anvik | Iliamna AP | Sitka-Japonski Island AP |
| | Barrow-W Post-W Rogers AP | Juneau Intl AP | Skagway AP |
| | Bethel AP | Kake Seaplane Base | Sleetmute |
| | Bettles Field | Kenai Muni AP | Soldotna |
| | Big Delta-Allen AAF | Ketchikan Intl AP | St Paul Island AP |
| | Big River Lake | King Salmon AP | Summit |
| | Birchwood | Kodiak AP | Talkeetna State AP |
| | Chulitna | Kotzebue-Ralph Wein Mem AP | Tanana-Ralph Calhoun AP |
| | Cold Bay AP | McGrath AP | Togiak Village AWOS |
| | Cordova | Mekoryuk | Unalakleet Field |
| | Deadhorse | Middleton Island | Unalaska-Dutch Harbor Field |
| | Dillingham AWOS | Minchumina | Valdez |
| | Eielson AFB | Nenana Muni AP | Valdez-Pioneer Field |
| | Emmonak | Nome Muni AP | Whittier |
| | Fairbanks Intl AP | Northway AP | Wrangell |
| | Fort Yukon | Palmer Muni AP | Yakutat State AP |
| | Gambell | Petersburg | |
| Arizona | Casa Grande AWOS | Luke AFB | Scottsdale Muni AP |
| | Davis-Monthan AFB | Page Muni AWOS | Show Low Muni AP |
| | Douglas-Bisbee Douglas Intl AP | Phoenix-Deer Valley AP | Tucson Intl AP |
| | Flagstaff-Pulliam AP | Phoenix-Sky Harbor Intl AP | Winslow Muni AP |
| | Grand Canyon National Park AP | Prescott-Love Field | Yuma Intl AP |

| | | | |
|-------------------|--|------------------------------------|-----------------------------------|
| | Kingman AWOS | Safford AWOS | Yuma MCAS |
| Arkansas | Batesville AWOS | Harrison AP | Rogers AWOS |
| | Bentonville AWOS | Hot Springs Mem AP | Siloam Spring AWOS |
| | El Dorado-Goodwin Field | Jonesboro Muni AP | Springdale Muni AP |
| | Fayetteville-Drake Field | Little Rock AFB | Stuttgart AWOS |
| | Flippin AWOS | Little Rock-Adams Field | Texarkana-Webb Field |
| | Fort Smith Rgnl AP | Pine Bluff AP | Walnut Ridge AWOS |
| California | Alturas | Lemoore NAS | Sacramento McClellan Airfield |
| | Arcata AP | Livermore Muni AP | Sacramento Exec AP |
| | Bakersfield-Meadows Field | Lompoc AWOS | Sacramento Metro AP |
| | Barstow Daggett AP | Long Beach-Daugherty Field | Salinas Muni AP |
| | Beale AFB | Los Angeles Intl AP | San Diego-Lindbergh Field |
| | Bishop AP | March AFB | San Diego-Miramar NAS |
| | Blue Canyon AP | Merced-Macready Field | San Diego-Montgomery Field |
| | Blythe-Riverside County AP | Modesto Muni AP | San Diego-North Island NAS |
| | Burbank-Glendale-Pasadena Bob Hope AP | Montague-Siskiyou County AP | San Francisco Intl AP |
| | Camarillo AWOS | Monterey NAF | San Jose Intl AP |
| | Camp Pendleton MCAS | Mount Shasta | San Luis Obispo AP |
| | Carlsbad | Mountain View-Moffett Field NAS | Sandberg |
| | China Lake NAF | Napa County AP | Santa Ana-John Wayne AP |
| | Chino AP | Needles AP | Santa Barbara Muni AP |
| | Chula Vista-Brown Field Muni AP | Oakland Intl AP | Santa Maria Public AP |
| | Concord-Buchanan Field | Oxnard AP | Santa Monica Muni AP |
| | Crescent City-Jack McNamara Field | Palm Springs Intl AP | Santa Rosa AWOS |
| | Edwards AFB | Palm Springs-Thermal AP | South Lake Tahoe-Lake Tahoe AP |
| | El Toro MCAS | Palmdale AP | Stockton Metro AP |
| | Fairfield-Travis AFB | Paso Robles Muni AP | Truckee Tahoe AP |
| | Fresno Air Terminal | Point Mugu NAS | Twentynine Palms |
| | Fullerton Muni AP | Porterville AWOS | Ukiah Muni AP |
| | Hawthorne-Jack Northrop Field | Red Bluff Muni AP | Van Nuys AP |
| | Hayward Air Terminal | Redding Muni AP | Visalia Muni AWOS |
| | Imperial County AP | Riverside Muni AP | Yuba County AP |
| | Lancaster-Gen Wm Fox Field | | |
| Colorado | Akron-Washington County AP | Denver-Stapleton | La Junta Muni AP |

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|--------------------|--|------------------------------------|--------------------------------------|
| | Alamosa Muni AP | Durango-La Plata County AP | Lamar Muni AP |
| | Aspen-Pitkin County-Sardy Field | Eagle County Rgnl AP | Leadville-Lake County AP |
| | Aurora-Buckley Field ANGB | Fort Collins AWOS | Limon Muni AP |
| | Boulder-Broomfield-Jefferson County AP | Golden-NREL | Montrose County AP |
| | Colorado Springs-Peterson Field | Grand Junction-Walker Field | Pueblo Mem AP |
| | Cortez-Montezuma County AP | Greeley-Weld County AWOS | Rifle-Garfield County Rgnl AP |
| | Craig Moffat AP | Gunnison County AWOS | Trinidad-Las Animas County AP |
| | Denver Intl AP | Hayden-Yampa AWOS | |
| Connecticut | Bridgeport-Sikorsky Mem AP | Hartford-Bradley Intl AP | New Haven-Tweed AP |
| | Danbury Muni AP | Hartford-Brainard Field | Oxford AWOS |
| Delaware | Dover AFB | Wilmington-New Castle County AP | |
| Florida | Apalachicola | Lakeland Linder Rgnl AP | Panama City-Bay County AP |
| | Crestview-Bob Sikes AP | MacDill AFB | Pensacola Rgnl AP |
| | Daytona Beach Intl AP | Marathon AP | Pensacola-Forest Sherman NAS |
| | Fort Lauderdale Executive AP | Mayport NS | Sarasota-Bradenton Intl AP |
| | Fort Lauderdale Intl AP | Melbourne Rgnl AP | Southwest Florida Intl AP |
| | Fort Myers-Page Field | Miami Intl AP | St Petersburg-Albert Whitted Station |
| | Fort Pierce-St Lucie County AP | Miami-Kendall-Tamiami Executive AP | St Petersburg-Clearwater Intl AP |
| | Fort Walton Beach-Hurlburt Field | Miami-Opa Locka AP | Tallahassee Rgnl AP |
| | Gainesville Rgnl AP | Naples Muni AP | Tampa Intl AP |
| | Homestead AFB | NASA Shuttle Landing Facility | Tyndall AFB |
| | Jacksonville Intl AP | Ocala Muni AWOS | Valparaiso-Elgin AFB |
| | Jacksonville NAS | Orlando Executive AP | Vero Beach Muni AP |
| | Jacksonville-Craig Field | Orlando Intl AP | West Palm Beach Intl AP |
| | Key West Intl AP | Orlando-Sanford AP | Whiting Field NAS |
| | Key West NAS | | |
| Georgia | Albany-Dougherty County AP | Columbus Metro AP | Rome-Richard B Russell AP |
| | Alma-Bacon County AP | Dekalb Peachtree AP | Savannah Intl AP |
| | Athens-Ben Epps AP | Fort Benning-Lawson Field | Savannah-Hunter AAF |
| | Atlanta-Hartsfield-Jackson Intl AP | Fulton County AP | Valdosta Rgnl AP |
| | Augusta-Bush-Field | Macon-Middle Georgia Rgnl AP | Valdosta-Moody AFB |
| | Brunswick-Golden Isles AP | Marietta-Dobbins AFB | Warner Robins AFB |

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|-----------------|---|----------------------------------|--|
| | Brunswick-Malcolm McKinnon AP | | |
| Hawaii | Barbers Point NAS | Kailua-Kaneohe Bay MCAS | Lanai AP |
| | Hilo Intl AP | Kapalua-West Maui AP | Lihue AP |
| | Honolulu Intl AP | Keahole-Kona Intl AP | Molokai AWOS |
| | Kahului AP | | |
| Idaho | Boise Air Terminal | Idaho Falls-Fanning Field | Pocatello Muni AP |
| | Burley Muni AP | Lewiston-Nez Perce County AP | Salmon-Lemhi AWOS |
| | Caldwell AWOS | Malad City AP | Soda Springs-Tigert AP |
| | Coeur d'Alene AWOS | Mountain Home AFB | Twin Falls-Magic Valley Rgnl AP-Joslin Field |
| | Hailey-Sun Valley AP | | |
| Illinois | Aurora Muni AP | Decatur AP | Quincy Muni AP |
| | Belleville-Scott AFB | Du Page AP | Rockford-Greater Rockford AP |
| | Bloomington Normal-Central Illinois Rgnl AP | Marion-Williamson County Rgnl AP | Springfield-Capital AP |
| | Cahokia AP | Moline-Quad City Intl AP | Sterling-Rock Falls-Whiteside County AP |
| | Carbondale-Southern Illinois AP | Mount Vernon AWOS | University of Illinois-Willard AP |
| | Chicago-Midway AP | Peoria-Greater Peoria AP | Waukegan Rgnl AP |
| | Chicago-O'Hare Intl AP | | |
| Indiana | Delaware County-Johnson Field | Huntingburg Muni AP | Monroe County AP |
| | Evansville Rgnl AP | Indianapolis Intl AP | South Bend-Michiana Rgnl AP |
| | Fort Wayne Intl AP | Lafayette-Purdue University AP | Terre Haute-Hulman Rgnl AP |
| | Grissom AFB | | |
| Iowa | Algona Muni AP | Denison Muni AP | Newton Muni AP |
| | Atlantic Muni AP | Des Moines Intl AP | Oelwein Muni AP |
| | Boone Muni AP | Dubuque Rgnl AP | Orange City Muni AP |
| | Burlington Muni AP | Estherville Muni AP | Ottumwa Industrial AP |
| | Carroll Muni AP | Fairfield Muni AP | Red Oak Muni AP |
| | Cedar Rapids Muni AP | Fort Dodge AWOS | Sheldon Muni AP |
| | Chariton Muni AP | Fort Madison Muni AP | Shenandoah Muni AP |
| | Charles City Muni AP | Keokuk Muni AP | Sioux City-Sioux Gateway AP |
| | Clarinda Muni AP | Knoxville Muni AP | Spencer Muni AP |
| | Clinton Muni AWOS | Le Mars Muni AP | Storm Lake Muni AP |
| | Council Bluffs Muni AP | Mason City Muni AP | Washington Muni AP |
| | Creston Muni AP | Monticello Muni AP | Waterloo Muni AP |
| | Decorah Muni AP | Muscatine Muni AP | Webster City Muni AP |
| Kansas | Chanute-Martin Johnson AP | Hays Muni AWOS | Russell Muni AP |

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|----------------------|---------------------------------|---------------------------------------|-----------------------------------|
| | Concordia-Blosser Muni AP | Hill City Muni AP | Salina Muni AP |
| | Dodge City Rgnl AP | Hutchinson Muni AP | Topeka-Forbes AFB |
| | Emporia Muni AP | Liberal Muni AP | Topeka-Phillip Billard Muni AP |
| | Fort Riley-Marshall AAF | Manhattan Rgnl AP | Wichita-Col Jabara Field |
| | Garden City Muni AP | Newton AWOS | Wichita-McConnell AFB |
| | Goodland-Renner Field | Olathe-Johnson County Executive AP | Wichita-Mid Continent AP |
| | Great Bend AWOS | Olathe-Johnson County Industrial AP | |
| Kentucky | Bowling Green-Warren County AP | Henderson City County AP | Louisville-Bowman Field |
| | Cincinnati-Northern Kentucky AP | Jackson-Julian Carroll AP | Louisville-Standiford Field |
| | Fort Campbell AAF | Lexington-Bluegrass AP | Paducah-Barkley Rgnl AP |
| | Fort Knox-Godman AAF | London-Corbin-Magee Field | Somerset-Pulaski County AWOS |
| Louisiana | Alexandria-England AFB | Lafayette Rgnl AP | New Orleans-Alvin Callender Field |
| | Alexandria-Esler Rgnl AP | Lake Charles AP | New Orleans-Lakefront AP |
| | Barksdale AFB | Lake Charles Rgnl AP | Patterson Mem AP |
| | Baton Rouge-Ryan AP | Monroe Rgnl AP | Shreveport Downtown |
| | Fort Polk | New Iberia | Shreveport Rgnl AP |
| | Houma-Terrebonne AP | New Orleans Intl AP | |
| Maine | Auburn-Lewiston Muni AP | Caribou Muni AP | Presque Isle Muni AP |
| | Augusta AP | Edmundston-Northern Aroostook Rgnl AP | Rockland-Knox AWOS |
| | Bangor Intl AP | Houlton Intl AP | Sanford Muni AWOS |
| | Bar Harbor AWOS | Millinocket Muni AP | Waterville AWOS |
| | Brunswick NAS | Portland Intl Jetport | Wiscasset AP |
| Maryland | Andrews AFB | Hagerstown-Washington County Rgnl AP | Salisbury-Wicomico County Rgnl AP |
| | Baltimore-Washington Intl AP | Patuxent River NAS | |
| Massachusetts | Barnstable-Boardman Poland AP | Martha's Vineyard AP | Otis ANGB |
| | Beverly Muni AP | Nantucket Mem AP | Plymouth Muni AP |
| | Boston-Logan Intl AP | New Bedford Rgnl AP | Provincetown AWOS |
| | Chicopee Falls-Westover AFB | North Adams AP | Westfield-Barnes Muni AP |
| | Lawrence Muni AP | Norwood Mem AP | Worcester Rgnl AP |
| Michigan | Alpena County Rgnl AP | Grand Rapids-Kent County Intl AP | Menominee AWOS |

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|--------------------|---|-----------------------------------|---------------------------------|
| | Ann Arbor Muni AP | Hancock-Houghton County AP | Mount Clemens-Selfridge ANGB |
| | Battle Creek-Kellogg AP | Houghton-Lake Roscommon County AP | Muskegon County AP |
| | Benton Harbor-Ross Field-Twin Cities AP | Howell-Livingston County AP | Oakland County Intl AP |
| | Cadillac-Wexford County AP | Iron Mountain-Ford Field | Oscoda-Wurtsmith AFB |
| | Chippewa County Intl AP | Ironwood AWOS | Pellston-Emmet County AP |
| | Detroit Metro AP | Jackson-Reynolds Field | Saginaw-Tri City Intl AP |
| | Detroit-City AP | Kalamazoo-Battle Creek Intl AP | Sault Ste Marie-Sanderson Field |
| | Detroit-Willow Run AP | Lansing-Capital City AP | St Clair County Intl AP |
| | Escanaba AWOS | Manistee AWOS | Traverse City-Cherry Capital AP |
| | Flint-Bishop Intl AP | | |
| Minnesota | Aitkin AWOS | Faribault Muni AWOS | Orr Rgnl AP |
| | Albert Lea AWOS | Fergus Falls AWOS | Owatonna AWOS |
| | Alexandria Muni AP | Fosston AWOS | Park Rapids Muni AP |
| | Austin Muni AP | Glenwood AWOS | Pipestone AWOS |
| | Baudette Intl AP | Grand Rapids AWOS | Red Wing Muni AP |
| | Bemidji Muni AP | Hallock | Redwood Falls Muni AP |
| | Benson Muni AP | Hibbing-Chisholm Hibbing AP | Rochester Intl AP |
| | Brainerd-Crow Wing County AP | Hutchinson AWOS | Roseau Muni AWOS |
| | Cambridge Muni AP | International Falls Intl AP | Silver Bay Muni AP |
| | Cloquet AWOS | Litchfield Muni AP | South St Paul Muni AP |
| | Crane Lake AWOS | Little Falls AWOS | St Cloud Muni AP |
| | Crookston Muni Field | Mankato AWOS | St Paul-Downtown AP |
| | Detroit Lakes AWOS | Marshall Muni-Ryan Field AWOS | Thief River AWOS |
| | Duluth Intl AP | Minneapolis-Crystal AP | Two Harbors Muni AP |
| | Edin Prairie-Flying Cloud AP | Minneapolis-St Paul Intl AP | Wheaton AWOS |
| | Ely Muni AP | Mora Muni AWOS | Willmar Muni AP |
| | Eveleth Muni AWOS | Morris Muni AWOS | Winona Muni AWOS |
| | Fairmont Muni AWOS | New Ulm Muni AWOS | Worthington AWOS |
| Mississippi | Biloxi-Keesler AFB | Gulfport-Biloxi Intl AP | Meridian NAS |
| | Columbus AFB | Hattiesburg-Laurel AP | Meridian-Key Field |
| | Golden Triangle Rgnl AWOS | Jackson Intl AP | Natchez-Hardy Anders Field |
| | Greenville Muni AP | McComb-Pike Co AP | Tupelo Muni-C D Lemons AP |
| | Greenwood-Leflore AP | | |
| Missouri | Cape Girardeau Muni AP | Kaiser-Lee Fine Mem AWOS | Springfield Rgnl AP |

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|----------------------|-----------------------------------|---------------------------------------|--------------------------------|
| | Columbia Rgnl AP | Kansas City Downtown AP | St Joseph-Rosecrans Mem AP |
| | Farmington Rgnl AP | Kansas City Intl AP | St Louis-Lambert Intl AP |
| | Fort Leonard Wood-Forney AAF | Kirksville Muni AP | St Louis-Spirit of St Louis AP |
| | Jefferson City Mem AP | Poplar Bluff AWOS | Whiteman AFB |
| | Joplin Muni AP | Rolla National AP | |
| Montana | Billings-Logan Intl AP | Glendive AWOS | Lewistown Muni AP |
| | Bozeman-Gallatin Field | Great Falls -Malmstrom AFB | Livingston-Mission Field |
| | Butte-Bert Mooney AP | Great Falls Intl AP | Miles City Muni AP |
| | Cut Bank Muni AP | Havre City-County AP | Missoula Intl AP |
| | Dillon | Helena Rgnl AP | Sidney-Richland Muni AP |
| | Glasgow Intl AP | Kalispell-Glacier Park Intl AP | Wolf Point Intl AP |
| Nebraska | Ainsworth Muni AP | Grand Island-Central Nebraska Rgnl AP | Omaha WSFO |
| | Alliance Muni AP | Hastings Muni AP | Omaha-Eppley Airfield |
| | Beatrice Muni AP | Holdrege-Brewster Field | O'Neill-Baker Field |
| | Bellevue-Offutt AFB | Imperial Muni AP | Ord-Sharp Field |
| | Broken Bow Muni AP | Kearney Muni AWOS | Scottsbluff-W B Heilig Field |
| | Chadron Muni AP | Lincoln Muni AP | Sidney Muni AP |
| | Columbus Muni AP | McCook Muni AP | Tekamah AWOS |
| | Falls City-Brenner Field | Norfolk-Karl Stefan Mem AP | Valentine-Miller Field |
| | Fremont Muni AP | North Platte Rgnl AP | |
| Nevada | Elko Muni AP | Lovelock-Derby Field | Tonopah AP |
| | Ely-Yelland Field | Mercury-Desert Rock AP | Winnemucca Muni AP |
| | Fallon NAS | Nellis AFB | Yucca Flat Test Site |
| | Las Vegas-McCarran Intl AP | Reno-Tahoe Intl AP | |
| New Hampshire | Berlin Muni AP | Laconia Muni AWOS | Mount Washington |
| | Concord Muni AP | Lebanon Muni AP | Pease Intl Tradeport |
| | Keene-Dillant Hopkins AP | Manchester Muni AP | |
| New Jersey | Atlantic City Intl AP | Cape May County AP | Newark Intl AP |
| | Belmar-Monmouth County AP | McGuire AFB | Teterboro AP |
| | Caldwell-Essex County AP | Millville Muni AP | Trenton-Mercer County AP |
| New Mexico | Albuquerque Intl AP | Farmington-Four Corners Rgnl AP | Roswell Industrial Air Park |
| | Carlsbad Cavern City Air Terminal | Gallup-Sen Clarke Field | Ruidoso-Sierra Blanca Rgnl AP |
| | Clayton Muni AP | Holloman AFB | Santa Fe County Muni AP |
| | Clovis Muni AWOS | Las Cruces Intl AP | Taos Muni AP |

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|-----------------------|---------------------------------|-----------------------------------|-------------------------------------|
| | Clovis-Cannon AFB | Las Vegas-Muni AP | Truth or Consequences Muni AP |
| | Deming Muni AP | Los Alamos | Tucumcari AP |
| New York | Albany County AP | Massena AP | Republic AP |
| | Binghamton-Edwin A Link Field | Monticello AWOS | Rochester-Greater Rochester Intl AP |
| | Buffalo-Greater Buffalo Intl AP | New York-Central Park | Saranac Lake-Adirondack Rgnl AP |
| | Elmira Rgnl AP | New York-J F Kennedy Intl AP | Syracuse-Hancock Intl AP |
| | Fort Drum-Wheeler Sack AAF | New York-LaGuardia AP | Utica-Oneida County AP |
| | Glens Falls-Bennett Mem AP | Newburgh-Stewart Intl AP | Watertown AP |
| | Islip-Long Island MacArthur AP | Niagara Falls Intl AP | Westhampton-Suffolk County AP |
| | Jamestown AWOS | Poughkeepsie-Dutchess County AP | White Plains-Westchester County AP |
| North Carolina | Asheville Rgnl AP | Goldsboro-Seymour Johnson AFB | New River MCAS |
| | Cape Hatteras | Greensboro-Piedmont Triad Intl AP | Pitt Greenville AP |
| | Charlotte-Douglas Intl AP | Hickory Rgnl AP | Raleigh-Durham Intl AP |
| | Cherry Point MCAS | Jacksonville AWOS | Rocky Mount-Wilson AP |
| | Elizabeth City CGAS | Kinston Stallings AFB | Southern Pines-Moore County AP |
| | Fayetteville Muni AP | Manteo-Dare County Rgnl AP | Wilmington Intl AP |
| | Fayetteville-Pope AFB | New Bern-Craven County Rgnl AP | Winston Salem-Smith Reynolds AP |
| | Fort Bragg-Simmons AAF | | |
| North Dakota | Bismarck Muni AP | Grand Forks AFB | Minot AFB |
| | Devils Lake AWOS | Grand Forks Intl AP | Minot Intl AP |
| | Dickinson Muni AP | Jamestown Muni AP | Williston-Sloulin Field Intl AP |
| | Fargo-Hector Intl AP | | |
| Ohio | Akron Canton Rgnl AP | Dayton Intl AP | Ohio State University AP |
| | Cincinnati Muni AP-Lunken Field | Dayton-Wright Patterson AFB | Toledo Express AP |
| | Cleveland-Burke Lakefront AP | Findlay AP | Youngstown Rgnl AP |
| | Cleveland-Hopkins Intl AP | Mansfield-Lahm Muni AP | Zanesville Muni AP |
| | Columbus-Port Columbus Intl AP | | |
| Oklahoma | Altus AFB | Hobart Muni AP | Oklahoma City-Will Rogers World AP |
| | Bartlesville-Phillips Field | Lawton Muni AP | Ponca City Muni AP |

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|-----------------------|---------------------------------|----------------------------------|---------------------------------------|
| | Clinton Sherman AP | McAlester Rgnl AP | Stillwater Rgnl AP |
| | Fort Sill-Henry Post AAF | Oklahoma City-Tinker AFB | Tulsa Intl AP |
| | Gage AP | Oklahoma City-Wiley Post Field | Vance AFB |
| Oregon | Astoria Rgnl AP | La Grande Muni AP | Portland-Hillsboro AP |
| | Aurora State AP | Lakeview AWOS | Portland-Troutdale AP |
| | Baker Muni AP | Medford-Rogue Valley Intl AP | Redmond-Roberts Field |
| | Burns Muni AP | North Bend Muni AP | Roseburg Rgnl AP |
| | Corvallis Muni AP | Pendleton-Eastern Oregon Rgnl AP | Salem-McNary Field |
| | Eugene-Mahlon Sweet AP | Portland Intl AP | Sexton Summit |
| | Klamath Falls Intl AP | | |
| Pennsylvania | Allentown-Lehigh Valley Intl AP | Harrisburg Intl AP | Pittsburgh-Allegheny County AP |
| | Altoona-Blair County AP | Harrisburg-Capital City AP | Reading Mem AP-Spaatz Field |
| | Bradford Rgnl AP | Johnstown-Cambria County AP | State College-Penn State University |
| | Butler County AWOS | Lancaster AP | Washington AWOS |
| | DuBois-Jefferson County AP | Philadelphia Intl AP | Wilkes-Barre-Scranton Intl AP |
| | Erie Intl AP | Philadelphia-NE Philadelphia AP | Williamsport Rgnl AP |
| | Franklin-Chess Lemberton AP | Pittsburgh Intl AP | Willow Grove NAS |
| Rhode Island | Block Island State AP | Pawtucket AWOS | Providence-T F Green State AP |
| South Carolina | Anderson County AP | Florence Rgnl AP | Myrtle Beach AFB |
| | Beaufort MCAS | Greenville-Downtown AP | North Myrtle Beach-Grand Strand Field |
| | Charleston Intl AP | Greer Greenville-Spartanburg AP | Shaw AFB |
| | Columbia Metro AP | | |
| South Dakota | Aberdeen Rgnl AP | Mitchell AWOS | Sioux Falls-Foss Field |
| | Brookings AWOS | Mobridge Muni AP | Watertown Muni AP |
| | Ellsworth AFB | Pierre Muni AP | Yankton-Chan Gurney Muni AP |
| | Huron Rgnl AP | Rapid City Rgnl AP | |
| Tennessee | Bristol-TriCities Rgnl AP | Dyersburg Muni AP | Memphis Intl AP |
| | Chattanooga-Lovell Field AP | Jackson-McKellar Sipes Rgnl AP | Nashville Intl AP |
| | Crossville Mem AP | Knoxville-McGhee Tyson AP | |
| Texas | Abilene Rgnl AP | El Paso Intl AP | Lufkin-Angelina Co AP |
| | Abilene-Dyess AFB | Fort Hood | Marfa AP |
| | Alice Intl AP | Fort Worth NAS | McAllen-Miller Intl AP |
| | Amarillo Intl AP | Fort Worth-Alliance AP | McGregor AWOS |

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|-----------------|--|--------------------------------------|-------------------------------|
| | Austin-Camp Mabry | Fort Worth-Meacham AP | Midland Intl AP |
| | Austin-Mueller Muni AP | Fort Worth Stephenville-Clark Field | Mineral Wells Muni AP |
| | Brownsville-South Padre Island AP | Galveston | Nacogdoches AWOS |
| | Childress Muni AP | Georgetown AWOS | Palacios Muni AP |
| | College Station-Easterwood Field | Greenville Muni AP | Port Arthur-Jefferson Co AP |
| | Corpus Christi Intl AP | Harlingen-Valley Intl AP | Randolph AFB |
| | Corpus Christi NAS | Hondo Muni AP | Rockport-Aransas Co AP |
| | Cotulla AP | Houston-Bush Intercontinental AP | San Angelo-Mathis AP |
| | Cox Field | Houston-D W Hooks AP | San Antonio Intl AP |
| | Dalhart Muni AP | Houston-Ellington AFB | San Antonio-Kelly AFB |
| | Dallas-Addison AP | Houston-William P Hobby AP | San Antonio-Stinson AP |
| | Dallas-Fort Worth Intl AP | Killeen Muni AWOS | Sherman-Perrin |
| | Dallas-Love Field | Killeen-Fort Hood Rgnl AP | Tyler-Pounds Field |
| | Dallas-Redbird AP | Kingsville | Victoria Rgnl AP |
| | Del Rio | Laredo Intl AP | Waco Rgnl AP |
| | Del Rio-Laughlin AFB | Longview-Gregg County AP | Wichita Falls Muni AP |
| | Draughton-Miller Central Texas AP | Lubbock Intl AP | Wink-Winkler County AP |
| Utah | Blanding Muni AP | Moab-Canyonlands Field | Saint George AWOS |
| | Bryce Canyon AP | Ogden-Hill AFB | Salt Lake City Intl AP |
| | Cedar City Muni AP | Ogden-Hinkley AP | Vernal AP |
| | Delta Muni AP | Provo Muni AWOS | Wendover USAF Auxiliary Field |
| | Hanksville AP | | |
| Vermont | Burlington Intl AP | Rutland State AP | Springfield-Hartnes State AP |
| | Montpelier AP | | |
| Virginia | Abingdon-Virgina Highlands AP | Langley AFB | Oceana NAS |
| | Arlington-Ronald Reagan Washington Natl AP | Leesburg Muni AP-Godfrey Field | Petersburg Muni AP |
| | Blacksburg-Virginia Tech AP | Lynchburg Rgnl AP-Preston Glen Field | Pulaski-New River Valley AP |
| | Charlottesville-Albemarle County AP | Manassas Muni AWOS | Quantico MCAS |
| | Danville Rgnl AP | Marion-Wytheville-Mountain Empire AP | Richmond Intl AP |
| | Davison AAF | Martinsville-Blue Ridge AP | Roanoke Rgnl AP-Woodrum Field |

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|----------------------|------------------------------------|---|---|
| | Farmville Muni AP | Melfa-Accomack County AP | Staunton-Shenandoah Valley Rgnl AP |
| | Franklin Muni AP | Newport News | Sterling-Washington Dulles Intl AP |
| | Fredericksburg-Shannon AP | Norfolk Intl AP | Winchester Rgnl AP |
| | Hillsville-Twin County AP | Norfolk NAS | Wise-Lonesome Pine AP |
| | Hot Springs-Ingalls Field | | |
| Washington | Bellingham Intl AP | Pasco-Tri Cities AP | Stampede Pass |
| | Bremerton National AP | Port Angeles-William R Fairchild Intl AP | Tacoma Narrows AP |
| | Ephrata Muni AP | Pullman-Moscow Rgnl AP | Tacoma-McChord AFB |
| | Fairchild AFB | Quillayute State AP | The Dalles Muni AP |
| | Fort Lewis-Gray AAF | Renton Muni AP | Toledo-Winlock-Ed Carlson Mem AP |
| | Hanford | Seattle-Boeing Field | Walla Walla City-County AP |
| | Hoquiam AP | Seattle-Tacoma Intl AP | Wenatchee-Pangborn Mem AP |
| | Kelso AP | Snohomish County AP | Whidbey Island NAS |
| | Moses Lake-Grant County AP | Spokane Intl AP | Yakima Air Terminal-McAllister Field |
| | Olympia AP | Spokane-Felts Field | |
| West Virginia | Beckley-Raleigh County Mem AP | Elkins-Randolph County AP | Morgantown Muni-Hart Field |
| | Bluefield-Mercer County AP | Huntington-Tri State Walker Long Field | Parkersburg-Wood County-Gill Robb Wilson AP |
| | Charleston-Yeager AP | Lewisburg-Greenbrier Valley AP | Wheeling-Ohio County AP |
| | Clarksburg-Harrison Marion Rgnl AP | Martinsburg-Eastern WV Rgnl AP | |
| Wisconsin | Appleton-Outagamie County AP | Madison-Dane County Rgnl AP | Rhineland-Oneida County AP |
| | Eau Claire County AP | Manitowac Muni AWOS | Rice Lake Muni AP |
| | Ephraim AWOS | Marshfield Muni AP | Sturgeon Bay-Door County AP |
| | Green Bay-Austin Straubel Intl AP | Milwaukee-Mitchell Intl AP | Watertown Muni AP |
| | Janesville-Rock County AP | Minocqua-Woodruff-Lee Field | Wausau Muni AP |
| | La Crosse Muni AP | Mosinee-Central Wisconsin AP | Wittman Rgnl AP |
| | Lone Rock AP | Phillips-Price County AP | |
| Wyoming | Casper-Natrona County Intl AP | Greater Green River Intergalactic Spaceport | Rawlins Muni AP |
| | Cheyenne Muni AP | Jackson Hole AP | Riverton Rgnl AP |
| | Cody Muni AWOS | Lander-Hunt Field | Sheridan County AP |

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|------------------------------------|--------------------------------------|-------------------------------|-----------------------------------|
| | Evanston-Uinta County AP-Burns Field | Laramie-General Brees Field | Worland Muni AP |
| | Gillette-Gillette County AP | | |
| Pacific Islands | American Samoa | Tamuning-Won Pat Intl AP-GUAM | Wake Island |
| | Andersen AFB-GUAM | Kwajalein Atoll | |
| Puerto Rico | Aguadilla-Borinquen AP | Mercedita AP | San Juan Intl AP |
| | Mayaguez-Eugenio Maria de Hostos AP | Roosevelt Roads NAS | San Juan-Luis Munoz Marin Intl AP |
| Virgin Islands | Charlotte Amalie-Harry S Truman AP | | |
| Alberta | Calgary | Fort McMurray | Lethbridge |
| | Edmonton | Grand Prairie | Medicine Hat |
| British Columbia | Abbotsford | Port Hardy | Smithers |
| | Comox | Prince George | Summerland |
| | Cranbrook | Prince Rupert | Vancouver |
| | Fort St John | Sandspit | Victoria |
| | Kamloops | | |
| Manitoba | Brandon | The Pas | Winnipeg |
| | Churchill | | |
| New Brunswick | Fredericton | Miramichi | Saint John |
| Newfoundland & Labrador | Battle Harbour | Goose | Stephenville |
| | Gander | St Johns | |
| Northwest Territories | Inuvik | Yellowknife | |
| Nova Scotia | Greenwood | Shearwater | Truro |
| | Sable Island | Sydney | |
| Nunavut | Resolute | | |
| Ontario | Kingston | Ottawa | Timmins |
| | London | Sault Ste Marie | Toronto |
| | Mount Forest | Simcoe | Trenton |
| | Muskoka | Thunder Bay | Windsor |
| | North Bay | | |
| Prince Edward Island | Charlottetown | | |
| Quebec | Bagotville | Mont Joli | Roberval |
| | Baie Comeau | Montreal Intl AP | Schefferville |

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|---------------------|-------------------|-----------------------|----------------------|
| | Grindstone Island | Montreal Jean Brebeuf | Sept-Iles |
| | Kuujjuarapik | Montreal Mirabel | Sherbrooke |
| | Kuujuuaq | Nitchequon | St Hubert |
| | La Grande Riviere | Quebec | Ste Agathe des Monts |
| | Lake Eon | Riviere du Loup | Val d Or |
| Saskatchewan | Estevan | Regina | Swift Current |
| | North Battleford | Saskatoon | |
| Yukon | Whitehorse | | |

Appendix E – Building and Use-Area Types

Building type describes the original intent and construction characteristic of the buildings in a building set.

Use-area type describes the current function and operating characteristics of the buildings within a building set.

Civilian / Military class: These classes describe general characteristics of the buildings but should serve only as initial guidance, and not the determining factor. If a suitable building or use-area type exists within both classes, select that one that most closely corresponds to the class of the site being modeled. However, a "military" class building or use-area type may be the most appropriate choice for a non-military building or use-area (and vice versa) when no better option exists within the other class.

E.1 Civilian Building and Use-Area Types

The civilian building and use-area types are the same as evaluated by the U.S. Energy Information Administration in the CBECS and RECS surveys.

Assembly

Examples: entertainment, recreational, religious, social/public/civic buildings

Characteristics: building for public gatherings

Education

Examples: preschool, elementary, junior high, senior high, college or university classrooms, vocational school

Characteristics: buildings that house technical classroom instruction

Food Sales

Examples: convenience store, market, bakery, supermarket, grocery store

Characteristics: retail or wholesale food selling

Food Service

Examples: cafeteria, carryout-service, full-service restaurant

Characteristics: preparation and sale of food and beverage for consumption

Health Care

Examples: hospital, mental health facility, rehabilitation facility, veterinary facility, clinics

Characteristics: diagnostic and treatment facilities for both inpatient and outpatient care

Lodging

Examples: hotel, motel, inn, boarding house, dormitory/sorority/fraternity, nursing home

Characteristics: multiple accommodations for short- or long-term residents

Mercantile and Service

Examples: retail sales, department stores, drugstores, post office

Characteristics: sales and displays of goods or services (excluding food)

Office

Examples: bank, financial office building, professional office building

Characteristics: general, professional, and administrative office spaces

Public Order/Safety

Examples: courthouse, fire station, jail/prison, penitentiary, police station, reformatory, sheriff's office

Characteristics: building used in the preservation of law and order or safety

Warehouse and Storage

Examples: warehouse, storage facility

Characteristics: building used to store good, manufactured products, merchandise, or raw material

Other

Examples:

Characteristics: not elsewhere classified

Single Family Detached

Examples: typical single family home

Characteristics: structure that provides living space for one household or family that is not attached to another living unit

Single Family Attached

Examples: town house, row house

Characteristics: structure that provides living space for one household or family that is attached to another living unit

2 to 4 Unit Multifamily

Examples: duplex, triplex, or four-plex

Characteristics: structure that has living quarters for two, three, or four families or households

5 or More Unit Multifamily

Examples: apartment building

Characteristics: structure that has living quarters for five or more families or households

Mobile Homes

Examples: trailer

Characteristics: structure that provides living space for one household or family that is not attached to another living unit and is built on a movable chassis

E.2 Military Building and Use-Area Types

The military building and use-area types were developed in conjunction with USA-CERL and are not intended to represent an official list of military buildings or categories. Rather, the list is intended to represent the range and type of buildings typically found on a military installation.

Administration

Examples: headquarter buildings, R&D offices

Similar Civilian Type: Office

Characteristics: sedentary activities, high lighting levels, approx. 2 occupants/100 square feet, highly regular schedule, heating and cooling present.

Barracks

Examples: UEPH, UOPH

Similar Civilian Type: Lodging, dormitories

Characteristics: long term occupancy, centralized bathing and laundry facilities, typically 1-2 occupants per room, residential type schedule.

Chapel

Examples: post chapel, unit chapel, chapel center facilities

Similar Civilian Type: church, Assembly

Characteristics: high occupancy density, low frequency occupancy, high ceilings

Clinic

Examples: dental and medical clinics

Similar Civilian Type: clinic, Health Care

Characteristics: no overnight stays, high density of specialty equipment, high lighting levels

Clubs

Examples: restaurant, officer and enlisted clubs, rod and gun clubs, golf club house

Similar Civilian Type: Food Service

Characteristics: table service, low number of meals served, typically no breakfast service, high density of food preparation and refrigeration equipment

Commissaries

Examples: grocery stores

Similar Civilian Type: Food Sales

Characteristics: high ceilings, high lighting density, high refrigeration density

Dining Halls

Examples: enlisted personnel dining, fast food restaurants, cafeterias, food malls

Similar Civilian Type: Food Service

Characteristics: self-service dining, long operating hours, large number of meals served, high food preparation and refrigeration equipment densities, high occupant density

Electronics

Examples: data centers, communication buildings, ADP, simulators, R&D electronics labs

Similar Civilian Type: None

Characteristics: very high density of electronic specialty equipment (computers, lab devices), cooling provided, potential special ventilation requirements

Exchange Facilities

Examples: banks, dry good retail, post offices, shopettes (convenience stores)

Similar Civilian Type: Mercantile and Service

Characteristics: high ceilings, regular schedules, high lighting density, typically metered and bills paid separately

Single Family Detached House

Examples:

Similar Civilian Type: Single Family Detached House

Characteristics: residential schedule, cooled regionally

Single Family Attached House

Examples:

Similar Civilian Type: Single Family Attached House

Characteristics: residential schedule, cooled regionally

Duplex

Examples:

Similar Civilian Type: 2 to 4 Unit Buildings (with modification)

Characteristics: residential schedule, cooled regionally

Multi-Family 3 or More Unit

Examples:

Similar Civilian Type: 5 or More Unit Buildings (with modification)

Characteristics: residential schedule, cooled regionally

Mobile Homes

Examples:

Similar Civilian Type: Mobile Homes

Characteristics: residential schedule, cooled regionally

Guest Houses

Examples: hotels, civilian dormitories, BEQ, BOQ

Similar Civilian Type: Lodging

Characteristics: short duration occupancy, lightly occupied over weekends, bathing facilities in each room, no laundry facilities, residential type schedule

Hangar

Examples: maintenance hangar, storage hangar

Similar Civilian Type: hangar (Other)

Characteristics: very large, semi-conditioned space, potential special ventilation requirements, high density of specialty equipment (e.g., power tools)

Hospital

Examples: hospital/clinic, medical center

Similar Civilian Type: hospital, Health Care

Characteristics: overnight stays, staffed 24-hours, high density of specialty equipment, always heated and cooled, more energy intensive than civilian hospitals (e.g., 20 ACH in operating suites)

Labs

Examples: medical/veterinary labs, R&D labs, chemical labs

Similar Civilian Type: None

Characteristics: high density of specialty equipment, special ventilation requirements, high lighting density

Laundry

Examples: institutional/commercial laundries and dry cleaning plants

Similar Civilian Type: None

Characteristics: process dominated consumption, special ventilation requirements

Morale, Welfare, and Recreation

Examples: libraries, bus terminals, scout building, theaters

Similar Civilian Type: Assembly

Characteristics: irregular or low frequency occupancy schedule, high occupancy density

Military Other

Examples: fuel dispensing buildings, detached restrooms, huts, kennels, plant (heating, cooling, electrical) buildings, pump houses, outdoor pool buildings

Similar Civilian Type: None

Characteristics: typically unheated, low equipment density--typically lighting only, low occupancy density

Production and/or Process

Examples: industrial buildings, foundries

Similar Civilian Type: None

Characteristics: process dominated consumption

Recreation

Examples: gyms, skating rinks, bowling alleys, indoor pools

Similar Civilian Type: None

Characteristics: high occupant activity level, high ventilation requirements, high ceilings

Schools and/or Training

Examples: dependent schools, dependent day care, training classrooms; no simulators (see ELECTRONICS)

Similar Civilian Type: Education

Characteristics: regularly scheduled occupancy, high occupant density, high lighting density, possible seasonal occupancy

Security

Examples: fire stations, confinement, guard stations, police stations

Similar Civilian Type: Public Order/Safety

Characteristics: typically 24-hour occupancy, office-like equipment and lighting densities, sedentary occupants

Shops

Examples: motor pools, aircraft, electric, heavy equipment, weapons, maintenance shops

Similar Civilian Type: None

Characteristics: semi-conditioned or unheated, high density of specialty equipment, potential special ventilation requirements

Storage

Examples: hazardous materials storage, ammunition storage

Similar Civilian Type: None

Characteristics: unheated and usually unoccupied

Warehouse

Examples: general purpose warehouse, shipping and receiving building

Similar Civilian Type: Warehouse

Characteristics: occupied, heated, high occupant activity level

Appendix F – FEDS Envelope Types

F.1 FEDS Floor Types

- **Slab on grade** – a concrete slab typically set on grade. Buildings with basements should typically also select a slab on grade floor type.
- **Crawlspace** – floor set above a crawlspace area that is typically partially ventilated such that the air within the crawlspace is generally between the building interior and outside ambient temperature conditions.
- **Pier** – similar to a high crawlspace, but with full airflow beneath the floor such that the underside of the bottom floor is exposed to outside ambient conditions. This type of construction is common along coastal areas to lift and protect occupied spaces from storm surges. This type can also be useful to model buildings that sit atop ventilated parking garages or have similar characteristics.

F.2 FEDS Wall Types

- **Wood siding over wood frame** – also includes vinyl or metal siding on a wood frame.
- **Masonry façade on wood frame** – standard wood frame with brick, stone, stucco, or other masonry exterior.
- **Masonry façade on masonry frame** – represents a solid masonry wall where both the outside surface and the structural wall is masonry. Also includes wood, plastic, or metal siding on masonry frame or concrete wall construction panel whether prefabricated or poured in place.
- **Masonry façade on steel frame** – steel frame with brick, stone, stucco, or other masonry exterior.
- **Pre-engineered metal** – outside walls which are factory fabricated aluminum or galvanized steel panel which are fastened to the building frame.

F.3 FEDS Roof Types

- **Built-up** – several layers of roofing felt with asphalt between and covered by a mineral-surfaced layer of a heavy asphalt coat embedded with gravel. Roof deck can be wood, concrete, or metal.
- **Pre-engineered metal** – light gauge metal roofing sheets (often corrugated).
- **Shingles or shakes** – pitched roof covered with a series of overlapping rows of roofing material, including wood, plastic, fiber glass, baked clay, tile, slate, asbestos, asphalt, and aluminum. A key distinguishing feature of this roof type is that there is typically an attic space in which insulation can be added.

F.4 FEDS Window Types

- **Commercial style** – “commercial style” refers to larger, single vision or fixed lite, punched windows that are typically non-operable and more common in newer commercial buildings. FEDS models their thermal and cost parameters based on a 48”x72” opening.
- **Residential style** – smaller, operable dual vision vertical windows (e.g., single or double hung). Thermal parameters and cost estimates are based on a typical 36” x 48” opening.

Note: despite the style names, select the most applicable window type regardless of whether you are modeling commercial or residential buildings.

Appendix G – Lighting Fixture Name Abbreviations

G.1 Exit Signs

| Abbreviation | | Description |
|--------------|------------------------|--|
| EX1 | EXIT – INC (2X20) | Two 20-watt incandescent lamps |
| EX2 | EXIT – INC (2X15) | Two 15-watt incandescent lamps |
| EX3 | EXIT – FL 1-PL9 | One 9-watt compact fluorescent lamp |
| EX4 | EXIT – FL 2-PL9 | Two 9-watt compact fluorescent lamps |
| EX5 | EXIT – FL RET 1-PL9 | One 9-watt compact fluorescent lamp retrofit kit |
| EX6 | EXIT – LED | Light emitting diode |
| EX7 | EXIT – SELF LUMINOUS | Tritium gas self-luminous |
| EX8 | EXIT – INC (2X25) | Two 25-watt incandescent lamps |
| EX9 | EXIT – FLEX TUBE 8 | Flexible tube, 8-watt fixture |
| EX10 | EXIT – LED RETRO KIT | Light emitting diode retrofit kit |
| EX11 | EXIT – PANEL | Light emitting capacitor (LEC) |
| EX12 | EXIT – PANEL RETRO KIT | Light emitting capacitor (LEC) retrofit kit |

G.2 Fluorescent

Fluorescent fixtures are based on a standard notation comprising codes that describe the different fixture parts. Fluorescent fixtures are further subdivided into fluorescent and compact fluorescent (CFL) fixtures. Compact fluorescent fixtures are discussed in the next subsection. The naming convention for fluorescent fixtures can be divided into five parts: dimension of the fixture, number of lamps, lamp type, ballast type, and reflector. As each part is described, an example will be given to illustrate how that part fits into the whole description based on a standard 4-40-watt lamp fixture.

Table 1 lists the possible fixture dimensions (**2X4 4F40T12 STD2 REF**). The fixture dimension is the size of the "box" that contains the lamps, ballasts, and reflectors, in feet.

The second part of the naming convention refers to the number of lamps contained within the fixture (**2X4 4F40T12 STD2 REF**). The number of lamps can vary from one to four lamps per fixture.

Table G.1. Fixture Dimensions

| Dimensions | Common Fixture Types |
|------------|---|
| 1X4 | One or two four-foot fluorescent lamps |
| 2X4 | One to four foot four fluorescent lamps, most commonly three or four lamps, or eight biax lamps |
| 2X2 | One or two U-shaped fluorescent lamps or two or four straight lamps |
| 2X3 | Six biax lamps |
| 1X8 | One or two eight-foot fluorescent lamps |

The third part of the naming convention refers to the type of lamp in the fixture (2X4 4F40T12 STD2 REF). The "T" number (T12, T8, or T5) describes the diameter of the lamp tube, in eighths of an inch; e.g., a T12 lamp has a diameter of 12/8 or 1.5 inches. Table G.2 lists the possible lamp types and their descriptions.

Table G.2. Lamp Types

| Lamp Type | Description |
|-----------|---|
| F40T12 | 40-watt T12 lamp, 48-in. length |
| F40T12U | 40-watt T12 U-shaped lamp, 22-in. length |
| F40T12ES | Energy saving 40-watt T12 lamp (approx. 34 watts), 48-in. length |
| F40T12UES | Energy saving 40-watt T12 U-shaped lamp (approx. 34 watts), 22-in. length |
| F40T12HO | High-output 40-watt T12 lamp (approx. 60 watts), 48-in. length |
| F32T8 | 32-watt T8 lamp, 48-in. length |
| F32T8U | 32-watt T8 U-shaped lamp, 22-in. length |
| F25ST8 | 25-watt Super T8, 48-in. length |
| F28ST8 | 28-watt Super T8, 48-in. length |
| F30ST8 | 30-watt Super T8, 48-in. length |
| F32ST8 | 32-watt Super T8, 48-in. length |
| F28T5 | 28-watt T5 lamp, 46-in. length |
| F14T5 | 14-watt T5 lamp, 22-in. length |
| F54T5HO | High-output 54-watt T5 lamp, 46-in. length |
| F96T12 | 75-watt T12 lamp, 96-in. length |
| F96T12ES | Energy saving 75-watt T12 lamp (approx. 60 watts), 96-in. length |
| F96T12HO | High-output 75-watt T12 lamp (approx. 110 watts), 96-in. length |
| F96T8 | T8 lamp, 96-in. length |
| F40BX | 40-watt Biax lamp 22½-in. length |

The fourth part of the naming convention refers to the type of ballast within the fixture (2X4 4F40T12 **STD2** REF). Table G.3 lists the possible ballast types and their descriptions.

Table G.3. Ballast Type

| Ballast Type | Description |
|---------------------|---|
| STD1 | Standard magnetic ballast designed for one lamp |
| STD2 | Standard magnetic ballast designed for two lamps; for four-lamp fixtures, two STD2s are used |
| STD1,2 | Combination of one lamp and two lamp standard magnetic ballasts, for use with three-lamp fixtures |
| EEF1 | Energy-efficient magnetic ballast designed for one lamp |
| EEF2 | Energy-efficient magnetic ballast designed for two lamps; for four-lamp fixtures, two EEF2s are used |
| EEF1,2 | Combination of one- and two-lamp energy-efficient magnetic ballasts, for use with three-lamp fixtures |
| ELC1 | Electronic ballast designed for one lamp |
| ELC2 | Electronic ballast designed for two lamps; for four-lamp fixtures, two ELC2s or one ELC4 can be used |
| ELC1,2 | Combination of one- and two-lamp electronic ballasts, for use with three-lamp fixtures |
| ELC3 | Electronic ballast designed for three lamps |
| ELC4 | Electronic ballast designed for four lamps |

The final part of the naming convention indicates whether a reflector is added to the fixture (2X4 4F40T12 STD2 **REF**). If the fixture is followed with "REF", a reflector is part of the fixture. If the fixture is not followed with the reflector indicator, then the fixture does not contain a reflector.

G.3 Compact Fluorescent

| Abbreviation | | Description |
|--------------|--------------------------|---|
| CF1 | CFL 7 INTEGRAL UNIT ELC | 7-watt compact fluorescent lamp w/integral electronic ballast |
| CF2 | CFL 9 INTEGRAL UNIT ELC | 9-watt compact fluorescent lamp w/integral electronic ballast |
| CF3 | CFL 11 INTEGRAL UNIT ELC | 11-watt compact fluorescent lamp w/integral electronic ballast |
| CF4 | CFL 15 INTEGRAL UNIT ELC | 15-watt compact fluorescent lamp w/integral electronic ballast |
| CF5 | CFL 18 INTEGRAL UNIT ELC | 18-watt compact fluorescent lamp w/integral electronic ballast |
| CF6 | CFL 20 INTEGRAL UNIT ELC | 20-watt compact fluorescent lamp w/integral electronic ballast |
| CF7 | CFL 23 INTEGRAL UNIT ELC | 23-watt compact fluorescent lamp w/integral electronic ballast |
| CF8 | CFL 25 INTEGRAL UNIT ELC | 25-watt compact fluorescent lamp w/integral electronic ballast |
| CF9 | CFL 26 INTEGRAL UNIT ELC | 26-watt compact fluorescent lamp w/integral electronic ballast |
| CF10 | CFL 27 INTEGRAL UNIT ELC | 27-watt compact fluorescent lamp w/integral electronic ballast |
| CF11 | CFL 30 INTEGRAL UNIT ELC | 30-watt compact fluorescent lamp w/integral electronic ballast |
| CF12 | CFL 15 GLOBE UNIT | 15-watt compact fluorescent globe lamp |
| CF13 | CFL 18 GLOBE UNIT | 18-watt compact fluorescent globe lamp |
| CF14 | CFL 5 + BLST UNIT | 5-watt compact fluorescent lamp and adapter assembly (obsolete) |
| CF15 | CFL 7 + BLST UNIT | 7-watt compact fluorescent lamp and adapter assembly (obsolete) |
| CF16 | CFL 9 + BLST UNIT | 9-watt compact fluorescent lamp and adapter assembly (obsolete) |
| CF17 | CFL 2-9 + BLST UNIT | Two 9-watt compact fluorescent lamps and adapter assemblies (obsolete) |
| CF18 | CFL 11 + BLST UNIT | 11-watt compact fluorescent lamp and adapter assembly (obsolete) |
| CF19 | CFL 13 + BLST UNIT | 13-watt compact fluorescent lamp and adapter assembly (obsolete) |
| CF20 | CFL 2-13 + BLST UNIT | Two 13-watt compact fluorescent lamps and adapter assemblies (obsolete) |
| CF21 | CFL 15 + BLST UNIT | 15-watt compact fluorescent lamp and adapter assembly (obsolete) |
| CF22 | CFL 20 + BLST UNIT | 20-watt compact fluorescent lamp and adapter assembly (obsolete) |
| CF23 | CFL 7 CEIL FIXT | 7-watt compact fluorescent hardwired ceiling fixture |

| Abbreviation | | Description |
|--------------|-------------------------------|--|
| CF24 | CFL 11 CEIL FIXT | 11-watt compact fluorescent hardwired ceiling fixture |
| CF25 | CFL 15 CEIL FIXT | 15-watt compact fluorescent hardwired ceiling fixture |
| CF26 | CFL 2-11 CEIL FIXT | Hardwired ceiling fixture w/two 11-watt compact fluorescent lamps |
| CF27 | CFL 2-15 CEIL FIXT | Hardwired ceiling fixture w/two 15-watt compact fluorescent lamps |
| CF28 | CFL 7 WALL FIXT | 7-watt compact fluorescent hardwired wall fixture |
| CF29 | CFL 11 WALL FIXT | 11-watt compact fluorescent hardwired wall fixture |
| CF30 | CFL 15 WALL FIXT | 15-watt compact fluorescent hardwired wall fixture |
| CF31 | CFL 2-11 WALL FIXT | Hardwired wall fixture w/two 11-watt compact fluorescent lamps |
| CF32 | CFL 2-15 WALL FIXT | Hardwired wall fixture w/two 15-watt compact fluorescent lamps |
| CF33 | CFL 7 CAN | 7-watt compact fluorescent hardwired recessed can fixture |
| CF34 | CFL 11 CAN | 11-watt compact fluorescent hardwired recessed can fixture |
| CF35 | CFL 15 CAN | 15-watt compact fluorescent hardwired recessed can fixture |
| CF36 | CFL 13 INTEGRAL UNIT ELC | 13-watt compact fluorescent lamp w/integral electronic ballast |
| CF37 | CFL 32 INTEGRAL UNIT ELC | 32-watt compact fluorescent lamp w/integral electronic ballast |
| CF38 | CFL 42 INTEGRAL UNIT ELC | 42-watt compact fluorescent lamp w/integral electronic ballast |
| CF39 | CFL 55 INTEGRAL UNIT ELC | 55-watt compact fluorescent lamp w/integral electronic ballast |
| CF40 | CFL 85 INTEGRAL UNIT ELC | 85-watt compact fluorescent lamp w/integral electronic ballast |
| CF41 | CFL 105 INTEGRAL UNIT ELC | 105-watt compact fluorescent lamp w/integral electronic ballast |
| CF42 | CFL 4 GLOBE UNIT | 4-watt compact fluorescent globe lamp |
| CF43 | CFL 9 GLOBE UNIT | 9-watt compact fluorescent globe lamp |
| CF44 | CFL 14 INTEGRAL FLOOD ELC | 14-watt compact fluorescent flood lamp w/integral electronic ballast |
| CF45 | CFL 16 INTEGRAL FLOOD ELC | 16-watt compact fluorescent flood lamp w/integral electronic ballast |
| CF46 | CFL 23 INTEGRAL FLOOD ELC | 23-watt compact fluorescent flood lamp w/integral electronic ballast |
| CF47 | CFL 27 INTEGRAL FLOOD ELC | 27-watt compact fluorescent flood lamp w/integral electronic ballast |
| CF48 | CFL 18 + BLST UNIT (Obsolete) | 18-watt compact fluorescent lamp and adapter assembly (obsolete) |
| CF49 | CFL 26 + BLST UNIT (Obsolete) | 26-watt compact fluorescent lamp and adapter assembly (obsolete) |

| Abbreviation | | Description |
|--------------|---------------------------|---|
| CF50 | CFL 20 INTEGRAL FLOOD ELC | 20-watt compact fluorescent lamp w/integral electronic ballast |
| CF51 | CFL 30 INTEGRAL FLOOD ELC | 30-watt compact fluorescent lamp w/integral electronic ballast |
| CF52 | CFL 2-9 CAN | Can light w/two 9-watt compact fluorescent lamps |
| CF53 | CFL 2-11 CAN | Can light w/two 11-watt compact fluorescent lamps |
| CF54 | CFL 2-13 CAN | Can light w/two 13-watt compact fluorescent lamps |
| CF55 | CFL 2-15 CAN | Can light w/two 15-watt compact fluorescent lamps |
| CF56 | CFL 120 INTEGRAL UNIT ELC | 120-watt compact fluorescent lamp w/integral electronic ballast |
| CF57 | CFL 150 INTEGRAL UNIT ELC | 150-watt compact fluorescent lamp w/integral electronic ballast |
| CF58 | CFL 180 INTEGRAL UNIT ELC | 180-watt compact fluorescent lamp w/integral electronic ballast |
| CF59 | CFL 200 INTEGRAL UNIT ELC | 200-watt compact fluorescent lamp w/integral electronic ballast |
| CF60 | CFL 2-18 CEIL FIXT | Hardwired ceiling fixture w/two 18-watt compact fluorescent lamps |
| CF61 | CFL 2-26 CEIL FIXT | Hardwired ceiling fixture w/two 26-watt compact fluorescent lamps |
| CF62 | CFL 2-18 CAN | Can light w/two 18-watt compact fluorescent lamps |
| CF63 | CFL 2-26 CAN | Can light w/two 26-watt compact fluorescent lamps |

G.4 High-Pressure Sodium

| Abbreviation | | Description |
|--------------|---------------|--|
| HS1 | HPS 35 POLE | 35-watt high-pressure sodium pole fixture |
| HS2 | HPS 50 POLE | 50-watt high-pressure sodium pole fixture |
| HS3 | HPS 70 POLE | 70-watt high-pressure sodium pole fixture |
| HS4 | HPS 100 POLE | 100-watt high-pressure sodium pole fixture |
| HS5 | HPS 150 POLE | 150-watt high-pressure sodium pole fixture |
| HS6 | HPS 200 POLE | 200-watt high-pressure sodium pole fixture |
| HS7 | HPS 250 POLE | 250-watt high-pressure sodium pole fixture |
| HS8 | HPS 310 POLE | 310-watt high-pressure sodium pole fixture |
| HS9 | HPS 400 POLE | 400-watt high-pressure sodium pole fixture |
| HS10 | HPS 1000 POLE | 1000-watt high-pressure sodium pole fixture |
| HS11 | HPS 35 PEND | 35-watt high-pressure sodium pendant fixture |
| HS12 | HPS 50 PEND | 50-watt high-pressure sodium pendant fixture |
| HS13 | HPS 70 PEND | 70-watt high-pressure sodium pendant fixture |
| HS14 | HPS 100 PEND | 100-watt high-pressure sodium pendant fixture |
| HS15 | HPS 150 PEND | 150-watt high-pressure sodium pendant fixture |
| HS16 | HPS 200 PEND | 200-watt high-pressure sodium pendant fixture |
| HS17 | HPS 250 PEND | 250-watt high-pressure sodium pendant fixture |
| HS18 | HPS 310 PEND | 310-watt high-pressure sodium pendant fixture |
| HS19 | HPS 400 PEND | 400-watt high-pressure sodium pendant fixture |
| HS20 | HPS 1000 PEND | 1000-watt high-pressure sodium pendant fixture |
| HS21 | HPS 35 WALL | 35-watt high-pressure sodium wall fixture |
| HS22 | HPS 50 WALL | 50-watt high-pressure sodium wall fixture |
| HS23 | HPS 70 WALL | 70-watt high-pressure sodium wall fixture |
| HS24 | HPS 100 WALL | 100-watt high-pressure sodium wall fixture |
| HS25 | HPS 150 WALL | 150-watt high-pressure sodium wall fixture |
| HS26 | HPS 200 WALL | 200-watt high-pressure sodium wall fixture |
| HS27 | HPS 250 WALL | 250-watt high-pressure sodium wall fixture |
| HS28 | HPS 310 WALL | 310-watt high-pressure sodium wall fixture |
| HS29 | HPS 400 WALL | 400-watt high-pressure sodium wall fixture |

| Abbreviation | | Description |
|--------------|-------------------------|--|
| HS30 | HPS 35 FLD | 35-watt high-pressure sodium floodlight |
| HS31 | HPS 70 FLD | 70-watt high-pressure sodium floodlight |
| HS32 | HPS 50 CAN | 50-watt high-pressure sodium can fixture |
| HS33 | HPS 70 CAN | 70-watt high-pressure sodium can fixture |
| HS34 | HPS 100 CAN | 100-watt high-pressure sodium can fixture |
| HS35 | HPS 150 REP FOR MV PEND | 150-watt high-pressure sodium lamp for merc. vapor pendant fixture |
| HS36 | HPS 215 REP FOR MV PEND | 215-watt high-pressure sodium lamp for merc. vapor pendant fixture |
| HS37 | HPS 220 REP FOR MV PEND | 220-watt high-pressure sodium lamp for merc. vapor pendant fixture |
| HS38 | HPS 360 REP FOR MV PEND | 360-watt high-pressure sodium lamp for merc. vapor pendant fixture |
| HS39 | HPS 880 REP FOR MV PEND | 880-watt high-pressure sodium lamp for merc. vapor pendant fixture |
| HS40 | HPS 940 REP FOR MV PEND | 940-watt high-pressure sodium lamp for merc. vapor pendant fixture |
| HS41 | HPS 150 REP FOR MV WALL | 150-watt high-pressure sodium lamp for merc. vapor wall fixture |
| HS42 | HPS 215 REP FOR MV WALL | 215-watt high-pressure sodium lamp for merc. vapor wall fixture |
| HS43 | HPS 220 REP FOR MV WALL | 220-watt high-pressure sodium lamp for merc. vapor wall fixture |
| HS44 | HPS 360 REP FOR MV WALL | 360-watt high-pressure sodium lamp for merc. vapor wall fixture |
| HS45 | HPS 880 REP FOR MV WALL | 880-watt high-pressure sodium lamp for merc. vapor wall fixture |
| HS46 | HPS 940 REP FOR MV WALL | 940-watt high-pressure sodium lamp for merc. vapor wall fixture |
| HS47 | HPS 150 REP FOR MV POLE | 150-watt high-pressure sodium lamp for merc. vapor pole fixture |
| HS48 | HPS 215 REP FOR MV POLE | 215-watt high-pressure sodium lamp for merc. vapor pole fixture |
| HS49 | HPS 220 REP FOR MV POLE | 220-watt high-pressure sodium lamp for merc. vapor pole fixture |
| HS50 | HPS 360 REP FOR MV POLE | 360-watt high-pressure sodium lamp for merc. vapor pole fixture |
| HS51 | HPS 880 REP FOR MV POLE | 880-watt high-pressure sodium lamp for merc. vapor pole fixture |
| HS52 | HPS 940 REP FOR MV POLE | 940-watt high-pressure sodium lamp for merc. vapor pole fixture |

| Abbreviation | | Description |
|--------------|-----------------|---|
| HS53 | HPS 70 IS PEND | 70-watt high-pressure sodium instant start pendant fixture |
| HS54 | HPS 100 IS PEND | 100-watt high-pressure sodium instant start pendant fixture |
| HS55 | HPS 150 IS PEND | 150-watt high-pressure sodium instant start pendant fixture |
| HS56 | HPS 250 IS PEND | 250-watt high-pressure sodium instant start pendant fixture |
| HS57 | HPS 400 IS PEND | 400-watt high-pressure sodium instant start pendant fixture |
| HS58 | HPS 70 IS WALL | 70-watt high-pressure sodium instant start wall fixture |
| HS59 | HPS 100 IS WALL | 100-watt high-pressure sodium instant start wall fixture |
| HS60 | HPS 150 IS WALL | 150-watt high-pressure sodium instant start wall fixture |
| HS61 | HPS 250 IS WALL | 250-watt high-pressure sodium instant start wall fixture |
| HS62 | HPS 400 IS WALL | 400-watt high-pressure sodium instant start wall fixture |
| HS63 | HPS 70 IS POLE | 70-watt high-pressure sodium instant start pole fixture |
| HS64 | HPS 100 IS POLE | 100-watt high-pressure sodium instant start pole fixture |
| HS65 | HPS 150 IS POLE | 150-watt high-pressure sodium instant start pole fixture |
| HS66 | HPS 250 IS POLE | 250-watt high-pressure sodium instant start pole fixture |
| HS67 | HPS 400 IS POLE | 400-watt high-pressure sodium instant start pole fixture |
| HS68 | HPS 35 WL PEND | 35-watt high-pressure sodium "white light" pendant fixture |
| HS69 | HPS 50 WL PEND | 50-watt high-pressure sodium "white light" pendant fixture |
| HS70 | HPS 100 WL PEND | 100-watt high-pressure sodium "white light" pendant fixture |
| HS71 | HPS 35 WL WALL | 35-watt high-pressure sodium "white light" wall fixture |
| HS72 | HPS 50 WL WALL | 50-watt high-pressure sodium "white light" wall fixture |
| HS73 | HPS 100 WL WALL | 100-watt high-pressure sodium "white light" wall fixture |

| Abbreviation | | Description |
|--------------|-------------------------|---|
| HS74 | HPS 35 WL POLE | 35-watt high-pressure sodium "white light" pole fixture |
| HS75 | HPS 50 WL POLE | 50-watt high-pressure sodium "white light" pole fixture |
| HS76 | HPS 100 WL POLE | 100-watt high-pressure sodium "white light" pole fixture |
| HS77 | HPS 150 REP FOR MH PEND | 150-watt high-pressure sodium lamp for metal halide pendant fixture |
| HS78 | HPS 215 REP FOR MH PEND | 215-watt high-pressure sodium lamp for metal halide pendant fixture |
| HS79 | HPS 220 REP FOR MH PEND | 220-watt high-pressure sodium lamp for metal halide pendant fixture |
| HS80 | HPS 360 REP FOR MH PEND | 360-watt high-pressure sodium lamp for metal halide pendant fixture |
| HS81 | HPS 880 REP FOR MH PEND | 880-watt high-pressure sodium lamp for metal halide pendant fixture |
| HS82 | HPS 940 REP FOR MH PEND | 940-watt high-pressure sodium lamp for metal halide pendant fixture |
| HS83 | HPS 150 REP FOR MH WALL | 150-watt high-pressure sodium lamp for metal halide wall fixture |
| HS84 | HPS 215 REP FOR MH WALL | 215-watt high-pressure sodium lamp for metal halide wall fixture |
| HS85 | HPS 220 REP FOR MH WALL | 220-watt high-pressure sodium lamp for metal halide wall fixture |
| HS86 | HPS 360 REP FOR MH WALL | 360-watt high-pressure sodium lamp for metal halide wall fixture |
| HS87 | HPS 880 REP FOR MH WALL | 880-watt high-pressure sodium lamp for metal halide wall fixture |
| HS88 | HPS 940 REP FOR MH WALL | 940-watt high-pressure sodium lamp for metal halide wall fixture |
| HS89 | HPS 150 REP FOR MH POLE | 150-watt high-pressure sodium lamp for metal halide pole fixture |
| HS90 | HPS 215 REP FOR MH POLE | 215-watt high-pressure sodium lamp for metal halide pole fixture |
| HS91 | HPS 220 REP FOR MH POLE | 220-watt high-pressure sodium lamp for metal halide pole fixture |
| HS92 | HPS 360 REP FOR MH POLE | 360-watt high-pressure sodium lamp for metal halide pole fixture |
| HS93 | HPS 880 REP FOR MH POLE | 880-watt high-pressure sodium lamp for metal halide pole fixture |
| HS94 | HPS 940 REP FOR MH POLE | 940-watt high-pressure sodium lamp for metal halide pole fixture |

| Abbreviation | | Description |
|--------------|------------------|--|
| HS95 | HPS 70 POLE ELC | 70-watt high-pressure sodium pole fixture w/electronic ballast |
| HS96 | HPS 70 PEND ELC | 70-watt high-pressure sodium pendant fixture w/electronic ballast |
| HS97 | HPS 70 WALL ELC | 70-watt high-pressure sodium wall fixture w/electronic ballast |
| HS98 | HPS 70 FLD ELC | 70-watt high-pressure sodium floodlight w/electronic ballast |
| HS99 | HPS 70 CAN ELC | 70-watt high-pressure sodium can fixture w/electronic ballast |
| HS100 | HPS 100 POLE ELC | 100-watt high-pressure sodium pole fixture w/electronic ballast |
| HS101 | HPS 100 PEND ELC | 100-watt high-pressure sodium pendant fixture w/electronic ballast |
| HS102 | HPS 100 WALL ELC | 100-watt high-pressure sodium wall fixture w/electronic ballast |
| HS103 | HPS 100 CAN ELC | 100-watt high-pressure sodium can fixture w/electronic ballast |

G.5 Incandescent

| Abbreviation | | Description |
|--------------|--------------------|--|
| IN1 | INC 40 CEIL | 40-watt incandescent ceiling fixture |
| IN2 | INC 2-40 CEIL | Incandescent ceiling fixture w/two 40-watt lamps |
| IN3 | INC 3-40 CEIL | Incandescent ceiling fixture w/three 40-watt lamps |
| IN4 | INC 4-40 CEIL | Incandescent ceiling fixture w/four 40-watt lamps |
| IN5 | INC 60 CEIL | 60-watt incandescent ceiling fixture |
| IN6 | INC 2-60 CEIL | Incandescent ceiling fixture w/two 60-watt lamps |
| IN7 | INC 3-60 CEIL | Incandescent ceiling fixture w/three 60-watt lamps |
| IN8 | INC 75 CEIL | 75-watt incandescent ceiling fixture |
| IN9 | INC 2-75 CEIL | Incandescent ceiling fixture w/two 75-watt lamps |
| IN10 | INC 3-75 CEIL | Incandescent ceiling fixture w/three 75-watt lamps |
| IN11 | INC 100 CEIL | 100-watt incandescent ceiling fixture |
| IN12 | INC 2-100 CEIL | Incandescent ceiling fixture w/two 100-watt lamps |
| IN13 | INC 25 TABLE LAMP | 25-watt incandescent table lamp |
| IN14 | INC 40 TABLE LAMP | 40-watt incandescent table lamp |
| IN15 | INC 60 TABLE LAMP | 60-watt incandescent table lamp |
| IN16 | INC 75 TABLE LAMP | 75-watt incandescent table lamp |
| IN17 | INC 100 TABLE LAMP | 100-watt incandescent table lamp |
| IN18 | INC 25 WALL | 25-watt incandescent wall fixture |
| IN19 | INC 40 WALL | 40-watt incandescent wall fixture |
| IN20 | INC 2-40 WALL | Incandescent wall fixture w/two 40-watt lamps |
| IN21 | INC 3-40 WALL | Incandescent wall fixture w/three 40-watt lamps |
| IN22 | INC 4-40 WALL | Incandescent wall fixture w/four 40-watt lamps |
| IN23 | INC 60 WALL | 60-watt incandescent wall fixture |
| IN24 | INC 2-60 WALL | Incandescent wall fixture w/two 60-watt lamps |
| IN25 | INC 75 WALL | 75-watt incandescent wall fixture |
| IN26 | INC 2-75 WALL | Incandescent wall fixture w/two 75-watt lamps |
| IN27 | INC 100 WALL | 100-watt incandescent wall fixture |
| IN28 | INC 150 PEND | 150-watt incandescent pendant fixture |
| IN29 | INC 200 PEND | 200-watt incandescent pendant fixture |
| IN30 | INC 300 PEND | 300-watt incandescent pendant fixture |
| IN31 | INC 40 CAN | 40-watt incandescent can fixture |
| IN32 | INC 60 CAN | 60-watt incandescent can fixture |

| | | |
|------|-------------|-----------------------------------|
| IN33 | INC 75 CAN | 75-watt incandescent can fixture |
| IN34 | INC 100 CAN | 100-watt incandescent can fixture |
| IN35 | INC 40 FLD | 40-watt incandescent floodlight |
| IN36 | INC 60 FLD | 60-watt incandescent floodlight |
| IN37 | INC 75 FLD | 75-watt incandescent floodlight |
| IN38 | INC 100 FLD | 100-watt incandescent floodlight |
| IN39 | INC 150 FLD | 150-watt incandescent floodlight |
| IN40 | INC 200 FLD | 200-watt incandescent floodlight |
| IN41 | INC 250 FLD | 250-watt incandescent floodlight |
| IN42 | INC 500 FLD | 500-watt incandescent floodlight |

G.6 Halogen

| Abbreviation | | Description |
|--------------|-------------------------|---|
| HI1 | HAL 20 PAR | 20-watt halogen parabolic aluminized reflector (PAR) lamp |
| HI2 | HAL 35 PAR | 35-watt halogen PAR lamp |
| HI3 | HAL 40 PAR | 40-watt halogen PAR lamp |
| HI4 | HAL 45 PAR | 45-watt halogen PAR lamp |
| HI5 | HAL 50 PAR | 50-watt halogen PAR lamp |
| HI6 | HAL 60 PAR | 60-watt halogen PAR lamp |
| HI7 | HAL 65 PAR | 65-watt halogen PAR lamp |
| HI8 | HAL 70 PAR | 70-watt halogen PAR lamp |
| HI9 | HAL 75 PAR | 75-watt halogen PAR lamp |
| HI10 | HAL 85 PAR | 85-watt halogen PAR lamp |
| HI11 | HAL 90 PAR | 90-watt halogen PAR lamp |
| HI12 | HAL 100 PAR | 100-watt halogen PAR lamp |
| HI13 | HAL 120 PAR | 120-watt halogen PAR lamp |
| HI14 | HAL 250 PAR | 250-watt halogen PAR lamp |
| HI15 | HAILIR 40 PAR | 40-watt halogen infrared PAR lamp |
| HI16 | HAILIR 45 PAR | 45-watt halogen infrared PAR lamp |
| HI17 | HAILIR 48 PAR | 48-watt halogen infrared PAR lamp |
| HI18 | HAILIR 55 PAR | 55-watt halogen infrared PAR lamp |
| HI19 | HAILIR 60 PAR | 60-watt halogen infrared PAR lamp |
| HI20 | HAILIR 67 PAR | 67-watt halogen infrared PAR lamp |
| HI21 | HAILIR 70 PAR | 70-watt halogen infrared PAR lamp |
| HI22 | HAILIR 83 PAR | 83-watt halogen infrared PAR lamp |
| HI23 | HAILIR 100 PAR | 100-watt halogen infrared PAR lamp |
| HI24 | HAL 20 MR16 (12V) SPOT | 20-watt halogen 2" multifaceted reflector (MR) spot lamp |
| HI25 | HAL 35 MR16 (12V) SPOT | 35-watt halogen 2" multifaceted reflector (MR) spot lamp |
| HI26 | HAL 50 MR16 (12V) SPOT | 50-watt halogen 2" multifaceted reflector (MR) spot lamp |
| HI27 | HAL 75 MR16 (12V) SPOT | 75-watt halogen 2" multifaceted reflector (MR) spot lamp |
| HI28 | HAL 100 MR16 (12V) SPOT | 100-watt halogen 2" multifaceted reflector (MR) spot lamp |
| HI29 | HAL 20 MR16 (12V) FLOOD | 20-watt halogen 2" multifaceted reflector (MR) flood lamp |

| | | |
|------|-----------------------------|--|
| HI30 | HAL 35 MR16 (12V) FLOOD | 35-watt halogen 2" multifaceted reflector (MR) flood lamp |
| HI31 | HAL 50 MR16 (12V) FLOOD | 50-watt halogen 2" multifaceted reflector (MR) flood lamp |
| HI32 | HAL 75 MR16 (12V) FLOOD | 75-watt halogen 2" multifaceted reflector (MR) flood lamp |
| HI33 | HAL 100 MR16 (12V) FLOOD | 100-watt halogen 2" multifaceted reflector (MR) flood lamp |
| HI34 | HAL 20 MR11 (12V) SPOT | 20-watt halogen 1.375" multifaceted reflector (MR) spot lamp |
| HI35 | HAL 35 MR11 (12V) SPOT | 35-watt halogen 1.375" multifaceted reflector (MR) spot lamp |
| HI36 | HAL 20 MR11 (12V) FLOOD | 20-watt halogen 1.375" multifaceted reflector (MR) flood lamp |
| HI37 | HAL 35 MR11 (12V) FLOOD | 35-watt halogen 1.375" multifaceted reflector (MR) flood lamp |

G.7 Induction

| Abbreviation | | Description |
|--------------|---------------------------|---|
| IL1 | INDUCTION 150Wx1 High Bay | High bay induction fixture w/one 150-watt lamp |
| IL2 | INDUCTION 150Wx2 High Bay | High bay induction fixture w/two 150-watt lamps |
| IL3 | INDUCTION 150Wx3 High Bay | High bay induction fixture w/three 150-watt lamps |
| IL4 | INDUCTION 85W Low Bay | Low bay induction fixture w/one 85-watt lamp |
| IL5 | INDUCTION 100W Low Bay | Low bay induction fixture w/one 100-watt lamp |

G.8 Light Emitting Diode (LED)

| Abbreviation | | Description |
|--------------|-------------------------------------|--------------------------------------|
| LD1 | LED 3W A-Line (200 Lumens) | 3-watt A-Line screw-in LED lamp |
| LD2 | LED 5W A-Line (350 Lumens) | 5 -watt A-Line screw-in LED lamp |
| LD3 | LED 7W A-Line (500 Lumens) | 7-watt A-Line screw-in LED lamp |
| LD4 | LED 11W A-Line (850 Lumens) | 11-watt A-Line screw-in LED lamp |
| LD5 | LED 15W A-Line (1200 Lumens) | 15-watt A-Line screw-in LED lamp |
| LD6 | LED 20W A-Line (1700 Lumens) | 20-watt A-Line screw-in LED lamp |
| LD7 | LED 30W A-Line (2850 Lumens) | 30-watt A-Line screw-in LED lamp |
| LD8 | LED 40W A-Line (4000 Lumens) | 40-watt A-Line screw-in LED lamp |
| LD9 | LED 52W A-Line (5800 Lumens) | 52-watt A-Line screw-in LED lamp |
| LD30 | LED 4W MR16 SPOT (240 Lumens) | 4-watt pin-based MR16 spot LED lamp |
| LD31 | LED 7W MR16 SPOT (490 Lumens) | 7-watt pin-based MR16 spot LED lamp |
| LD35 | LED 4W MR16 FLOOD (240 Lumens) | 4-watt pin-based MR16 flood LED lamp |
| LD36 | LED 7W MR16 FLOOD (490 Lumens) | 7-watt pin-based MR16 flood LED lamp |
| LD40 | LED 4W MR11 SPOT (240 Lumens) | 4-watt pin-based MR11 spot LED lamp |
| LD41 | LED 7W MR11 SPOT (490 Lumens) | 7-watt pin-based MR11 spot LED lamp |
| LD45 | LED 4W MR11 FLOOD (240 Lumens) | 4-watt pin-based MR11 flood LED lamp |
| LD46 | LED 7W MR11 FLOOD (490 Lumens) | 7-watt pin-based MR11 flood LED lamp |
| LD70 | LED 4W Reflector Lamp (240 Lumens) | 4-watt screw-in LED reflector lamp |
| LD71 | LED 5W Reflector Lamp (350 Lumens) | 5-watt screw-in LED reflector lamp |
| LD72 | LED 7W Reflector Lamp (450 Lumens) | 7-watt screw-in LED reflector lamp |
| LD73 | LED 8W Reflector Lamp (500 Lumens) | 8-watt screw-in LED reflector lamp |
| LD74 | LED 9W Reflector Lamp (575 Lumens) | 9-watt screw-in LED reflector lamp |
| LD75 | LED 10W Reflector Lamp (630 Lumens) | 10-watt screw-in LED reflector lamp |
| LD76 | LED 11W Reflector Lamp (750 Lumens) | 11-watt screw-in LED reflector lamp |
| LD77 | LED 13W Reflector Lamp (850 Lumens) | 13-watt screw-in LED reflector lamp |
| LD78 | LED 14W Reflector Lamp (900 Lumens) | 14-watt screw-in LED reflector lamp |
| LD79 | LED 14W Reflector Lamp (950 Lumens) | 14-watt screw-in LED reflector lamp |

| Abbreviation | | Description |
|--------------|---|---|
| LD80 | LED 15W Reflector Lamp (1000 Lumens) | 15-watt screw-in LED reflector lamp |
| LD81 | LED 16W Reflector Lamp (1050 Lumens) | 16-watt screw-in LED reflector lamp |
| LD82 | LED 18W Reflector Lamp (1200 Lumens) | 18-watt screw-in LED reflector lamp |
| LD83 | LED 25W Reflector Lamp (1750 Lumens) | 25-watt screw-in LED reflector lamp |
| LD84 | LED 39W Reflector Lamp (2850 Lumens) | 39-watt screw-in LED reflector lamp |
| LD85 | LED 53W Reflector Lamp (4000 Lumens) | 53-watt screw-in LED reflector lamp |
| LD86 | LED 62W Reflector Lamp (4850 Lumens) | 62-watt screw-in LED reflector lamp |
| LD87 | LED 116W Reflector Lamp (10500 Lumens) | 116-watt screw-in LED reflector lamp |
| LD110 | LED 8W Can Fixture Repl (500 Lumens) | 8-watt hardwired LED can fixture |
| LD111 | LED 15W Can Fixture Repl (1000 Lumens) | 15-watt hardwired LED can fixture |
| LD112 | LED 23W Can Fixture Repl (1500 Lumens) | 23-watt hardwired LED can fixture |
| LD113 | LED 31W Can Fixture Repl (2000 Lumens) | 31-watt hardwired LED can fixture |
| LD114 | LED 39W Can Fixture Repl (2500 Lumens) | 39-watt hardwired LED can fixture |
| LD150 | LED 19Wx1 4' 25W ST8 Lamp Repl (2110 Lumens/Lamp) | One 4-foot 19-watt LED replacement lamp for a 25-watt super T8 lamp |
| LD151 | LED 19Wx2 4' 25W ST8 Lamp Repl (2110 Lumens/Lamp) | Two 4-foot 19-watt LED replacement lamps for 25-watt super T8 lamps |
| LD152 | LED 19Wx3 4' 25W ST8 Lamp Repl (2110 Lumens/Lamp) | Three 4-foot 19-watt LED replacement lamps for 25-watt super T8 lamps |
| LD153 | LED 19Wx4 4' 25W ST8 Lamp Repl (2110 Lumens/Lamp) | Four 4-foot 19-watt LED replacement lamps for 25-watt super T8 lamps |
| LD160 | LED 19Wx1 4' 25W ST8 REF Lamp Repl (2110 Lumens/Lamp) | One 4-foot 19-watt LED replacement lamp for a 25-watt super T8 lamp in a fixture with a reflector |
| LD161 | LED 19Wx2 4' 25W ST8 REF Lamp Repl (2110 Lumens/Lamp) | Two 4-foot 19-watt LED replacement lamps for 25W super T8 lamps in a fixture with a reflector |
| LD162 | LED 19Wx3 4' 25W ST8 REF Lamp Repl (2110 Lumens/Lamp) | Three 4-foot 19-watt LED replacement lamps for 25W super T8 lamps in a fixture with a reflector |

| Abbreviation | | Description |
|--------------|--|---|
| LD163 | LED 19Wx4 4' 25W ST8 REF Lamp Repl (2110 Lumens/Lamp) | Four 4-foot 19-watt LED replacement lamps for 25W super T8 lamps in a fixture with a reflector |
| LD170 | LED 21Wx1 4' 28W ST8 Lamp Repl (2330 Lumens/Lamp) | One 4-foot 21-watt LED replacement lamp for a 28-watt super T8 lamp |
| LD171 | LED 21Wx2 4' 28W ST8 Lamp Repl (2330 Lumens/Lamp) | Two 4-foot 21-watt LED replacement lamps for 28-watt super T8 lamps |
| LD172 | LED 21Wx3 4' 28W ST8 Lamp Repl (2330 Lumens/Lamp) | Three 4-foot 21-watt LED replacement lamps for 28-watt super T8 lamps |
| LD173 | LED 21Wx4 4' 28W ST8 Lamp Repl (2330 Lumens/Lamp) | Four 4-foot 21-watt LED replacement lamps for 28-watt super T8 lamps |
| LD180 | LED 21Wx1 4' 28W ST8 REF Lamp Repl (2330 Lumens/Lamp) | One 4-foot 21-watt LED replacement lamp for a 28-watt super T8 lamp in a fixture with a reflector |
| LD181 | LED 21Wx2 4' 28W ST8 REF Lamp Repl (2330 Lumens/Lamp) | Two 4-foot 21-watt LED replacement lamps for 28-watt super T8 lamps in a fixture with a reflector |
| LD182 | LED 21Wx3 4' 28W ST8 REF Lamp Repl (2330 Lumens/Lamp) | Three 4-foot 21-watt LED replacement lamps for 28-watt super T8 lamps in a fixture with a reflector |
| LD183 | LED 21Wx4 4' 28W ST8 REF Lamp Repl (2330 Lumens/Lamp) | Four 4-foot 21-watt LED replacement lamps for 28-watt super T8 lamps in a fixture with a reflector |
| LD190 | LED 23Wx1 4' 30W ST8/32W T8 Lamp Repl (2550 Lumens/Lamp) | One 4-foot 23-watt LED replacement lamp for a 30-watt super T8 lamp or 32-watt T8 lamp |
| LD191 | LED 23Wx2 4' 30W ST8/32W T8 Lamp Repl (2550 Lumens/Lamp) | Two 4-foot 23-watt LED replacement lamps for 30-watt super T8 lamps or 32-watt T8 lamps |
| LD192 | LED 23Wx3 4' 30W ST8/32W T8 Lamp Repl (2550 Lumens/Lamp) | Three 4-foot 23-watt LED replacement lamps for 28-watt super T8 lamps or 32-watt T8 lamps |
| LD193 | LED 23Wx4 4' 30W ST8/32W T8 Lamp Repl (2550 Lumens/Lamp) | Four 4-foot 23-watt LED replacement lamps for 28-watt super T8 lamps or 32-watt T8 lamps |
| LD200 | LED 23Wx1 4' 30W ST8/32W T8 REF Lamp Repl (2550 Lumens/Lamp) | One 4-foot 23-watt LED replacement lamp for a 30-watt super T8 lamp or 32-watt T8 lamp in a fixture with a reflector |
| LD201 | LED 23Wx2 4' 30W ST8/32W T8 REF Lamp Repl (2550 Lumens/Lamp) | Two 4-foot 23-watt LED replacement lamps for 30-watt super T8 lamps or 32-watt T8 lamps in a fixture with a reflector |

| Abbreviation | | Description |
|--------------|--|---|
| LD202 | LED 23Wx3 4' 30W ST8/32W T8 REF Lamp Repl (2550 Lumens/Lamp) | Three 4-foot 23-watt LED replacement lamps for 28-watt super T8 lamps or 32-watt T8 lamps in a fixture with a reflector |
| LD203 | LED 23Wx4 4' 30W ST8/32W T8 REF Lamp Repl (2550 Lumens/Lamp) | Four 4-foot 23-watt LED replacement lamps for 28-watt super T8 lamps or 32-watt T8 lamps in a fixture with a reflector |
| LD210 | LED 25Wx1 4' 32W ST8 Lamp Repl (2730 Lumens/Lamp) | One 4-foot 25-watt LED replacement lamp for a 32-watt super T8 lamp |
| LD211 | LED 25Wx2 4' 32W ST8 Lamp Repl (2730 Lumens/Lamp) | Two 4-foot 25-watt LED replacement lamps for 32-watt super T8 lamps |
| LD212 | LED 25Wx3 4' 32W ST8 Lamp Repl (2730 Lumens/Lamp) | Three 4-foot 25-watt LED replacement lamps for 32-watt super T8 lamps |
| LD213 | LED 25Wx4 4' 32W ST8 Lamp Repl (2730 Lumens/Lamp) | Four 4-foot 25-watt LED replacement lamps for 32-watt super T8 lamps |
| LD220 | LED 25Wx1 4' 32W ST8 REF Lamp Repl (2730 Lumens/Lamp) | One 4-foot 25-watt LED replacement lamp for a 32-watt super T8 lamp in a fixture with a reflector |
| LD221 | LED 25Wx2 4' 32W ST8 REF Lamp Repl (2730 Lumens/Lamp) | Two 4-foot 25-watt LED replacement lamps for 32-watt super T8 lamps in a fixture with a reflector |
| LD222 | LED 25Wx3 4' 32W ST8 REF Lamp Repl (2730 Lumens/Lamp) | Three 4-foot 25-watt LED replacement lamps for 32-watt super T8 lamps in a fixture with a reflector |
| LD223 | LED 25Wx4 4' 32W ST8 REF Lamp Repl (2730 Lumens/Lamp) | Four 4-foot 25-watt LED replacement lamps for 32-watt super T8 lamps in a fixture with a reflector |
| LD230 | LED 10Wx2 2' 15W T8 Lamp Repl (1040 Lumens/Lamp) | Two 2-foot 10-watt LED replacement lamps for 15-watt T8 lamps |
| LD231 | LED 10Wx3 2' 15W T8 Lamp Repl (1040 Lumens/Lamp) | Three 2-foot 10-watt LED replacement lamps for 15-watt T8 lamps |
| LD232 | LED 10Wx4 2' 15W T8 Lamp Repl (1040 Lumens/Lamp) | Four 2-foot 10-watt LED replacement lamps for 15-watt T8 lamps |
| LD240 | LED 10Wx2 2' 15W T8 REF Lamp Repl (1040 Lumens/Lamp) | Two 2-foot 10-watt LED replacement lamps for 15-watt T8 lamps in a fixture with a reflector |
| LD241 | LED 10Wx3 2' 15W T8 REF Lamp Repl (1040 Lumens/Lamp) | Three 2-foot 10-watt LED replacement lamps for 15-watt T8 lamps in a fixture with a reflector |
| LD242 | LED 10Wx4 2' 15W T8 REF Lamp Repl (1040 Lumens/Lamp) | Four 2-foot 10-watt LED replacement lamps for 15-watt T8 lamps in a fixture with a reflector |
| LD250 | LED 12Wx2 2' 17W ST8 Lamp Repl (1150 Lumens/Lamp) | Two 2-foot 12-watt LED replacement lamps for 17-watt T8 lamps |

| Abbreviation | | Description |
|--------------|---|---|
| LD251 | LED 12Wx3 2' 17W ST8 Lamp Repl (1150 Lumens/Lamp) | Three 2-foot 10-watt LED replacement lamps for 17-watt T8 lamps |
| LD252 | LED 12Wx4 2' 17W ST8 Lamp Repl (1150 Lumens/Lamp) | Four 2-foot 10-watt LED replacement lamps for 17-watt T8 lamps |
| LD260 | LED 12Wx2 2' 17W ST8 REF Lamp Repl (1150 Lumens/Lamp) | Two 2-foot 10-watt LED replacement lamps for 17-watt T8 lamps in a fixture with a reflector |
| LD261 | LED 12Wx3 2' 17W ST8 REF Lamp Repl (1150 Lumens/Lamp) | Three 2-foot 10-watt LED replacement lamps for 17-watt T8 lamps in a fixture with a reflector |
| LD262 | LED 12Wx4 2' 17W ST8 REF Lamp Repl (1150 Lumens/Lamp) | Four 2-foot 10-watt LED replacement lamps for 17-watt T8 lamps in a fixture with a reflector |
| LD280 | LED 34W 2x4 Fixture (3300 Lumens) | 34-watt 2x4 LED fixture—fluorescent troffer replacement |
| LD281 | LED 41W 2x4 Fixture (4000 Lumens) | 41-watt 2x4 LED fixture—fluorescent troffer replacement |
| LD282 | LED 51W 2x4 Fixture (5000 Lumens) | 51-watt 2x4 LED fixture—fluorescent troffer replacement |
| LD283 | LED 61W 2x4 Fixture (6000 Lumens) | 61-watt 2x4 LED fixture—fluorescent troffer replacement |
| LD284 | LED 71W 2x4 Fixture (7000 Lumens) | 71-watt 2x4 LED fixture—fluorescent troffer replacement |
| LD300 | LED 44W 2x4 Retrofit Panel (4678 Lumens) | 44-watt 2x4 LED retrofit panel—fluorescent troffer replacement |
| LD301 | LED 59W 2x4 Retrofit Panel (6227 Lumens) | 59-watt 2x4 LED retrofit panel—fluorescent troffer replacement |
| LD320 | LED 20W 1x4 Fixture (2000 Lumens) | 20-watt 1x4 LED fixture—fluorescent troffer replacement |
| LD321 | LED 34W 1x4 Fixture (3300 Lumens) | 34-watt 1x4 LED fixture—fluorescent troffer replacement |
| LD322 | LED 41W 1x4 Fixture (4000 Lumens) | 41-watt 1x4 LED fixture—fluorescent troffer replacement |
| LD340 | LED 34W 1x4 Retrofit Panel (2980 Lumens) | 34-watt 1x4 LED retrofit panel—fluorescent troffer replacement |
| LD341 | LED 41W 1x4 Retrofit Panel (3369 Lumens) | 41-watt 1x4 LED retrofit panel—fluorescent troffer replacement |
| LD342 | LED 52W 1x4 Retrofit Panel (4083 Lumens) | 52-watt 1x4 LED retrofit panel—fluorescent troffer replacement |
| LD360 | LED 20W 2x2 Fixture (2000 Lumens) | 20-watt 2x2 LED fixture—fluorescent troffer replacement |
| LD361 | LED 26W 2x2 Fixture (2500 Lumens) | 26-watt 2x2 LED fixture—fluorescent troffer replacement |

| Abbreviation | | Description |
|--------------|--|--|
| LD362 | LED 31W 2x2 Fixture (3000 Lumens) | 31-watt 2x2 LED fixture—fluorescent troffer replacement |
| LD363 | LED 36W 2x2 Fixture (3500 Lumens) | 36-watt 2x2 LED fixture—fluorescent troffer replacement |
| LD364 | LED 41W 2x2 Fixture (4000 Lumens) | 41-watt 2x2 LED fixture—fluorescent troffer replacement |
| LD380 | LED 34W 2x2 Retrofit Panel (3430 Lumens) | 34-watt 2x2 LED retrofit panel—fluorescent troffer replacement |
| LD381 | LED 41W 2x2 Retrofit Panel (3904 Lumens) | 41-watt 2x2 LED retrofit panel—fluorescent troffer replacement |
| LD382 | LED 52W 2x2 Retrofit Panel (4679 Lumens) | 52-watt 2x2 LED retrofit panel—fluorescent troffer replacement |
| LD430 | LED 30W Low Bay Fixture (3500 Lumens) | 30-watt LED low bay fixture |
| LD431 | LED 34W Low Bay Fixture (4000 Lumens) | 34-watt LED low bay fixture |
| LD432 | LED 43W Low Bay Fixture (5000 Lumens) | 43-watt LED low bay fixture |
| LD433 | LED 51W Low Bay Fixture (6000 Lumens) | 51-watt LED low bay fixture |
| LD460 | LED 91W High Bay Fixture (10000 Lumens) | 91-watt LED high bay fixture |
| LD461 | LED 136W High Bay Fixture (15000 Lumens) | 136-watt LED high bay fixture |
| LD462 | LED 182W High Bay Fixture (20000 Lumens) | 182-watt LED high bay fixture |
| LD463 | LED 227W High Bay Fixture (25000 Lumens) | 227-watt LED high bay fixture |
| LD464 | LED 273W High Bay Fixture (30000 Lumens) | 273-watt LED high bay fixture |
| LD465 | LED 364W High Bay Fixture (40000 Lumens) | 364-watt LED high bay fixture |
| LD466 | LED 455W High Bay Fixture (50000 Lumens) | 455-watt LED high bay fixture |
| LD467 | LED 546W High Bay Fixture (60000 Lumens) | 546-watt LED high bay fixture |
| LD500 | LED 9W Wall Pack (1000 Lumens) | 9-watt LED wall pack fixture |
| LD501 | LED 19W Wall Pack (2000 Lumens) | 19-watt LED wall pack fixture |
| LD502 | LED 37W Wall Pack (4000 Lumens) | 37-watt LED wall pack fixture |
| LD503 | LED 56W Wall Pack (6000 Lumens) | 56-watt LED wall pack fixture |
| LD504 | LED 75W Wall Pack (8000 Lumens) | 75-watt LED wall pack fixture |

| Abbreviation | | Description |
|--------------|-----------------------------------|--------------------------------|
| LD505 | LED 111W Wall Pack (10000 Lumens) | 111-watt LED wall pack fixture |
| LD506 | LED 167W Wall Pack (15000 Lumens) | 167-watt LED wall pack fixture |
| LD550 | LED 20W Pole Lamp (2000 Lumens) | 20-watt LED pole lamp fixture |
| LD551 | LED 30W Pole Lamp (3000 Lumens) | 30-watt LED pole lamp fixture |
| LD552 | LED 40W Pole Lamp (4000 Lumens) | 40-watt LED pole lamp fixture |
| LD553 | LED 50W Pole Lamp (5000 Lumens) | 50-watt LED pole lamp fixture |
| LD554 | LED 60W Pole Lamp (6000 Lumens) | 60-watt LED pole lamp fixture |
| LD555 | LED 80W Pole Lamp (8000 Lumens) | 80-watt LED pole lamp fixture |
| LD556 | LED 120W Pole Lamp (12000 Lumens) | 120-watt LED pole lamp fixture |
| LD557 | LED 160W Pole Lamp (16000 Lumens) | 160-watt LED pole lamp fixture |
| LD558 | LED 240W Pole Lamp (24000 Lumens) | 240-watt LED pole lamp fixture |
| LD559 | LED 360W Pole Lamp (36000 Lumens) | 360-watt LED pole lamp fixture |

G.9 Low-Pressure Sodium

| Abbreviation | | Description |
|--------------|--------------|--|
| LS1 | LPS 18 PEND | 18-watt low-pressure sodium pendant fixture |
| LS2 | LPS 35 PEND | 35-watt low-pressure sodium pendant fixture |
| LS3 | LPS 55 PEND | 55-watt low-pressure sodium pendant fixture |
| LS4 | LPS 90 PEND | 90-watt low-pressure sodium pendant fixture |
| LS5 | LPS 135 PEND | 135-watt low-pressure sodium pendant fixture |
| LS6 | LPS 180 PEND | 180-watt low-pressure sodium pendant fixture |
| LS7 | LPS 18 POLE | 18-watt low-pressure sodium pole fixture |
| LS8 | LPS 35 POLE | 35-watt low-pressure sodium pole fixture |
| LS9 | LPS 55 POLE | 55-watt low-pressure sodium pole fixture |
| LS10 | LPS 90 POLE | 90-watt low-pressure sodium pole fixture |
| LS11 | LPS 135 POLE | 135-watt low-pressure sodium pole fixture |
| LS12 | LPS 180 POLE | 180-watt low-pressure sodium pole fixture |
| LS13 | LPS 18 WALL | 18-watt low-pressure sodium wall fixture |
| LS14 | LPS 35 WALL | 35-watt low-pressure sodium wall fixture |
| LS15 | LPS 55 WALL | 55-watt low-pressure sodium wall fixture |
| LS16 | LPS 90 WALL | 90-watt low-pressure sodium wall fixture |
| LS17 | LPS 135 WALL | 135-watt low-pressure sodium wall fixture |
| LS18 | LPS 180 WALL | 180-watt low-pressure sodium wall fixture |

G.10 Metal Halide

| Abbreviation | | Description |
|--------------|---------------|--|
| MH1 | MH 50 PEND | 50-watt metal halide pendant fixture |
| MH2 | MH 70 PEND | 70-watt metal halide pendant fixture |
| MH3 | MH 100 PEND | 100-watt metal halide pendant fixture |
| MH4 | MH 175 PEND | 175-watt metal halide pendant fixture |
| MH5 | MH 250 PEND | 250-watt metal halide pendant fixture |
| MH6 | MH 400 PEND | 400-watt metal halide pendant fixture |
| MH7 | MH 1000 PEND | 1000-watt metal halide pendant fixture |
| MH8 | MH 1500 PEND | 1500-watt metal halide pendant fixture |
| MH9 | MH 50 WALL | 50-watt metal halide wall fixture |
| MH 10 | MH 70 WALL | 70-watt metal halide wall fixture |
| MH11 | MH 100 WALL | 100-watt metal halide wall fixture |
| MH12 | MH 175 WALL | 175-watt metal halide wall fixture |
| MH13 | MH 250 WALL | 250-watt metal halide wall fixture |
| MH14 | MH 400 WALL | 400-watt metal halide wall fixture |
| MH15 | MH 1000 WALL | 1000-watt metal halide wall fixture |
| MH16 | MH 1500 WALL | 1500-watt metal halide wall fixture |
| MH17 | MH 50 POLE | 50-watt metal halide pole fixture |
| MH18 | MH 70 POLE | 70-watt metal halide pole fixture |
| MH19 | MH 100 POLE | 100-watt metal halide pole fixture |
| MH20 | MH 175 POLE | 175-watt metal halide pole fixture |
| MH21 | MH 250 POLE | 250-watt metal halide pole fixture |
| MH22 | MH 400 POLE | 400-watt metal halide pole fixture |
| MH23 | MH 1000 POLE | 1000-watt metal halide pole fixture |
| MH24 | MH 1500 POLE | 1500-watt metal halide pole fixture |
| MH25 | MH 50 CAN | 50-watt metal halide can fixture |
| MH26 | MH 70 CAN | 70-watt metal halide can fixture |
| MH27 | MH 750 WALL | 750-watt metal halide wall fixture |
| MH28 | MH 32 WALL | 32-watt metal halide wall fixture |
| MH29 | MH 32 PEND | 32-watt metal halide pendant fixture |
| MH30 | MH 750 POLE | 750-watt metal halide pole fixture |
| MH31 | MH 750 PEND | 750-watt metal halide pendant fixture |
| MH32 | MH 32 POLE | 32-watt metal halide pole fixture |
| MH33 | MH 70 HE PEND | 70-watt metal halide high-efficiency pendant fixture |

| | | |
|------|-----------------|---|
| MH34 | MH 150 HE PEND | 150-watt metal halide high-efficiency pendant fixture |
| MH35 | MH 175 HE PEND | 175-watt metal halide high-efficiency pendant fixture |
| MH36 | MH 250 HE PEND | 250-watt metal halide high-efficiency pendant fixture |
| MH37 | MH 400 HE PEND | 400-watt metal halide high-efficiency pendant fixture |
| MH38 | MH 1000 HE PEND | 1000-watt metal halide high-efficiency pendant fixture |
| MH39 | MH 70 HE WALL | 70-watt metal halide high-efficiency wall fixture |
| MH40 | MH 150 HE WALL | 150-watt metal halide high-efficiency wall fixture |
| MH41 | MH 175 HE WALL | 175-watt metal halide high-efficiency wall fixture |
| MH42 | MH 250 HE WALL | 250-watt metal halide high-efficiency wall fixture |
| MH43 | MH 400 HE WALL | 400-watt metal halide high-efficiency wall fixture |
| MH44 | MH 1000 HE WALL | 1000-watt metal halide high-efficiency wall fixture |
| MH45 | MH 70 HE POLE | 70-watt metal halide high-efficiency pole fixture |
| MH46 | MH 150 HE POLE | 150-watt metal halide high-efficiency pole fixture |
| MH47 | MH 175 HE POLE | 175-watt metal halide high-efficiency pole fixture |
| MH48 | MH 250 HE POLE | 250-watt metal halide high-efficiency pole fixture |
| MH49 | MH 400 HE POLE | 400-watt metal halide high-efficiency pole fixture |
| MH50 | MH 1000 HE POLE | 1000-watt metal halide high-efficiency pole fixture |
| MH51 | MH 32 POLE ELC | 32-watt metal halide pole fixture w/electronic ballast |
| MH52 | MH 50 PEND ELC | 50-watt metal halide pendant fixture w/electronic ballast |
| MH53 | MH 32 WALL ELC | 32-watt metal halide wall fixture w/electronic ballast |
| MH54 | MH 50 POLE ELC | 50-watt metal halide pole fixture w/electronic ballast |
| MH55 | MH 50 PEND ELC | 50-watt metal halide pendant fixture w/electronic ballast |
| MH56 | MH 50 WALL ELC | 50-watt metal halide wall fixture w/electronic ballast |
| MH57 | MH 50 CAN ELC | 50-watt metal halide can fixture w/electronic ballast |
| MH58 | MH 70 POLE ELC | 70-watt metal halide pole fixture w/electronic ballast |
| MH59 | MH 70 PEND ELC | 70-watt metal halide pendant fixture w/electronic ballast |

| | | |
|-------|--------------------|--|
| MH60 | MH 70 WALL ELC | 70-watt metal halide wall fixture w/electronic ballast |
| MH61 | MH 70 CAN ELC | 70-watt metal halide can fixture w/electronic ballast |
| MH62 | MH 100 POLE ELC | 100-watt metal halide pole fixture w/electronic ballast |
| MH 63 | MH 100 PEND ELC | 100-watt metal halide pendant fixture w/electronic ballast |
| MH64 | MH 100 WALL ELC | 100-watt metal halide wall fixture w/electronic ballast |
| MH65 | MH 150 HE POLE ELC | 150-watt metal halide high-efficiency pole fixture w/electronic ballast |
| MH66 | MH 150 HE PEND ELC | 150-watt metal halide high-efficiency pendant fixture w/electronic ballast |
| MH67 | MH 150 HE WALL ELC | 150-watt metal halide high-efficiency wall fixture w/electronic ballast |

G.11 Mercury Vapor

| Abbreviation | | Description |
|--------------|----------------|---|
| MV1 | MERC 50 PEND | 50-watt mercury vapor pendant fixture |
| MV2 | MERC 75 PEND | 75-watt mercury vapor pendant fixture |
| MV3 | MERC 100 PEND | 100-watt mercury vapor pendant fixture |
| MV4 | MERC 175 PEND | 175-watt mercury vapor pendant fixture |
| MV5 | MERC 250 PEND | 250-watt mercury vapor pendant fixture |
| MV6 | MERC 400 PEND | 400-watt mercury vapor pendant fixture |
| MV7 | MERC 700 PEND | 700-watt mercury vapor pendant fixture |
| MV8 | MERC 1000 PEND | 1000-watt mercury vapor pendant fixture |
| MV9 | MERC 50 POLE | 50-watt mercury vapor pole fixture |
| MV10 | MERC 75 POLE | 75-watt mercury vapor pole fixture |
| MV11 | MERC 100 POLE | 100-watt mercury vapor pole fixture |
| MV12 | MERC 175 POLE | 175-watt mercury vapor pole fixture |
| MV13 | MERC 250 POLE | 250-watt mercury vapor pole fixture |
| MV14 | MERC 400 POLE | 400-watt mercury vapor pole fixture |
| MV15 | MERC 700 POLE | 700-watt mercury vapor pole fixture |
| MV16 | MERC 1000 POLE | 1000-watt mercury vapor pole fixture |
| MV17 | MERC 50 WALL | 50-watt mercury vapor wall fixture |
| MV18 | MERC 75 WALL | 75-watt mercury vapor wall fixture |
| MV19 | MERC 100 WALL | 100-watt mercury vapor wall fixture |
| MV20 | MERC 175 WALL | 175-watt mercury vapor wall fixture |
| MV21 | MERC 250 WALL | 250-watt mercury vapor wall fixture |
| MV22 | MERC 400 WALL | 400-watt mercury vapor wall fixture |
| MV23 | MERC 700 WALL | 700-watt mercury vapor wall fixture |
| MV24 | MERC 1000 WALL | 1000-watt mercury vapor wall fixture |

Appendix H – Lighting Fixture Codes

| Fixture Code | Fixture Name |
|--------------|---------------------------------|
| CF1 | CFL 7 INTEGRAL UNIT ELC |
| CF2 | CFL 9 INTEGRAL UNIT ELC |
| CF3 | CFL 11 INTEGRAL UNIT ELC |
| CF4 | CFL 15 INTEGRAL UNIT ELC |
| CF5 | CFL 18 INTEGRAL UNIT ELC |
| CF6 | CFL 20 INTEGRAL UNIT ELC |
| CF7 | CFL 23 INTEGRAL UNIT ELC |
| CF8 | CFL 25 INTEGRAL UNIT ELC |
| CF9 | CFL 26 INTEGRAL UNIT ELC |
| CF10 | CFL 27 INTEGRAL UNIT ELC |
| CF11 | CFL 30 INTEGRAL UNIT ELC |
| CF12 | CFL 15 GLOBE UNIT |
| CF13 | CFL 18 GLOBE UNIT |
| CF14 | CFL 5 + BLST UNIT (Obsolete) |
| CF15 | CFL 7 + BLST UNIT (Obsolete) |
| CF16 | CFL 9 + BLST UNIT (Obsolete) |
| CF17 | CFL 2-9 + BLST UNIT (Obsolete) |
| CF18 | CFL 11 + BLST UNIT (Obsolete) |
| CF19 | CFL 13 + BLST UNIT (Obsolete) |
| CF20 | CFL 2-13 + BLST UNIT (Obsolete) |
| CF21 | CFL 15 + BLST UNIT (Obsolete) |
| CF22 | CFL 20 + BLST UNIT (Obsolete) |
| CF23 | CFL 7 CEIL FIXT |
| CF24 | CFL 11 CEIL FIXT |
| CF25 | CFL 15 CEIL FIXT |
| CF26 | CFL 2-11 CEIL FIXT |
| CF27 | CFL 2-15 CEIL FIXT |
| CF28 | CFL 7 WALL FIXT |
| CF29 | CFL 11 WALL FIXT |
| CF30 | CFL 15 WALL FIXT |
| CF31 | CFL 2-11 WALL FIXT |
| CF32 | CFL 2-15 WALL FIXT |
| CF33 | CFL 7 CAN |
| CF34 | CFL 11 CAN |
| CF35 | CFL 15 CAN |
| CF36 | CFL 13 INTEGRAL UNIT ELC |
| CF37 | CFL 32 INTEGRAL UNIT ELC |
| CF38 | CFL 42 INTEGRAL UNIT ELC |
| CF39 | CFL 55 INTEGRAL UNIT ELC |
| CF40 | CFL 85 INTEGRAL UNIT ELC |
| CF41 | CFL 105 INTEGRAL UNIT ELC |
| CF42 | CFL 4 GLOBE UNIT |
| CF43 | CFL 9 GLOBE UNIT |
| CF44 | CFL 14 INTEGRAL FLOOD ELC |

| Fixture Code | Fixture Name |
|--------------|---|
| CF45 | CFL 16 INTEGRAL FLOOD ELC |
| CF46 | CFL 23 INTEGRAL FLOOD ELC |
| CF47 | CFL 27 INTEGRAL FLOOD ELC |
| CF48 | CFL 18 + BLST UNIT (Obsolete) |
| CF49 | CFL 26 + BLST UNIT (Obsolete) |
| CF50 | CFL 20 INTEGRAL FLOOD ELC |
| CF51 | CFL 30 INTEGRAL FLOOD ELC |
| CF52 | CFL 2-9 CAN |
| CF53 | CFL 2-11 CAN |
| CF54 | CFL 2-13 CAN |
| CF55 | CFL 2-15 CAN |
| CF56 | CFL 120 INTEGRAL UNIT ELC |
| CF57 | CFL 150 INTEGRAL UNIT ELC |
| CF58 | CFL 180 INTEGRAL UNIT ELC |
| CF59 | CFL 200 INTEGRAL UNIT ELC |
| CF60 | CFL 2-18 CEIL FIXT |
| CF61 | CFL 2-26 CEIL FIXT |
| CF62 | CFL 2-18 CAN |
| CF63 | CFL 2-26 CAN |
| EX1 | EXIT - INC (2x20) |
| EX2 | EXIT - INC (2x15) |
| EX3 | EXIT - FL 1-PL9 |
| EX4 | EXIT - FL 2-PL9 |
| EX5 | EXIT - FL RET 1-PL9 |
| EX6 | EXIT - LED |
| EX7 | EXIT - SELF LUMINOUS |
| EX8 | EXIT - INC (2x25) |
| EX9 | EXIT - FLEX TUBE 8 |
| EX10 | EXIT - LED RETRO KIT |
| EX11 | EXIT - ELECTROLUMINESCENT PANEL |
| EX12 | EXIT - ELECTROLUMINESCENT PANEL RETRO KIT |
| FL1 | FL 2X4 4F40T12 STD2 |
| FL2 | FL 2X4 3F40T12 STD1,2 |
| FL3 | FL 2X4 2F40T12 STD2 |
| FL4 | FL 1X4 2F40T12 STD2 |
| FL5 | FL 1X4 1F40T12 STD1 |
| FL6 | FL 2X2 2F40T12U STD2 |
| FL7 | FL 2X4 4F40T12 STD2 REF |
| FL8 | FL 2X4 3F40T12 STD1,2 REF |
| FL9 | FL 2X4 2F40T12 STD2 REF |
| FL10 | FL 1X4 2F40T12 STD2 REF |
| FL11 | FL 1X4 1F40T12 STD1 REF |
| FL12 | FL 2X2 2F40T12U STD2 REF |

| Fixture Code | Fixture Name |
|--------------|---------------------------|
| FL13 | FL 2X4 4F40T12 EEF2 |
| FL14 | FL 2X4 3F40T12 EEF1,2 |
| FL15 | FL 2X4 2F40T12 EEF2 |
| FL16 | FL 1X4 2F40T12 EEF2 |
| FL17 | FL 1X4 1F40T12 EEF1 |
| FL18 | FL 2X2 2F40T12U EEF2 |
| FL19 | FL 2X4 4F40T12 EEF2 REF |
| FL20 | FL 2X4 3F40T12 EEF1,2 REF |
| FL21 | FL 2X4 2F40T12 EEF2 REF |
| FL22 | FL 1X4 2F40T12 EEF2 REF |
| FL23 | FL 1X4 1F40T12 EEF1 REF |
| FL24 | FL 2X2 2F40T12U EEF2 REF |
| FL25 | FL 2X4 4F40T12 ELC2 |
| FL26 | FL 2X4 3F40T12 ELC1,2 |
| FL27 | FL 2X4 2F40T12 ELC2 |
| FL28 | FL 1X4 2F40T12 ELC2 |
| FL29 | FL 1X4 1F40T12 ELC1 |
| FL30 | FL 2X2 2F40T12U ELC2 |
| FL31 | FL 2X4 4F40T12 ELC2 REF |
| FL32 | FL 2X4 3F40T12 ELC1,2 REF |
| FL33 | FL 2X4 2F40T12 ELC2 REF |
| FL34 | FL 1X4 2F40T12 ELC2 REF |
| FL35 | FL 1X4 1F40T12 ELC1 REF |
| FL36 | FL 2X2 2F40T12U ELC2 REF |
| FL37 | FL 2X4 4F32T8 EEF2 |
| FL38 | FL 2X4 3F32T8 EEF1,2 |
| FL39 | FL 2X4 2F32T8 EEF2 |
| FL40 | FL 1X4 2F32T8 EEF2 |
| FL41 | FL 1X4 1F32T8 EEF1 |
| FL42 | FL 2X2 2F32T8U EEF2 |
| FL43 | FL 2X4 4F32T8 EEF2 REF |
| FL44 | FL 2X4 3F32T8 EEF1,2 REF |
| FL45 | FL 2X4 2F32T8 EEF2 REF |
| FL46 | FL 1X4 2F32T8 EEF2 REF |
| FL47 | FL 1X4 1F32T8 EEF1 REF |
| FL48 | FL 2X2 2F32T8U EEF2 REF |
| FL49 | FL 2X4 4F32T8 ELC2 |
| FL50 | FL 2X4 3F32T8 ELC1,2 |
| FL51 | FL 2X4 2F32T8 ELC2 |
| FL52 | FL 1X4 2F32T8 ELC2 |
| FL53 | FL 1X4 1F32T8 ELC1 |
| FL54 | FL 2X2 2F32T8U ELC2 |
| FL55 | FL 2X4 4F32T8 ELC2 REF |
| FL56 | FL 2X4 3F32T8 ELC1,2 REF |
| FL57 | FL 2X4 2F32T8 ELC2 REF |
| FL58 | FL 1X4 2F32T8 ELC2 REF |

| Fixture Code | Fixture Name |
|--------------|-----------------------------|
| FL59 | FL 1X4 1F32T8 ELC1 REF |
| FL60 | FL 2X2 2F32T8U ELC2 REF |
| FL61 | FL 1X8 4F96T12 STD2 |
| FL62 | FL 1X8 2F96T12 STD2 |
| FL63 | FL 1X8 1F96T12 STD1 |
| FL64 | FL 1X8 4F96T12 STD2 REF |
| FL65 | FL 1X8 2F96T12 STD2 REF |
| FL66 | FL 1X8 1F96T12 STD1 REF |
| FL67 | FL 1X8 4F96T12 EEF2 |
| FL68 | FL 1X8 2F96T12 EEF2 |
| FL69 | FL 1X8 1F96T12 EEF1 |
| FL70 | FL 1X8 4F96T12 EEF2 REF |
| FL71 | FL 1X8 2F96T12 EEF2 REF |
| FL72 | FL 1X8 1F96T12 EEF1 REF |
| FL73 | FL 1X8 4F96T12 ELC2 |
| FL74 | FL 1X8 2F96T12 ELC2 |
| FL75 | FL 1X8 1F96T12 ELC1 |
| FL76 | FL 1X8 4F96T12 ELC2 REF |
| FL77 | FL 1X8 2F96T12 ELC2 REF |
| FL78 | FL 1X8 1F96T12 ELC1 REF |
| FL79 | FL 2X4 4F40T12ES STD2 |
| FL80 | FL 2X4 3F40T12ES STD1,2 |
| FL81 | FL 2X4 2F40T12ES STD2 |
| FL82 | FL 1X4 2F40T12ES STD2 |
| FL83 | FL 1X4 1F40T12ES STD1 |
| FL84 | FL 2X2 2F40T12UES STD2 |
| FL85 | FL 2X4 4F40T12ES STD2 REF |
| FL86 | FL 2X4 3F40T12ES STD1,2 REF |
| FL87 | FL 2X4 2F40T12ES STD2 REF |
| FL88 | FL 1X4 2F40T12ES STD2 REF |
| FL89 | FL 1X4 1F40T12ES STD1 REF |
| FL90 | FL 2X2 2F40T12UES STD2 REF |
| FL91 | FL 2X4 4F40T12ES EEF2 |
| FL92 | FL 2X4 3F40T12ES EEF1,2 |
| FL93 | FL 2X4 2F40T12ES EEF2 |
| FL94 | FL 1X4 2F40T12ES EEF2 |
| FL95 | FL 1X4 1F40T12ES EEF1 |
| FL96 | FL 2X2 2F40T12UES EEF2 |
| FL97 | FL 2X4 4F40T12ES EEF2 REF |
| FL98 | FL 2X4 3F40T12ES EEF1,2 REF |
| FL99 | FL 2X4 2F40T12ES EEF2 REF |
| FL100 | FL 1X4 2F40T12ES EEF2 REF |
| FL101 | FL 1X4 1F40T12ES EEF1 REF |
| FL102 | FL 2X2 2F40T12UES EEF2 REF |
| FL103 | FL 2X4 4F40T12ES ELC2 |
| FL104 | FL 2X4 3F40T12ES ELC1,2 |

| Fixture Code | Fixture Name |
|--------------|-----------------------------|
| FL105 | FL 2X4 2F40T12ES ELC2 |
| FL106 | FL 1X4 2F40T12ES ELC2 |
| FL107 | FL 1X4 1F40T12ES ELC1 |
| FL108 | FL 2X2 2F40T12UES ELC2 |
| FL109 | FL 2X4 4F40T12ES ELC2 REF |
| FL110 | FL 2X4 3F40T12ES ELC1,2 REF |
| FL111 | FL 2X4 2F40T12ES ELC2 REF |
| FL112 | FL 1X4 2F40T12ES ELC2 REF |
| FL113 | FL 1X4 1F40T12ES ELC1 REF |
| FL114 | FL 2X2 2F40T12UES ELC2 REF |
| FL115 | FL 1X8 4F96T12ES STD2 |
| FL116 | FL 1X8 2F96T12ES STD2 |
| FL117 | FL 1X8 1F96T12ES STD1 |
| FL118 | FL 1X8 4F96T12ES STD2 REF |
| FL119 | FL 1X8 2F96T12ES STD2 REF |
| FL120 | FL 1X8 1F96T12ES STD1 REF |
| FL121 | FL 1X8 4F96T12ES EE2 |
| FL122 | FL 1X8 2F96T12ES EE2 |
| FL123 | FL 1X8 1F96T12ES EE1 |
| FL124 | FL 1X8 4F96T12ES EE2 REF |
| FL125 | FL 1X8 2F96T12ES EE2 REF |
| FL126 | FL 1X8 1F96T12ES EE1 REF |
| FL127 | FL 1X8 4F96T12ES ELC2 |
| FL128 | FL 1X8 2F96T12ES ELC2 |
| FL129 | FL 1X8 1F96T12ES ELC1 |
| FL130 | FL 1X8 4F96T12ES ELC2 REF |
| FL131 | FL 1X8 2F96T12ES ELC2 REF |
| FL132 | FL 1X8 1F96T12ES ELC1 REF |
| FL133 | FL 2X4 4F40T12HO STD2 REF |
| FL134 | FL 2X4 3F40T12HO STD1,2 REF |
| FL135 | FL 2X4 2F40T12HO STD2 REF |
| FL136 | FL 1X4 2F40T12HO STD2 REF |
| FL137 | FL 1X4 1F40T12HO STD1 REF |
| FL138 | FL 2X4 4F40T12HO EE2 |
| FL139 | FL 2X4 3F40T12HO EE1,2 |
| FL140 | FL 2X4 2F40T12HO EE2 |
| FL141 | FL 1X4 2F40T12HO EE2 |
| FL142 | FL 1X4 1F40T12HO EE1 |
| FL143 | FL 2X4 4F40T12HO EE2 REF |
| FL144 | FL 2X4 3F40T12HO EE1,2 REF |
| FL145 | FL 2X4 2F40T12HO EE2 REF |
| FL146 | FL 1X4 2F40T12HO EE2 REF |
| FL147 | FL 1X4 1F40T12HO EE1 REF |
| FL148 | FL 2X4 4F40T12HO ELC2 |
| FL149 | FL 2X4 3F40T12HO ELC1,2 |
| FL150 | FL 2X4 2F40T12HO ELC2 |

| Fixture Code | Fixture Name |
|--------------|-----------------------------|
| FL151 | FL 1X4 2F40T12HO ELC2 |
| FL152 | FL 1X4 1F40T12HO ELC1 |
| FL153 | FL 2X4 4F40T12HO ELC2 REF |
| FL154 | FL 2X4 3F40T12HO ELC1,2 REF |
| FL155 | FL 2X4 2F40T12HO ELC2 REF |
| FL156 | FL 1X4 2F40T12HO ELC2 REF |
| FL157 | FL 1X4 1F40T12HO ELC1 REF |
| FL158 | FL 1X8 4F96T12HO STD2 REF |
| FL159 | FL 1X8 2F96T12HO STD2 REF |
| FL160 | FL 1X8 1F96T12HO STD1 REF |
| FL161 | FL 1X8 4F96T12HO EE2 |
| FL162 | FL 1X8 2F96T12HO EE2 |
| FL163 | FL 1X8 1F96T12HO EE1 |
| FL164 | FL 1X8 4F96T12HO EE2 REF |
| FL165 | FL 1X8 2F96T12HO EE2 REF |
| FL166 | FL 1X8 1F96T12HO EE1 REF |
| FL167 | FL 1X8 4F96T12HO ELC2 |
| FL168 | FL 1X8 2F96T12HO ELC2 |
| FL169 | FL 1X8 1F96T12HO ELC1 |
| FL170 | FL 1X8 4F96T12HO ELC2 REF |
| FL171 | FL 1X8 2F96T12HO ELC2 REF |
| FL172 | FL 1X8 1F96T12HO ELC1 REF |
| FL198 | FL 1X8 4F96T8 EE2 |
| FL199 | FL 1X8 2F96T8 EE2 |
| FL200 | FL 1X8 1F96T8 EE1 |
| FL201 | FL 1X8 4F96T8 EE2 REF |
| FL202 | FL 1X8 2F96T8 EE2 REF |
| FL203 | FL 1X8 1F96T8 EE1 REF |
| FL204 | FL 2X4 3F40T12HO STD1,2 |
| FL205 | FL 2X4 2F40T12HO STD2 |
| FL206 | FL 1X4 2F40T12HO STD2 |
| FL207 | FL 1X4 1F40T12HO STD1 |
| FL208 | FL 1X8 2F96T12HO STD2 |
| FL209 | FL 1X8 1F96T12HO STD1 |
| FL210 | FL 1X8 3F96T12 STD1,2 REF |
| FL211 | FL 1X8 3F96T12 EE1,2 REF |
| FL212 | FL 1X8 3F96T12 ELC1,2 REF |
| FL213 | FL 1X8 3F96T8 EE1,2 REF |
| FL214 | FL 1X8 3F96T12HO STD1,2 |
| FL215 | FL 1X8 3F96T12HO STD1,2 REF |
| FL216 | FL 1X8 3F96T12HO EE1,2 |
| FL217 | FL 1X8 3F96T12HO ELC1,2 |
| FL218 | FL 1X8 3F96T12HO EE1,2 REF |
| FL219 | FL 1X8 3F96T12HO ELC1,2 REF |
| FL220 | FL 1X8 3F96T12ES STD1,2 |
| FL221 | FL 1X8 3F96T12ES STD1,2 REF |

| Fixture Code | Fixture Name |
|--------------|-----------------------------|
| FL222 | FL 1X8 3F96T12ES EEF1,2 |
| FL223 | FL 1X8 3F96T12ES EEF1,2 REF |
| FL224 | FL 1X8 3F96T12ES ELC1,2 |
| FL225 | FL 1X8 3F96T12ES ELC1,2 REF |
| FL226 | FL 1X8 3F96T12 STD1,2 |
| FL227 | FL 1X8 3F96T12 EEF1,2 |
| FL228 | FL 1X8 3F96T12 ELC1,2 |
| FL229 | FL 1X8 3F96T8 EEF1,2 |
| FL230 | FL 2X4 3F40T12ES ELC3 |
| FL231 | FL 2X4 3F40T12ES ELC3 REF |
| FL232 | FL 2X4 3F40T12 ELC3 |
| FL233 | FL 2X4 3F40T12 ELC3 REF |
| FL234 | FL 2X4 3F40T12HO ELC3 |
| FL235 | FL 2X4 3F40T12HO ELC3 REF |
| FL236 | FL 2X4 3F32T8 ELC3 |
| FL237 | FL 2X4 3F32T8 ELC3 REF |
| FL238 | FL 2X4 4F40T12ES ELC4 |
| FL239 | FL 2X4 4F40T12ES ELC4 REF |
| FL240 | FL 2X4 4F40T12 ELC4 |
| FL241 | FL 2X4 4F40T12 ELC4 REF |
| FL242 | FL 2X4 4F40T12HO ELC4 |
| FL243 | FL 2X4 4F40T12HO ELC4 REF |
| FL244 | FL 2X4 4F32T8 ELC4 |
| FL245 | FL 2X4 4F32T8 ELC4 REF |
| FL246 | FL 1X8 4F96T12HO STD2 |
| FL247 | FL 2X4 4F40T12HO STD2 |
| FL248 | FL 1X8 4F96T8 ELC2 |
| FL249 | FL 1X8 2F96T8 ELC2 |
| FL250 | FL 1X8 1F96T8 ELC1 |
| FL251 | FL 1X8 3F96T8 ELC1,2 |
| FL252 | FL 1X8 4F96T8 ELC2 REF |
| FL253 | FL 1X8 2F96T8 ELC2 REF |
| FL254 | FL 1X8 1F96T8 ELC1 REF |
| FL255 | FL 1X8 3F96T8 ELC1,2 REF |
| FL256 | FL 2X2 2F14T5 ELC2 |
| FL257 | FL 2X2 4F14T5 ELC4 |
| FL258 | FL 1X4 1F28T5 ELC1 |
| FL259 | FL 1X4 2F28T5 ELC2 |
| FL260 | FL 2X4 2F28T5 ELC2 |
| FL261 | FL 2X4 3F28T5 ELC3 |
| FL262 | FL 2X4 4F28T5 ELC4 |
| FL263 | FL 2X2 2F14T5 ELC2 REF |
| FL264 | FL 2X2 4F14T5 ELC4 REF |
| FL265 | FL 1X4 1F28T5 ELC1 REF |
| FL266 | FL 1X4 2F28T5 ELC2 REF |
| FL267 | FL 2X4 2F28T5 ELC2 REF |

| Fixture Code | Fixture Name |
|--------------|----------------------------|
| FL268 | FL 2X4 3F28T5 ELC3 REF |
| FL269 | FL 2X4 4F28T5 ELC4 REF |
| FL270 | FL 1X4 1F54T5HO ELC1 REF |
| FL271 | FL 2X4 2F54T5HO ELC2 REF |
| FL272 | FL 2X4 3F54T5HO ELC1,2 REF |
| FL273 | FL 2X4 4F54T5HO ELC2 REF |
| FL274 | FL 1X4 1F32ST8 ELC1 |
| FL275 | FL 2X4 2F32ST8 ELC2 |
| FL276 | FL 2X4 3F32ST8 ELC3 |
| FL277 | FL 2X4 4F32ST8 ELC2 |
| FL278 | FL 1X4 1F32ST8 ELC1 REF |
| FL279 | FL 2X4 2F32ST8 ELC2 REF |
| FL280 | FL 2X4 3F32ST8 ELC3 REF |
| FL281 | FL 2X4 4F32ST8 ELC2 REF |
| FL282 | FL 1X4 1F30ST8 ELC1 |
| FL283 | FL 2X4 2F30ST8 ELC2 |
| FL284 | FL 2X4 3F30ST8 ELC3 |
| FL285 | FL 2X4 4F30ST8 ELC2 |
| FL286 | FL 1X4 1F30ST8 ELC1 REF |
| FL287 | FL 2X4 2F30ST8 ELC2 REF |
| FL288 | FL 2X4 3F30ST8 ELC3 REF |
| FL289 | FL 2X4 4F30ST8 ELC2 REF |
| FL290 | FL 1X4 1F28ST8 ELC1 |
| FL291 | FL 2X4 2F28ST8 ELC2 |
| FL292 | FL 2X4 3F28ST8 ELC3 |
| FL293 | FL 2X4 4F28ST8 ELC2 |
| FL294 | FL 1X4 1F28ST8 ELC1 REF |
| FL295 | FL 2X4 2F28ST8 ELC2 REF |
| FL296 | FL 2X4 3F28ST8 ELC3 REF |
| FL297 | FL 2X4 4F28ST8 ELC2 REF |
| FL298 | FL 1X4 1F25ST8 ELC1 |
| FL299 | FL 2X4 2F25ST8 ELC2 |
| FL300 | FL 2X4 3F25ST8 ELC3 |
| FL301 | FL 2X4 4F25ST8 ELC2 |
| FL302 | FL 1X4 1F25ST8 ELC1 REF |
| FL303 | FL 2X4 2F25ST8 ELC2 REF |
| FL304 | FL 2X4 3F25ST8 ELC3 REF |
| FL305 | FL 2X4 4F25ST8 ELC2 REF |
| FL306 | FL 2X2 4F40BX EEF2 REF |
| FL307 | FL 2X2 4F40BX ELC2 REF |
| FL308 | FL 2X3 6F40BX EEF2 REF |
| FL309 | FL 2X3 6F40BX ELC2 REF |
| FL310 | FL 2X4 8F40BX EEF2 REF |
| FL311 | FL 2X4 8F40BX ELC2 REF |
| FL312 | FL 2X2 1F25BX ELC1 REF |
| FL313 | FL 2X2 2F25BX ELC2 REF |

| Fixture Code | Fixture Name |
|--------------|--------------------------|
| FL314 | FL 2X2 3F25BX ELC3 REF |
| FL315 | FL 2X2 1F40BX ELC1 REF |
| FL316 | FL 2X2 2F40BX ELC2 REF |
| FL317 | FL 2X2 3F40BX ELC3 REF |
| FL318 | FL 2X2 1F50BX ELC1 REF |
| FL319 | FL 2X2 2F50BX ELC2 REF |
| FL320 | FL 2X2 3F50BX ELC3 REF |
| FL321 | FL 2X2 1F55BX ELC1 REF |
| FL322 | FL 2X2 2F55BX ELC2 REF |
| FL323 | FL 2X2 3F55BX ELC3 REF |
| FL324 | FL 2X2 2F17T8 ELC2 |
| FL325 | FL 2X2 3F17T8 ELC3 |
| FL326 | FL 2X2 4F17T8 ELC4 |
| FL327 | FL 2X2 2F17T8 ELC2 REF |
| FL328 | FL 2X2 3F17T8 ELC3 REF |
| FL329 | FL 2X2 4F17T8 ELC4 REF |
| FL330 | FL 2X2 2F15ST8 ELC2 |
| FL331 | FL 2X2 3F15ST8 ELC3 |
| FL332 | FL 2X2 4F15ST8 ELC4 |
| FL333 | FL 2X2 2F15ST8 ELC2 REF |
| FL334 | FL 2X2 3F15ST8 ELC3 REF |
| FL335 | FL 2X2 4F15ST8 ELC4 REF |
| FL336 | FL 2X2 3F14T5 ELC3 |
| FL337 | FL 2X2 3F14T5 ELC3 REF |
| FL338 | FL 2X2 2F32ST8U ELC2 |
| FL339 | FL 2X2 2F29ST8U ELC2 |
| FL340 | FL 2X2 2F26ST8U ELC2 |
| FL341 | FL 2X2 2F32ST8U ELC2 REF |
| FL342 | FL 2X2 2F29ST8U ELC2 REF |
| FL343 | FL 2X2 2F26ST8U ELC2 REF |
| FL344 | FL 2x4 6F32T8 ELC3 |
| FL345 | FL 2x4 8F32T8 ELC4 |
| FL346 | FL 2x4 6F32T8 ELC3 REF |
| FL347 | FL 2x4 8F32T8 ELC4 REF |
| FL348 | FL 2x4 4F32ST8 ELC4 |
| FL349 | FL 2x4 6F32ST8 ELC3 |
| FL350 | FL 2x4 8F32ST8 ELC4 |
| FL351 | FL 2x4 4F32ST8 ELC4 REF |
| FL352 | FL 2x4 6F32ST8 ELC3 REF |
| FL353 | FL 2x4 8F32ST8 ELC4 REF |
| FL354 | FL 2x4 4F30ST8 ELC4 |
| FL355 | FL 2x4 6F30ST8 ELC3 |
| FL356 | FL 2x4 8F30ST8 ELC4 |
| FL357 | FL 2x4 4F30ST8 ELC4 REF |
| FL358 | FL 2x4 6F30ST8 ELC3 REF |
| FL359 | FL 2x4 8F30ST8 ELC4 REF |

| Fixture Code | Fixture Name |
|--------------|----------------------------|
| FL360 | FL 2x4 4F28ST8 ELC4 |
| FL361 | FL 2x4 6F28ST8 ELC3 |
| FL362 | FL 2x4 8F28ST8 ELC4 |
| FL363 | FL 2x4 4F28ST8 ELC4 REF |
| FL364 | FL 2x4 6F28ST8 ELC3 REF |
| FL365 | FL 2x4 8F28ST8 ELC4 REF |
| FL366 | FL 2x4 4F25ST8 ELC4 |
| FL367 | FL 2x4 6F25ST8 ELC3 |
| FL368 | FL 2x4 8F25ST8 ELC4 |
| FL369 | FL 2x4 4F25ST8 ELC4 REF |
| FL370 | FL 2x4 6F25ST8 ELC3 REF |
| FL371 | FL 2x4 8F25ST8 ELC4 REF |
| FL372 | FL 2x4 6F28T5 ELC3 |
| FL373 | FL 2x4 8F28T5 ELC4 |
| FL374 | FL 2x4 6F28T5 ELC3 REF |
| FL375 | FL 2x4 8F28T5 ELC4 REF |
| FL376 | FL 2X4 3F54T5HO ELC3 REF |
| FL377 | FL 2X4 4F54T5HO ELC4 REF |
| FL378 | FL 2x4 6F54T5HO ELC3 REF |
| FL379 | FL 2x4 8F54T5HO ELC4 REF |
| FL380 | FL 1X4 1F49T5HO ELC1 REF |
| FL381 | FL 2X4 2F49T5HO ELC2 REF |
| FL382 | FL 2X4 3F49T5HO ELC1,2 REF |
| FL383 | FL 2X4 4F49T5HO ELC2 REF |
| FL384 | FL 2X4 3F49T5HO ELC3 REF |
| FL385 | FL 2X4 4F49T5HO ELC4 REF |
| FL386 | FL 2x4 6F49T5HO ELC3 REF |
| FL387 | FL 2x4 8F49T5HO ELC4 REF |
| FL388 | FL 1X4 1F47T5HO ELC1 REF |
| FL389 | FL 2X4 2F47T5HO ELC2 REF |
| FL390 | FL 2X4 3F47T5HO ELC1,2 REF |
| FL391 | FL 2X4 4F47T5HO ELC2 REF |
| FL392 | FL 2X4 3F47T5HO ELC3 REF |
| FL393 | FL 2X4 4F47T5HO ELC4 REF |
| FL394 | FL 2x4 6F47T5HO ELC3 REF |
| FL395 | FL 2x4 8F47T5HO ELC4 REF |
| FL396 | FL 1X4 1F25T5 ELC1 |
| FL397 | FL 1X4 2F25T5 ELC2 |
| FL398 | FL 2X4 2F25T5 ELC2 |
| FL399 | FL 2X4 3F25T5 ELC3 |
| FL400 | FL 2X4 4F25T5 ELC4 |
| FL401 | FL 1X4 1F25T5 ELC1 REF |
| FL402 | FL 1X4 2F25T5 ELC2 REF |
| FL403 | FL 2X4 2F25T5 ELC2 REF |
| FL404 | FL 2X4 2F25T5 ELC3 REF |
| FL405 | FL 2X4 4F25T5 ELC4 REF |

| Fixture Code | Fixture Name |
|--------------|-------------------------|
| FL406 | FL 2x4 6F25T5 ELC3 |
| FL407 | FL 2x4 8F25T5 ELC4 |
| FL408 | FL 2x4 6F25T5 ELC3 REF |
| FL409 | FL 2x4 8F25T5 ELC4 REF |
| FL410 | FL 1x8 2F32T8 ELC2 |
| FL411 | FL 1x8 4F32T8 ELC4 |
| FL412 | FL 1x8 6F32T8 ELC3 |
| FL413 | FL 1x8 8F32T8 ELC4 |
| FL414 | FL 1x8 2F32T8 ELC2 REF |
| FL415 | FL 1x8 4F32T8 ELC4 REF |
| FL416 | FL 1x8 6F32T8 ELC3 REF |
| FL417 | FL 1x8 8F32T8 ELC4 REF |
| FL418 | FL 1X4 2F32ST8 ELC2 |
| FL419 | FL 1X4 2F32ST8 ELC2 REF |
| FL420 | FL 1X4 2F30ST8 ELC2 |
| FL421 | FL 1X4 2F30ST8 ELC2 REF |
| FL422 | FL 1X4 2F28ST8 ELC2 |
| FL423 | FL 1X4 2F28ST8 ELC2 REF |
| FL424 | FL 1X4 2F25ST8 ELC2 |
| FL425 | FL 1X4 2F25ST8 ELC2 REF |
| HI1 | HAL 20 PAR |
| HI2 | HAL 35 PAR |
| HI3 | HAL 40 PAR |
| HI4 | HAL 45 PAR |
| HI5 | HAL 50 PAR |
| HI6 | HAL 60 PAR |
| HI7 | HAL 65 PAR |
| HI8 | HAL 70 PAR |
| HI9 | HAL 75 PAR |
| HI10 | HAL 85 PAR |
| HI11 | HAL 90 PAR |
| HI12 | HAL 100 PAR |
| HI13 | HAL 120 PAR |
| HI14 | HAL 250 PAR |
| HI15 | HALIR 40 PAR |
| HI16 | HALIR 45 PAR |
| HI17 | HALIR 48 PAR |
| HI18 | HALIR 55 PAR |
| HI19 | HALIR 60 PAR |
| HI20 | HALIR 67 PAR |
| HI21 | HALIR 70 PAR |
| HI22 | HALIR 83 PAR |
| HI23 | HALIR 100 PAR |
| HI24 | HAL 20 MR16 (12V) SPOT |
| HI25 | HAL 35 MR16 (12V) SPOT |
| HI26 | HAL 50 MR16 (12V) SPOT |

| Fixture Code | Fixture Name |
|--------------|--------------------------|
| HI27 | HAL 75 MR16 (12V) SPOT |
| HI28 | HAL 100 MR16 (12V) SPOT |
| HI29 | HAL 20 MR16 (12V) FLOOD |
| HI30 | HAL 35 MR16 (12V) FLOOD |
| HI31 | HAL 50 MR16 (12V) FLOOD |
| HI32 | HAL 75 MR16 (12V) FLOOD |
| HI33 | HAL 100 MR16 (12V) FLOOD |
| HI34 | HAL 20 MR11 (12V) SPOT |
| HI35 | HAL 35 MR11 (12V) SPOT |
| HI36 | HAL 20 MR11 (12V) FLOOD |
| HI37 | HAL 35 MR11 (12V) FLOOD |
| HS1 | HPS 35 POLE |
| HS2 | HPS 50 POLE |
| HS3 | HPS 70 POLE |
| HS4 | HPS 100 POLE |
| HS5 | HPS 150 POLE |
| HS6 | HPS 200 POLE |
| HS7 | HPS 250 POLE |
| HS8 | HPS 310 POLE |
| HS9 | HPS 400 POLE |
| HS10 | HPS 1000 POLE |
| HS11 | HPS 35 PEND |
| HS12 | HPS 50 PEND |
| HS13 | HPS 70 PEND |
| HS14 | HPS 100 PEND |
| HS15 | HPS 150 PEND |
| HS16 | HPS 200 PEND |
| HS17 | HPS 250 PEND |
| HS18 | HPS 310 PEND |
| HS19 | HPS 400 PEND |
| HS20 | HPS 1000 PEND |
| HS21 | HPS 35 WALL |
| HS22 | HPS 50 WALL |
| HS23 | HPS 70 WALL |
| HS24 | HPS 100 WALL |
| HS25 | HPS 150 WALL |
| HS26 | HPS 200 WALL |
| HS27 | HPS 250 WALL |
| HS28 | HPS 310 WALL |
| HS29 | HPS 400 WALL |
| HS30 | HPS 35 FLD |
| HS31 | HPS 70 FLD |
| HS32 | HPS 50 CAN |
| HS33 | HPS 70 CAN |
| HS34 | HPS 100 CAN |
| HS35 | HPS 150 REP FOR MV PEND |

| Fixture Code | Fixture Name |
|--------------|-------------------------|
| HS36 | HPS 215 REP FOR MV PEND |
| HS37 | HPS 220 REP FOR MV PEND |
| HS38 | HPS 360 REP FOR MV PEND |
| HS39 | HPS 880 REP FOR MV PEND |
| HS40 | HPS 940 REP FOR MV PEND |
| HS41 | HPS 150 REP FOR MV WALL |
| HS42 | HPS 215 REP FOR MV WALL |
| HS43 | HPS 220 REP FOR MV WALL |
| HS44 | HPS 360 REP FOR MV WALL |
| HS45 | HPS 880 REP FOR MV WALL |
| HS46 | HPS 940 REP FOR MV WALL |
| HS47 | HPS 150 REP FOR MV POLE |
| HS48 | HPS 215 REP FOR MV POLE |
| HS49 | HPS 220 REP FOR MV POLE |
| HS50 | HPS 360 REP FOR MV POLE |
| HS51 | HPS 880 REP FOR MV POLE |
| HS52 | HPS 940 REP FOR MV POLE |
| HS53 | HPS 70 IS PEND |
| HS54 | HPS 100 IS PEND |
| HS55 | HPS 150 IS PEND |
| HS56 | HPS 250 IS PEND |
| HS57 | HPS 400 IS PEND |
| HS58 | HPS 70 IS WALL |
| HS59 | HPS 100 IS WALL |
| HS60 | HPS 150 IS WALL |
| HS61 | HPS 250 IS WALL |
| HS62 | HPS 400 IS WALL |
| HS63 | HPS 70 IS POLE |
| HS64 | HPS 100 IS POLE |
| HS65 | HPS 150 IS POLE |
| HS66 | HPS 250 IS POLE |
| HS67 | HPS 400 IS POLE |
| HS68 | HPS 35 WL PEND |
| HS69 | HPS 50 WL PEND |
| HS70 | HPS 100 WL PEND |
| HS71 | HPS 35 WL WALL |
| HS72 | HPS 50 WL WALL |
| HS73 | HPS 100 WL WALL |
| HS74 | HPS 35 WL POLE |
| HS75 | HPS 50 WL POLE |
| HS76 | HPS 100 WL POLE |
| HS77 | HPS 150 REP FOR MH PEND |
| HS78 | HPS 215 REP FOR MH PEND |
| HS79 | HPS 220 REP FOR MH PEND |
| HS80 | HPS 360 REP FOR MH PEND |
| HS81 | HPS 880 REP FOR MH PEND |

| Fixture Code | Fixture Name |
|--------------|---------------------------|
| HS82 | HPS 940 REP FOR MH PEND |
| HS83 | HPS 150 REP FOR MH WALL |
| HS84 | HPS 215 REP FOR MH WALL |
| HS85 | HPS 220 REP FOR MH WALL |
| HS86 | HPS 360 REP FOR MH WALL |
| HS87 | HPS 880 REP FOR MH WALL |
| HS88 | HPS 940 REP FOR MH WALL |
| HS89 | HPS 150 REP FOR MH POLE |
| HS90 | HPS 215 REP FOR MH POLE |
| HS91 | HPS 220 REP FOR MH POLE |
| HS92 | HPS 360 REP FOR MH POLE |
| HS93 | HPS 880 REP FOR MH POLE |
| HS94 | HPS 940 REP FOR MH POLE |
| HS95 | HPS 70 POLE ELC |
| HS96 | HPS 70 PEND ELC |
| HS97 | HPS 70 WALL ELC |
| HS98 | HPS 70 FLD ELC |
| HS99 | HPS 70 CAN ELC |
| HS100 | HPS 100 POLE ELC |
| HS101 | HPS 100 PEND ELC |
| HS102 | HPS 100 WALL ELC |
| HS103 | HPS 100 CAN ELC |
| IL1 | INDUCTION 150Wx1 High Bay |
| IL2 | INDUCTION 150Wx2 High Bay |
| IL3 | INDUCTION 150Wx3 High Bay |
| IL4 | INDUCTION 85W Low Bay |
| IL5 | INDUCTION 100W Low Bay |
| IN1 | INC 40 CEIL |
| IN2 | INC 2-40 CEIL |
| IN3 | INC 3-40 CEIL |
| IN4 | INC 4-40 CEIL |
| IN5 | INC 60 CEIL |
| IN6 | INC 2-60 CEIL |
| IN7 | INC 3-60 CEIL |
| IN8 | INC 75 CEIL |
| IN9 | INC 2-75 CEIL |
| IN10 | INC 3-75 CEIL |
| IN11 | INC 100 CEIL |
| IN12 | INC 2-100 CEIL |
| IN13 | INC 25 TABLE LAMP |
| IN14 | INC 40 TABLE LAMP |
| IN15 | INC 60 TABLE LAMP |
| IN16 | INC 75 TABLE LAMP |
| IN17 | INC 100 TABLE LAMP |
| IN18 | INC 25 WALL |
| IN19 | INC 40 WALL |

| Fixture Code | Fixture Name |
|--------------|------------------------------------|
| IN20 | INC 2-40 WALL |
| IN21 | INC 3-40 WALL |
| IN22 | INC 4-40 WALL |
| IN23 | INC 60 WALL |
| IN24 | INC 2-60 WALL |
| IN25 | INC 75 WALL |
| IN26 | INC 2-75 WALL |
| IN27 | INC 100 WALL |
| IN28 | INC 150 PEND |
| IN29 | INC 200 PEND |
| IN30 | INC 300 PEND |
| IN31 | INC 40 CAN |
| IN32 | INC 60 CAN |
| IN33 | INC 75 CAN |
| IN34 | INC 100 CAN |
| IN35 | INC 40 FLD |
| IN36 | INC 60 FLD |
| IN37 | INC 75 FLD |
| IN38 | INC 100 FLD |
| IN39 | INC 150 FLD |
| IN40 | INC 200 FLD |
| IN41 | INC 250 FLD |
| IN42 | INC 500 FLD |
| LD1 | LED 3W A-Line (200 Lumens) |
| LD2 | LED 5W A-Line (350 Lumens) |
| LD3 | LED 7W A-Line (500 Lumens) |
| LD4 | LED 11W A-Line (850 Lumens) |
| LD5 | LED 15W A-Line (1200 Lumens) |
| LD6 | LED 20W A-Line (1700 Lumens) |
| LD7 | LED 30W A-Line (2850 Lumens) |
| LD8 | LED 40W A-Line (4000 Lumens) |
| LD9 | LED 52W A-Line (5800 Lumens) |
| LD30 | LED 4W MR16 SPOT (240 Lumens) |
| LD31 | LED 7W MR16 SPOT (490 Lumens) |
| LD35 | LED 4W MR16 FLOOD (240 Lumens) |
| LD36 | LED 7W MR16 FLOOD (490 Lumens) |
| LD40 | LED 4W MR11 SPOT (240 Lumens) |
| LD41 | LED 7W MR11 SPOT (490 Lumens) |
| LD45 | LED 4W MR11 FLOOD (240 Lumens) |
| LD46 | LED 7W MR11 FLOOD (490 Lumens) |
| LD70 | LED 4W Reflector Lamp (240 Lumens) |
| | |

| Fixture Code | Fixture Name |
|--------------|---|
| LD71 | LED 5W Reflector Lamp (350 Lumens) |
| LD72 | LED 7W Reflector Lamp (450 Lumens) |
| LD73 | LED 8W Reflector Lamp (500 Lumens) |
| LD74 | LED 9W Reflector Lamp (575 Lumens) |
| LD75 | LED 10W Reflector Lamp (630 Lumens) |
| LD76 | LED 11W Reflector Lamp (750 Lumens) |
| LD77 | LED 13W Reflector Lamp (850 Lumens) |
| LD78 | LED 14W Reflector Lamp (900 Lumens) |
| LD79 | LED 14W Reflector Lamp (950 Lumens) |
| LD80 | LED 15W Reflector Lamp (1000 Lumens) |
| LD81 | LED 16W Reflector Lamp (1050 Lumens) |
| LD82 | LED 18W Reflector Lamp (1200 Lumens) |
| LD83 | LED 25W Reflector Lamp (1750 Lumens) |
| LD84 | LED 39W Reflector Lamp (2850 Lumens) |
| LD85 | LED 53W Reflector Lamp (4000 Lumens) |
| LD86 | LED 62W Reflector Lamp (4850 Lumens) |
| LD87 | LED 116W Reflector Lamp (10500 Lumens) |
| LD110 | LED 8W Can Fixture Repl (500 Lumens) |
| LD111 | LED 15W Can Fixture Repl (1000 Lumens) |
| LD112 | LED 23W Can Fixture Repl (1500 Lumens) |
| LD113 | LED 31W Can Fixture Repl (2000 Lumens) |
| LD114 | LED 39W Can Fixture Repl (2500 Lumens) |
| LD150 | LED 19Wx1 4' 25W ST8 Lamp Repl (2110 Lumens/Lamp) |
| LD151 | LED 19Wx2 4' 25W ST8 Lamp Repl (2110 Lumens/Lamp) |

| Fixture Code | Fixture Name |
|--------------|--|
| LD152 | LED 19Wx3 4' 25W ST8 Lamp Repl (2110 Lumens/Lamp) |
| LD153 | LED 19Wx4 4' 25W ST8 Lamp Repl (2110 Lumens/Lamp) |
| LD160 | LED 19Wx1 4' 25W ST8 REF Lamp Repl (2110 Lumens/Lamp) |
| LD161 | LED 19Wx2 4' 25W ST8 REF Lamp Repl (2110 Lumens/Lamp) |
| LD162 | LED 19Wx3 4' 25W ST8 REF Lamp Repl (2110 Lumens/Lamp) |
| LD163 | LED 19Wx4 4' 25W ST8 REF Lamp Repl (2110 Lumens/Lamp) |
| LD170 | LED 21Wx1 4' 28W ST8 Lamp Repl (2330 Lumens/Lamp) |
| LD171 | LED 21Wx2 4' 28W ST8 Lamp Repl (2330 Lumens/Lamp) |
| LD172 | LED 21Wx3 4' 28W ST8 Lamp Repl (2330 Lumens/Lamp) |
| LD173 | LED 21Wx4 4' 28W ST8 Lamp Repl (2330 Lumens/Lamp) |
| LD180 | LED 21Wx1 4' 28W ST8 REF Lamp Repl (2330 Lumens/Lamp) |
| LD181 | LED 21Wx2 4' 28W ST8 REF Lamp Repl (2330 Lumens/Lamp) |
| LD182 | LED 21Wx3 4' 28W ST8 REF Lamp Repl (2330 Lumens/Lamp) |
| LD183 | LED 21Wx4 4' 28W ST8 REF Lamp Repl (2330 Lumens/Lamp) |
| LD190 | LED 23Wx1 4' 30W ST8/32W T8 Lamp Repl (2550 Lumens/Lamp) |
| LD191 | LED 23Wx2 4' 30W ST8/32W T8 Lamp Repl (2550 Lumens/Lamp) |
| LD192 | LED 23Wx3 4' 30W ST8/32W T8 Lamp Repl (2550 Lumens/Lamp) |
| LD193 | LED 23Wx4 4' 30W ST8/32W T8 Lamp Repl (2550 Lumens/Lamp) |
| LD200 | LED 23Wx1 4' 30W ST8/32W T8 REF Lamp Repl (2550 Lumens/Lamp) |
| LD201 | LED 23Wx2 4' 30W ST8/32W T8 REF Lamp Repl (2550 Lumens/Lamp) |
| LD202 | LED 23Wx3 4' 30W ST8/32W T8 REF Lamp Repl (2550 Lumens/Lamp) |
| LD203 | LED 23Wx4 4' 30W ST8/32W T8 REF Lamp Repl (2550 Lumens/Lamp) |

| Fixture Code | Fixture Name |
|--------------|---|
| LD210 | LED 25Wx1 4' 32W ST8 Lamp Repl (2730 Lumens/Lamp) |
| LD211 | LED 25Wx2 4' 32W ST8 Lamp Repl (2730 Lumens/Lamp) |
| LD212 | LED 25Wx3 4' 32W ST8 Lamp Repl (2730 Lumens/Lamp) |
| LD213 | LED 25Wx4 4' 32W ST8 Lamp Repl (2730 Lumens/Lamp) |
| LD220 | LED 25Wx1 4' 32W ST8 REF Lamp Repl (2730 Lumens/Lamp) |
| LD221 | LED 25Wx2 4' 32W ST8 REF Lamp Repl (2730 Lumens/Lamp) |
| LD222 | LED 25Wx3 4' 32W ST8 REF Lamp Repl (2730 Lumens/Lamp) |
| LD223 | LED 25Wx4 4' 32W ST8 REF Lamp Repl (2730 Lumens/Lamp) |
| LD230 | LED 10Wx2 2' 15W T8 Lamp Repl (1040 Lumens/Lamp) |
| LD231 | LED 10Wx3 2' 15W T8 Lamp Repl (1040 Lumens/Lamp) |
| LD232 | LED 10Wx4 2' 15W T8 Lamp Repl (1040 Lumens/Lamp) |
| LD240 | LED 10Wx2 2' 15W T8 REF Lamp Repl (1040 Lumens/Lamp) |
| LD241 | LED 10Wx3 2' 15W T8 REF Lamp Repl (1040 Lumens/Lamp) |
| LD242 | LED 10Wx4 2' 15W T8 REF Lamp Repl (1040 Lumens/Lamp) |
| LD250 | LED 12Wx2 2' 17W ST8 Lamp Repl (1150 Lumens/Lamp) |
| LD251 | LED 12Wx3 2' 17W ST8 Lamp Repl (1150 Lumens/Lamp) |
| LD252 | LED 12Wx4 2' 17W ST8 Lamp Repl (1150 Lumens/Lamp) |
| LD260 | LED 12Wx2 2' 17W ST8 REF Lamp Repl (1150 Lumens/Lamp) |
| LD261 | LED 12Wx3 2' 17W ST8 REF Lamp Repl (1150 Lumens/Lamp) |
| LD262 | LED 12Wx4 2' 17W ST8 REF Lamp Repl (1150 Lumens/Lamp) |
| LD280 | LED 34W 2x4 Fixture (3300 Lumens) |
| LD281 | LED 41W 2x4 Fixture (4000 Lumens) |
| LD282 | LED 51W 2x4 Fixture (5000 Lumens) |
| LD283 | LED 61W 2x4 Fixture (6000 Lumens) |

| Fixture Code | Fixture Name |
|---------------------|--|
| LD284 | LED 71W 2x4 Fixture (7000 Lumens) |
| LD300 | LED 44W 2x4 Retrofit Panel (4678 Lumens) |
| LD301 | LED 59W 2x4 Retrofit Panel (6227 Lumens) |
| LD320 | LED 20W 1x4 Fixture (2000 Lumens) |
| LD321 | LED 34W 1x4 Fixture (3300 Lumens) |
| LD322 | LED 41W 1x4 Fixture (4000 Lumens) |
| LD340 | LED 34W 1x4 Retrofit Panel (2980 Lumens) |
| LD341 | LED 41W 1x4 Retrofit Panel (3369 Lumens) |
| LD342 | LED 52W 1x4 Retrofit Panel (4083 Lumens) |
| LD360 | LED 20W 2x2 Fixture (2000 Lumens) |
| LD361 | LED 26W 2x2 Fixture (2500 Lumens) |
| LD362 | LED 31W 2x2 Fixture (3000 Lumens) |
| LD363 | LED 36W 2x2 Fixture (3500 Lumens) |
| LD364 | LED 41W 2x2 Fixture (4000 Lumens) |
| LD380 | LED 34W 2x2 Retrofit Panel (3430 Lumens) |
| LD381 | LED 41W 2x2 Retrofit Panel (3904 Lumens) |
| LD382 | LED 52W 2x2 Retrofit Panel (4679 Lumens) |
| LD430 | LED 30W Low Bay Fixture (3500 Lumens) |
| LD431 | LED 34W Low Bay Fixture (4000 Lumens) |
| LD432 | LED 43W Low Bay Fixture (5000 Lumens) |
| LD433 | LED 51W Low Bay Fixture (6000 Lumens) |
| LD460 | LED 91W High Bay Fixture (10000 Lumens) |
| LD461 | LED 136W High Bay Fixture (15000 Lumens) |
| LD462 | LED 182W High Bay Fixture (20000 Lumens) |

| Fixture Code | Fixture Name |
|---------------------|--|
| LD463 | LED 227W High Bay Fixture (25000 Lumens) |
| LD464 | LED 273W High Bay Fixture (30000 Lumens) |
| LD465 | LED 364W High Bay Fixture (40000 Lumens) |
| LD466 | LED 455W High Bay Fixture (50000 Lumens) |
| LD467 | LED 546W High Bay Fixture (60000 Lumens) |
| LD500 | LED 9W Wall Pack (1000 Lumens) |
| LD501 | LED 19W Wall Pack (2000 Lumens) |
| LD502 | LED 37W Wall Pack (4000 Lumens) |
| LD503 | LED 56W Wall Pack (6000 Lumens) |
| LD504 | LED 75W Wall Pack (8000 Lumens) |
| LD505 | LED 111W Wall Pack (10000 Lumens) |
| LD506 | LED 167W Wall Pack (15000 Lumens) |
| LD550 | LED 20W Pole Lamp (2000 Lumens) |
| LD551 | LED 30W Pole Lamp (3000 Lumens) |
| LD552 | LED 40W Pole Lamp (4000 Lumens) |
| LD553 | LED 50W Pole Lamp (5000 Lumens) |
| LD554 | LED 60W Pole Lamp (6000 Lumens) |
| LD555 | LED 80W Pole Lamp (8000 Lumens) |
| LD556 | LED 120W Pole Lamp (12000 Lumens) |
| LD557 | LED 160W Pole Lamp (16000 Lumens) |
| LD558 | LED 240W Pole Lamp (24000 Lumens) |
| LD559 | LED 360W Pole Lamp (36000 Lumens) |
| LS1 | LPS 18 PEND |
| LS2 | LPS 35 PEND |
| LS3 | LPS 55 PEND |
| LS4 | LPS 90 PEND |
| LS5 | LPS 135 PEND |

| Fixture Code | Fixture Name |
|---------------------|---------------------|
| LS6 | LPS 180 PEND |
| LS7 | LPS 18 POLE |
| LS8 | LPS 35 POLE |
| LS9 | LPS 55 POLE |
| LS10 | LPS 90 POLE |
| LS11 | LPS 135 POLE |
| LS12 | LPS 180 POLE |
| LS13 | LPS 18 WALL |
| LS14 | LPS 35 WALL |
| LS15 | LPS 55 WALL |
| LS16 | LPS 90 WALL |
| LS17 | LPS 135 WALL |
| LS18 | LPS 180 WALL |
| MH1 | MH 50 PEND |
| MH2 | MH 70 PEND |
| MH3 | MH 100 PEND |
| MH4 | MH 175 PEND |
| MH5 | MH 250 PEND |
| MH6 | MH 400 PEND |
| MH7 | MH 1000 PEND |
| MH8 | MH 1500 PEND |
| MH9 | MH 50 WALL |
| MH10 | MH 70 WALL |
| MH11 | MH 100 WALL |
| MH12 | MH 175 WALL |
| MH13 | MH 250 WALL |
| MH14 | MH 400 WALL |
| MH15 | MH 1000 WALL |
| MH16 | MH 1500 WALL |
| MH17 | MH 50 POLE |
| MH18 | MH 70 POLE |
| MH19 | MH 100 POLE |
| MH20 | MH 175 POLE |
| MH21 | MH 250 POLE |
| MH22 | MH 400 POLE |
| MH23 | MH 1000 POLE |
| MH24 | MH 1500 POLE |
| MH25 | MH 50 CAN |
| MH26 | MH 70 CAN |
| MH27 | MH 750 WALL |
| MH28 | MH 32 WALL |
| MH29 | MH 32 PEND |
| MH30 | MH 750 POLE |
| MH31 | MH 750 PEND |
| MH32 | MH 32 POLE |
| MH33 | MH 70 HE PEND |

| Fixture Code | Fixture Name |
|---------------------|---------------------|
| MH34 | MH 150 HE PEND |
| MH35 | MH 175 HE PEND |
| MH36 | MH 250 HE PEND |
| MH37 | MH 400 HE PEND |
| MH38 | MH 1000 HE PEND |
| MH39 | MH 70 HE WALL |
| MH40 | MH 150 HE WALL |
| MH41 | MH 175 HE WALL |
| MH42 | MH 250 HE WALL |
| MH43 | MH 400 HE WALL |
| MH44 | MH 1000 HE WALL |
| MH45 | MH 70 HE POLE |
| MH46 | MH 150 HE POLE |
| MH47 | MH 175 HE POLE |
| MH48 | MH 250 HE POLE |
| MH49 | MH 400 HE POLE |
| MH50 | MH 1000 HE POLE |
| MH51 | MH 32 POLE ELC |
| MH52 | MH 32 PEND ELC |
| MH53 | MH 32 WALL ELC |
| MH54 | MH 50 POLE ELC |
| MH55 | MH 50 PEND ELC |
| MH56 | MH 50 WALL ELC |
| MH57 | MH 50 CAN ELC |
| MH58 | MH 70 POLE ELC |
| MH59 | MH 70 PEND ELC |
| MH60 | MH 70 WALL ELC |
| MH61 | MH 70 CAN ELC |
| MH62 | MH 100 POLE ELC |
| MH63 | MH 100 PEND ELC |
| MH64 | MH 100 WALL ELC |
| MH65 | MH 150 HE POLE ELC |
| MH66 | MH 150 HE PEND ELC |
| MH67 | MH 150 HE WALL ELC |
| MV1 | MERC 50 PEND |
| MV2 | MERC 75 PEND |
| MV3 | MERC 100 PEND |
| MV4 | MERC 175 PEND |
| MV5 | MERC 250 PEND |
| MV6 | MERC 400 PEND |
| MV7 | MERC 700 PEND |
| MV8 | MERC 1000 PEND |
| MV9 | MERC 50 POLE |
| MV10 | MERC 75 POLE |
| MV11 | MERC 100 POLE |
| MV12 | MERC 175 POLE |

| Fixture Code | Fixture Name |
|---------------------|---------------------|
| MV13 | MERC 250 POLE |
| MV14 | MERC 400 POLE |
| MV15 | MERC 700 POLE |
| MV16 | MERC 1000 POLE |
| MV17 | MERC 50 WALL |
| MV18 | MERC 75 WALL |

| Fixture Code | Fixture Name |
|---------------------|---------------------|
| MV19 | MERC 100 WALL |
| MV20 | MERC 175 WALL |
| MV21 | MERC 250 WALL |
| MV22 | MERC 400 WALL |
| MV23 | MERC 700 WALL |
| MV24 | MERC 1000 WALL |

Appendix I – FEDS Allowable HVAC Combinations

Unlinked heating types

Any combination of

- electric resistance baseboard
- radiator using central steam or hot water
- radiator using single-building boiler
- infrared heating
- radiant heat using district steam/hot water or single-building boiler
- window/through-wall air conditioning units
- fan coil units using single-building electric or gas engine-driven chiller
- fan coil units using single-building absorption chiller
- fan coil units using central chilled water
- rooftop packaged unit
- air handling unit using single-building electric or gas engine-driven chiller
- air handling unit using single-building absorption chiller
- air handling unit using central chilled water
- no heating
- no cooling

Linked heating types with any cooling types

Any combination of

- fan coil units using central steam, hot water or electricity
- fan coil units using single-building boiler
- forced air furnace
- air source heat pump (heating)
- ground-coupled heat pump (heating)
- air handling unit using central steam or hot water
- air handling unit using single-building boiler
- window/through-wall air conditioning units
- fan coil units using single-building electric or gas engine-driven chiller
- fan coil units using single-building absorption chiller
- fan coil units using central chilled water
- air source heat pump (cooling)
- ground-coupled heat pump (cooling)
- rooftop packaged unit
- air-handling unit using single-building electric or gas engine-driven chiller
- air-handling unit using single-building absorption chiller
- air-handling unit using central chilled water

- no heating
- no cooling

Evaporative Coolers

Evaporative coolers are compatible with any linked or unlinked heating types. However, evaporative coolers may not be combined with any other cooling equipment types, though they may be combined with no cooling.

Appendix J – Tips and Troubleshooting

J.1 Data Input Tips

Unreasonable but Valid Input: The model will accept unreasonable but valid inputs. For example, you could enter “1000” for the number of floors. This is clearly an unreasonable input. Unreasonable inputs will often generate very large or very small values for other variables that can result in overflow errors. Range checking for unreasonable values is performed to help identify such values. ***Pay attention to warning messages and verify inputs.***

Residential and Dual-Use Combinations: The model will allow you to use residential building or use-area types in dual-use buildings, that is, a residential building type that is dual use or a nonresidential building type with a residential use-area type. Because there are significant differences in some of the assumptions behind the design and operation of these building types, unreasonable inferences and/or output may occur. ***Exercise care when using residential building or use-area types in dual-use combinations. After updating inferences, check all inferred values for reasonableness.***

Truncation of Occupancy Hours and Time-of-Use Hours: The user interface will allow you to enter occupancy hours and time-of-use hours in the electric rate schedule in other than whole hours (e.g., 1230). The model performs hourly calculations and will truncate the input hours (e.g., 1230 becomes 1200). ***Be aware of this limitation and ensure that the total number of hours is correct.***

Lighting Percentage of Use-Area Illumination: FEDS applies a lighting density that assumes the buildings have the “correct” lighting levels according to the percentage of floor area input. However, that assumption can be overridden by entering the number of fixtures, or fixtures per square foot, for any lighting technology. Illumination from the fixtures is not required to match the “correct” lighting level (the space may be over-lit or under-lit). Similarly, you can increase or decrease the percentage of illumination for any technology to indicate that a space is under-lit or over-lit. For example, if a space is over-lit by 30%, the percent illumination input can be increased by 30%.

SHW—Buildings Without SHW: This input is intended to indicate whole buildings within a building set that do not have service hot water. Whether the input is provided as “percentage of buildings,” “number of buildings,” or “square footage of buildings,” it indicates the portion of the buildings within the building set that do not have SHW. If hot water is available only in a breakroom and restrooms that represent 5% of a building’s floor area, it is important to specify that the building is fully served by hot water.

SHW in Dual-Use Buildings: Loop systems are entered only in Use-Area 1. Any loop SHW system in a dual-use building is assumed to serve both use areas. If there is no SHW consumption in a use area, set the consumption and storage capacity for that use area to zero.

The percentages for “portion of the building set served” must add up to 100% for both use areas. The portion of buildings with no SHW value is added to both use areas, as is any loop SHW system. The rest of the SHW is provided by distributed systems within each use area.

Multiple Technologies (Heat, Cool, SHW) in a Single Building: The values for equipment and output capacities should typically be entered on a per-building basis as if it were the only technology in the building.

For heat or cool: if there are multiple technologies serving an individual building, or each building in the building set, select the ‘Percentage of each building served’ option from the heating or cooling end use inputs. Specifying this option for the ‘Portion of building set served’ will enable FEDS to adjust technology capacities so that they are represented properly for serving a portion of each building in the set.

For SHW: assume, for example, that there are two SHW heaters in a building, one electric and one gas, and they are both 80 gallons. Enter 160-gallons storage capacity for each technology and enter that they each provide 50% of the service.

J.2 Inference Errors

Inferences are updated at two points: when you explicitly request an inference update and at the start of a FEDS simulation run. Updating inferences catches any input errors and makes sure that all required inputs are provided. ***Update inferences often; it will help you to assess the reasonableness of your inputs and catch and errors early.***

Errors that may be caught while updating inferences are described below. One of the items enclosed in brackets [] will be present in the actual error message. These error messages typically identify the source of the error and the solution.

"Missing minset at level [default level, NOTE: not used], missing [description] [tech #]." ***A required input has not been entered. Make sure that all inputs with a blue arrow contain data.***

"Core zone must be at least 15 x 15. Adjust depth or reduce zone number to 4." ***For the building size and aspect ratio, the length of the short side of the building is less than twice the zone depth plus 15 feet (the minimum core zone width). Go to the Geometry Inputs screen and reset the perimeter zone depth to a value less than one-half the length of the short side of the building minus 15 feet or select 4 zones geometry.***

"Error: fractions for [heat, cool, shw] area [1, 2], add up to [frac >100%]." ***Portions served/unseen by each end-use must add up to 100%. Recheck all equipment records and verify.***

"Error: tech ducting scenario for [heat, cool] [tech #] does not match preceding techs." See [Appendix I](#).

"Error: tech ventilation linking scenario for [heat, cool] [tech #] does not match preceding techs." See [Appendix I](#).

"HVAC equipment requires ventilation, ventilation mode locked as NONE." ***Unlock or select different ventilation control mode.***

"Internal error routine: shw-UserTemp Adjustment Factor, supply temperature < ground water temperature." ***Service hot water system supply temperatures must be greater than the ground water temperature.***

Heat Pumps

You must make sure that the following heat pump attributes are the same in heating and cooling (for each heat pump system):

- Fuel type
- Equipment type
- Vintage
- Loop type for ground-coupled
- Number of pieces of equipment.

"Fuel for heat pump (heat #, cool #) set to different values." ***Make sure that both heating and cooling have the same fuel for the heat pump.***

"[Heat, Cool] Tech # is an unpaired heat pump technology (check attributes which would keep a pair from being inferred)." ***Make sure that both heating and cooling technologies are the same, the vintage is the same, and if it is a ground-coupled heat pump that the loop type is the same.***

"Number of equipment for heat # [number of heating equipment] and cool # [number of cooling equipment] do not match." ***Make sure that both heating and cooling have the same number of pieces of equipment for the heat pump.***

"Fractions for heat # [heat pump heating fraction for this technology] and cool # [heat pump cooling fraction for this technology] do not match." ***Make sure that both heating and cooling have the same value for the portion of the building set served by the heat pump.***

"Equipment vintage for heat # and cool # locked to different values." ***Make sure that both heating and cooling have the same equipment vintage for the heat pump.***

"[Air, water] source heat pump fraction mismatch in Heat and Cool end uses." ***The portion served by heat pumps must be equivalent for heating and cooling for each type (air and water source).***

Central Plants and Thermal Loops

"Central plant inferences cannot be run until the sum of equipment percentages = 100%." ***Make sure that equipment percentages for each central plant add to 100%.***

"The following records have 'central' fuels that are not also used in heat/cool/shw: Bld Set #: (set number) end use : (central fuel) Inference cannot continue until this is corrected" ***Change the fuel source or make sure that heat/cool/shw is from that fuel source.***

"The following central plants do not have loops associated with them: #. Central plant inferences cannot be run until loops are assigned to these central plants." ***Add loops or remove the central plant.***

"The following thermal loops are not linked to any HVAC, SHW, or other Central Plants: #. Inferences for these loops cannot be run until they are connected to a building or Central Plant load." ***Add a load or remove the loop.***

"Note: Inferences will not be run for unconnected loops having a supply pipe length equal to 0." ***Either add a load, increase the loop length, or delete the loop.***

"The following purchased fuel prices must be specified in the 'Installation Non-electric price' input screen: (central fuel)." ***Add fuel prices for purchased fuels in the Non-electric price input screen.***

"The following specified purchased fuel prices require a central plant and thermal loop reference this fuel: (central fuel)." ***Add a central plant, thermal loop, and load for this fuel or set the energy price to 0.***

J.3 Unexpected Results

The following describe some of the more common situations when the results from a FEDS run show something unexpected and suggest an input error. Some of the more usual causes of such problems are described along with their solutions.

No Retrofits Are Selected: You run a case and no retrofits (or only a couple of lighting retrofits) are selected. While this is a possible outcome, it could also mean that no energy price information was provided. FEDS interprets this to mean that all fuels that are available to the building(s) are free, so the only cost-effective retrofit projects would be those that save enough in maintenance or replacement costs to justify their purchase and installation. ***Check both the marginal electric and non-electric energy price inputs to ensure that the appropriate values have been provided.***

All Retrofits Are Electric: Your output shows that all retrofits are electric but you expected to see different fuels for a particular building set. You created a new building set and did not visit the *Fuel Type Inputs* screen. The model assumed that the only fuel available for retrofits was electricity. ***Go to the Non-Electric Energy Price Inputs screen and make sure that prices are entered for all available fuels and go to the Fuel Type Inputs screen and select the fuels that are available to that building set.***

Low Energy Use in All End Uses: Your output shows low energy use in all end uses for a particular building set. You created a new building set and did not visit the *Occupancy: General Inputs* screen. The model assumed that the building was unoccupied. ***Go to Occupancy Inputs and enter the occupancy hours for that building set.***

Lighting Energy Use: Your output shows 0 consumption for lights and/or that exit signs are not present for a particular building set (or use area). You created a new building set and did not visit the Lighting Inputs (or forgot to add lighting records for a second use area). The model assumed there were no lights in the building set or use area. ***Go to the Lighting Inputs and create the necessary records for the lighting types that you have.***

Miscellaneous Equipment Energy Use: Your output shows 0 consumption for miscellaneous equipment for a particular building set (or use area). You created a new building set (or use area) and did not visit the *Miscellaneous Equipment Inputs* screen. The model assumed there was no miscellaneous equipment. ***Go to the Miscellaneous Equipment Inputs screen and create the necessary records for the types of miscellaneous equipment that you have.***

Appendix K – FEDS Life-Cycle Cost Algorithms

The basic life-cycle cost algorithms used in FEDS and the economic figures-of-merit produced are explained below.

K.1 Annualized Costs

Annualized costs are computed by taking the present value of all the cash flows over the analysis period associated with a cost element and then annualizing the present value.

K.2 Cost Elements

There are four cost elements considered in the life-cycle cost analysis: installed cost (always zero for the existing technology), annual operating and maintenance (O&M) costs, non-annual O&M costs, and energy costs. Interim capital replacement costs, when appropriate, are included explicitly under non-annual O&M or implicitly in the annualized installed cost (when the retrofit life is less than the remaining life of the existing equipment). Salvage value/decommissioning costs are assumed to net to zero.

K.3 Present Value

The present value of each cost element is calculated as follows:

$$PV_j = \sum_{i=1}^n \frac{CF_{j,i} \times (1 + esc_{j,i})}{(1 + k)^i}$$

where:

| | | |
|-------------|---|---|
| PV_j | = | Present value of cost element j |
| n | = | Analysis period |
| $CF_{j,i}$ | = | Cash flow for cost element j in year i (by convention, cash inflows have a positive sign and cash outflows a negative sign) |
| $esc_{j,i}$ | = | Escalation rate for $CF_{j,i}$ if CF is first year cost (e.g., energy cost) |
| k | = | Discount rate. |

K.4 Annualizing

The annualized value of each cost element is calculated from the present value.

$$AV_j = PV_j \times \frac{k \times (1 + k)^n}{(1 + k)^n - 1}$$

where:

| | | |
|--------|---|-------------------------------------|
| AV_j | = | Annualized value of cost element j. |
|--------|---|-------------------------------------|

K.5 Total Annualized Life-Cycle Cost

The total annualized life-cycle cost for the baseline or retrofit is the sum of the present values of the cost elements.

$$TAV_j = \sum_{all\ j} AV_j$$

where:

TAV = Total annualized value of all cost elements.

K.6 Economic Figures of Merit

Several different economic figures-of-merit are calculated for each retrofit: total life-cycle cost savings or net present value (NPV), simple payback, savings-to-investment ratio (SIR), and adjusted internal rate of return (AIRR).

K.6.1 Net Present Value

The NPV represents the increase in wealth (deficit reduction) from doing the project. NPV is the difference between the LCC of the existing technology and the LCC of the retrofit technology. Only projects with positive net present values are selected by FEDS. This is the sole selection criterion by which FEDS selects retrofits, but it is subject to payback and SIR constraints as described below.

$$NPV = \sum_{all\ j} \sum_{i=1}^{n,existing} \frac{AV_{j,retrofit} - AV_{j,existing}}{(1+k)^i}$$

where:

| | | |
|-------------------|---|---|
| NPV | = | Net present value |
| n,existing | = | Analysis period for existing technology |
| $AV_{j,retrofit}$ | = | Annualized value of cost element j for the retrofit existing technology |
| $AV_{j,existing}$ | = | Annualized value of cost element j for the existing technology. |

K.6.2 Simple Payback

$$Simple\ Payback = \frac{Installed\ Cost}{\Delta CF_{energy} + \Delta CF_{demand} + \Delta AV_{O\&M} + \Delta AV_{non-ICR\ non-annual\ O\&M}}$$

Simple payback, the ratio of the total installed cost to the first year savings, is a commonly used economic metric for retrofit selection even though it often leads to the incorrect decision. Because payback ignores lifetime, real escalation, and discounting, it does not lead to the minimum life-cycle cost or maximize wealth. Optimization in FEDS can be constrained using simple payback. The user enters that maximum allowable simple payback and the model does not consider any retrofits that have paybacks

greater than the entered value. This constrains the model to select the retrofit with the maximum NPV that has a payback less than the entered value; it does not select the minimum payback retrofit.

where:

| | | |
|--|---|--|
| $\Delta CF_{\text{energy}}$ | = | The difference between building's first year energy cost without the retrofit and with the retrofit (existing - retrofit) |
| $\Delta CF_{\text{demand}}$ | = | The difference between building's first year demand cost without the retrofit and with the retrofit (existing - retrofit) |
| $\Delta AV_{\text{O\&M}}$ | = | The difference between building's annualized O&M cost without the retrofit and with the retrofit (existing - retrofit)--this is equivalent to the first year annual O&M savings if there is no real escalation of annual O&M costs |
| $\Delta AV_{\text{non-ICR non-annual O\&M}}$ | = | The difference between building's annualized non-annual O&M cost that are not interim capital replacements without the retrofit and with the retrofit (existing - retrofit)--e.g., lighting lamp and ballast replacements. |

K.6.3 Savings-to-Investment Ratio

Savings-to-investment ratio (SIR) is a useful method for ranking positive net present value projects that are not mutually exclusive.

When available appropriations will not permit all cost-effective energy conservation measures to be undertaken, they shall be ranked in descending order of their savings-to-investment ratios, or the adjusted internal rate of return, to establish priority. If available appropriations cannot be fully exhausted for a fiscal year by taking all budgeted energy conservation measures according to their rank, the set of energy conservation measures that will maximize net savings for available appropriations should be selected.

Optimization in FEDS can be constrained using SIR; the user enters that minimum allowable SIR.

$$SIR = \frac{NPV - PV_{\text{Installed Cost}}}{- PV_{\text{Installed Cost}}}$$

where:

| | | |
|------------------------------|---|---|
| SIR | = | Savings to investment ratio |
| $PV_{\text{Installed Cost}}$ | = | PV of installed cost (a cash outflow and thus a negative number by convention). |

K.6.4 *Adjusted Internal Rate of Return*

The adjusted internal rate of return (AIRR) is an approximation of the actual internal rate of return. An approximation is used because the internal rate of return is an iterative calculation that can have multiple results. The AIRR is a reasonable approximation of the actual desired internal rate of return.

$$AIRR = (1 + k) \times SIR^{\frac{1}{n, \text{retrofit}}} - 1$$

where:

AIRR = Adjusted internal rate of return.

Appendix L – Miscellaneous Resources

L.1 FEDS Support

Contact FEDS.Support@pnnl.gov with comments or questions on FEDS applications, issues, training, and more. We would love to hear what you are using FEDS for and welcome your suggestions.

Training workshops sponsored by the Federal Energy Management Program or other agencies are occasionally available. Additionally, customized training is available to meet your needs. Please contact [FEDS Support](#) with inquiries or requests.

L.2 FEDS Website

The FEDS website is located at FEDS.pnnl.gov and provides access to additional information and resources:

L.2.1 *How to Get FEDS*

Visit FEDS.pnnl.gov/Licensing for information on how to get FEDS. U.S. federal and state agencies, as well as federal contractors qualify for a free copy; other users can review licensing options.

L.2.2 *Software Updates*

Updates to the FEDS software are posted when available. Check in to see what's new.

L.2.3 *Frequently Asked Questions*

Visit FEDS.pnnl.gov/FAQs for a listing of FAQs along with detailed answers on all aspects of the FEDS software. The page provides useful information and tips for effectively using FEDS and is updated as common questions arise.

L.3 Data Collection Forms

Examples of FEDS data collection forms have been installed to your <FEDS\Documents\Data Collection Forms> folder (default location is C:\FEDS 8.0\Documents\). These are forms developed by FEDS users to collect building data used by FEDS – whether in a walk-through building audit or remote data collection process. Two different versions are available: a single page version listing the required FEDS building parameters and a multi-page detailed version, with a more comprehensive data listing. These may be printed and used during data collection activities.

The files are in pdf format and may be viewed by opening them with the Adobe Acrobat Reader. If you need to download the Acrobat Reader, visit <http://get.adobe.com/reader/>.

Appendix M – Third-Party Open Source Component Acknowledgements

This version of FEDS relies on the following Open Source software components:

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