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Introduction to FEDS

The Facility Energy Decision System (FEDS) model is under development at the Pacific Northwest National Laboratory (*PNNL*) for the Department of Energy's (DOE) Federal Energy Management Program (DOE-FEMP), the U.S. Army Construction Engineering Research Laboratory (*USA-CERL*), the U.S. Army Forces Command (*FORSCOM*), the DOE's Rebuild America Program, the Defense Commissary Agency (DeCA), and the U.S. Naval Facilities Engineering Service Center (*NFESC*). FEDS is an energy analysis software system designed to provide a comprehensive approach to fuel-neutral, technology-independent, integrated (energy) resource planning and acquisition. The FEDS system allows data input to range from minimal to extremely detailed. With minimal input, FEDS can be used as a top-down, first-pass energy systems analysis and energy resource acquisition decision software model for buildings and facilities. Providing FEDS with more detailed input allows the user to generate optimized building retrofits for an entire *installation* and provides detailed output for each retrofit in each *building set*.

FEDS is a user-friendly, Windows-based, menu driven software program for assessing the energy efficiency resource potential of facilities ranging from single buildings to large Federal installations. In the first pass, a user typically enters only high-level installation information (number, age, size, and types of buildings and energy systems). The internal database of typical energy-system configurations and performance data then infers likely building parameters, and the sophisticated energy simulation and optimization models estimate the net present value of potential energy retrofits.

The first-pass analysis will typically be followed by a more detailed FEDS analysis, where the inferred information is augmented with user-supplied details on energy system information. The result is detailed project-by-project technology selection and economic information. This release only covers building systems. Future releases will cover water *consumption* and other energy systems including central heating and cooling plants and thermal distribution loops.

This development effort is being managed by Ted Collins, *DOE FEMP*. Please refer any programmatic recommendations, comments, and/or questions to Mr. Collins at 202-586-1677.

Please report any software bugs and refer any recommendations, comments, and/or questions of a technical nature to Jim Dirks at 509-372-4272.

General Description of FEDS

FEDS provides a comprehensive fuel-neutral, technology-independent, integrated (energy) resource planning approach from the top down. The basic intent of the model is to provide information needed to determine the minimum life-cycle cost (*LCC*) configuration of the *installation*'s 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 generation 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 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 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.

New in Release 5.0

FEDS 5.0 marks a substantial step forward in the continued evolution of the FEDS software. Moving the code to a full 32-bit platform has enabled the software to provide a more complete and intuitive Windows-based interface, and has increased execution speed up to ten-fold (however, this and subsequent releases will no longer run on Windows 3.x operating systems). Additionally, FEDS 5.0 contains fully updated cost and performance data, new baseline and retrofit technologies, and many functionality enhancements aimed at making FEDS easier to use. A more complete listing of what’s new in FEDS 5.0 follows:

Full 32-bit Development and Operation Platform

- New 32-bit *installation* routine, including full file backup and uninstall capabilities
- Long filename capability removes 8-character limit, allowing for more descriptive case names
- Faster execution times (see below)

User Interface Enhancements

- New look and feel – easier to use for new and expert users alike
- Standard Windows-based screen navigation and file handling
- Menu bar and icon-driven command toolbar
- Minimal sub-screens for faster navigation
- New user-friendly lighting technology selection filter
- New, more intuitive data input locking mechanism
- New integrated User's Guide and help system

Data Updates

- All new retrofit technology cost and performance data
- Completely updated regional labor rates and material cost factors
- New lighting fixtures: added 64 new lighting technologies including 9 new CFLs, 14 T5 fixtures, 27 electronically ballasted HIDs, and 3 new exit sign options
- More window options: 216 different user-selectable window configurations with new corresponding retrofits
- Ability to specify recirculating hot water system loop length
- Updated building inference data for windows, heating, cooling, ventilation, service hot water, and more

Optimization

- Much faster execution times: 5 times faster on a Pentium® III and 10 times faster on a Pentium® IV

- New optimization status indicator, showing progress and estimated time to completion

Report Generation

- Spreadsheet output report changed from semi-colon delimited (*.prn) format to easier-opening comma separated variable (*.csv) format
- Ability to print output reports directly from FEDS

Getting Started

This section describes the minimum computer requirements, the *installation* of the software, opening cases, and running the model.

Minimum Computer Requirements

The FEDS software requires the following minimum computer platform:

- Windows 95, 98, NT, 2000, and XP are all compatible with FEDS.
- A Windows-based personal computer – the FEDS program is computationally intensive. The time required to run the program depends upon the computer platform used. On a typical computer system of average speed, running the program (after data input) will take anywhere from a few minutes to several hours, depending upon the size of the input file (number of building sets) and its complexity (e.g., number of *HVAC* types and energy sources).
- CD-ROM drive.
- Mouse – although the program can be operated fully from the keyboard.
- Available hard disk space of at least 40 MB – disk space is required for loading FEDS program files, and for storing FEDS input and output files. Additionally, during execution of the model, large temporary files are created; these are about 500 KB per *building set*.
- Power management features that affect the processor should be disabled prior to running the model. Certain power management utilities have been found to halt the FEDS optimization process when activated, greatly and unnecessarily prolonging run time. It is best to turn off these features (through the BIOS setup screens) and turn off the monitor when making extended runs.

FEDS Installation

1. Place CD into drive

2. *Installation* program will start automatically if Autorun feature is enabled. Otherwise, click Start, select Run…, type D:\Feds50Setup (or substitute your CD drive letter for "D".) Click OK.

3. Follow the prompts to complete installation.

Create New Case

To create a new case, select **Create New** under *Case Options*. The *New Case Selection* screen will appear and prompt you for a case name and path, as illustrated in Figure 1.3.

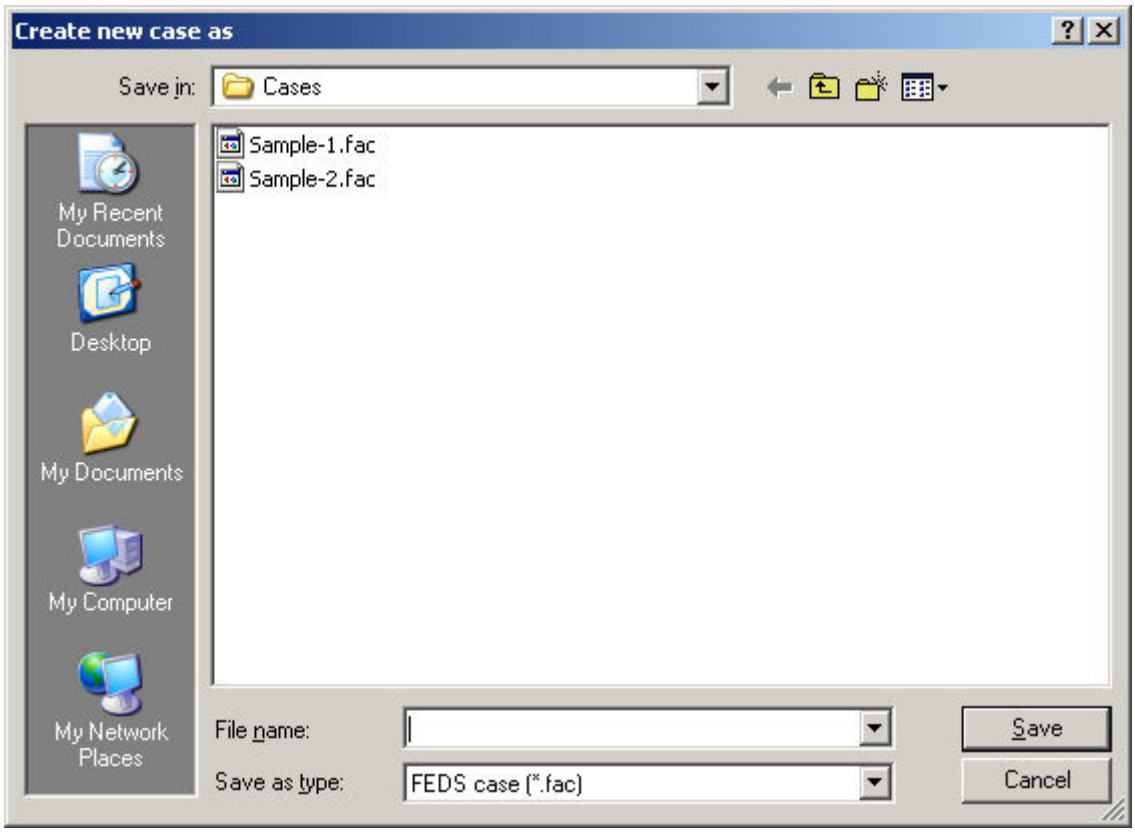


Figure 1.3 New Case Selection Screen

For each case, FEDS creates 10 input files:

{casename}.fac

{casename}.bld

{casename}.ecn

{casename}.eng

{casename}.reg

{casename}.elp

{casename}.enp

{casename}.flk

{casename}.blk

{casename}.rrs

There will be one additional file ({casename}.rxx) for each of the xx buildings that have any inputs of the *Refrigeration* end-use defined (only applicable for the Special-Commissary building types).

These files are needed to create, view, edit, and run a case. Nine additional files are created during optimization and are needed for generating output reports. Adding the four report options, a maximum of 25 files is possible for each case.

Open Existing Case

To open a previously created case, select **Open case** from the *File* menu. The *Existing Case Selection* screen will appear and prompt you for the location and name of the case (see Figure 1.4). 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.

Two cases are included with the FEDS software named “sample-1” and “sample-2.” 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:\Program Files\FEDS 5.0\Cases). For more information about the sample cases, see Description of Sample Cases.

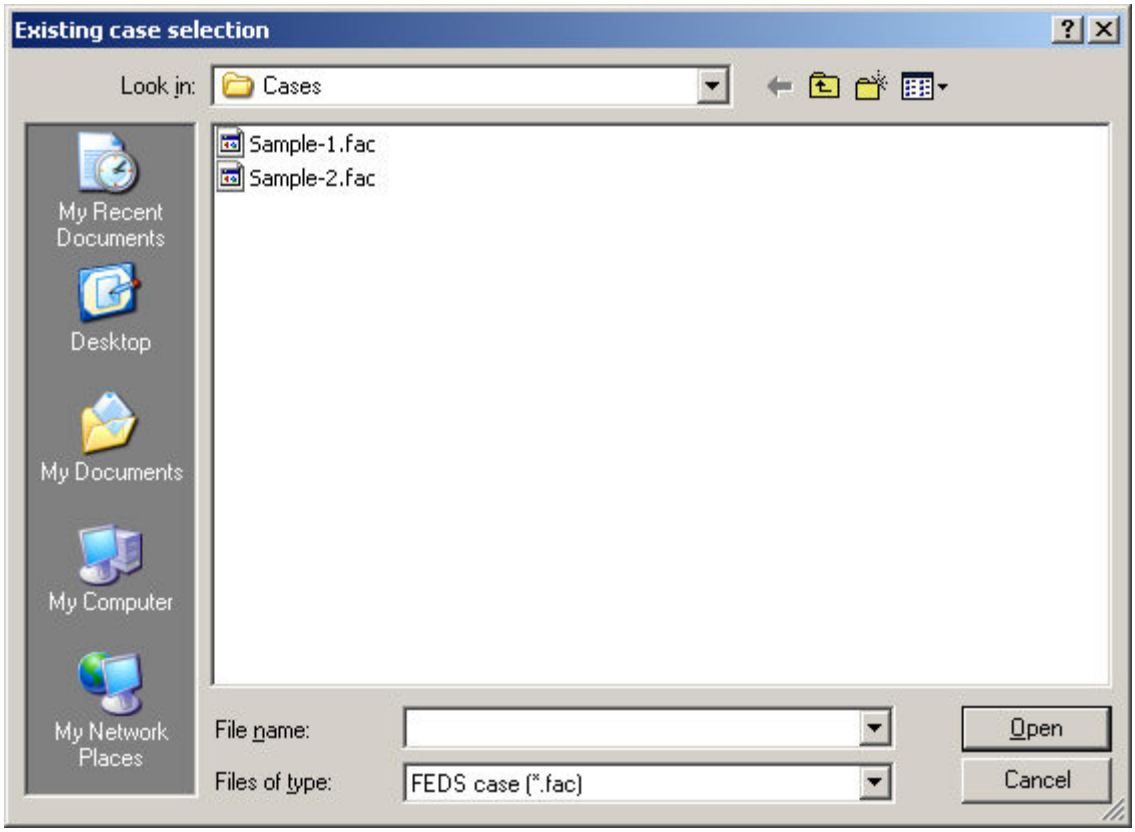


Figure 1.4 Existing Case Selection Screen

Converting Older FEDS Case Files

In order to run FEDS 5.0 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 existing FEDS input files for use with the latest version.

NOTE: Expect to see changes in both inferred and output values due to improved performance and cost data.

Convert case files (“*.fac”) created with FEDS 4.1 or a previous version to FEDS 5.0 format as follows:

Follow procedure for Open Existing Case

Select an existing file (“*.fac”) from any existing directory

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

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, if you would like to place the case in a different location (e.g., your FEDS 5.0\Cases directory), select the desired directory from the file structure list. When translating a case 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: The path and file names for the existing case must comply with the standard short file name (8 character limit) format. If the folders in the path or the case file name exceed 8 characters in length or contain any spaces, the translate operation may fail. If this happens you will need to move the files to a compliant folder and/or rename them before they can be translated.

Running FEDS

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. Enter or modify input data (see Screens and Functions)
2. Update *inferences* (see Program Options)
3. Examine new inferences, make appropriate changes, update inferences again, and repeat process until satisfied with data set
4. Exclude all building sets from optimization (see Exclude Building Sets from Optimization)
5. Run FEDS (see Program Options)
6. Generate and examine the *.txs output, comparing *consumption* estimates to actual metered data to reconcile data and uncover any input errors or omissions
7. Fix errors, remove *building set* exclusions and run FEDS
8. Generate output reports (see FEDS Output)

For more detailed information, see FEDS Process.

Description of Sample Cases

When you install FEDS onto your hard disk, the software will automatically create two sample input files for your use, "sample-1.fac" and "sample-2.fac". These files can be used for several purposes, including the following:

They may be recalled using the **Open case** option from the *File* menu to review on a screen-by-screen basis how data files are constructed.

They may be run by FEDS to check whether your computer platform is adequate for running the FEDS software. This can be especially useful if files that you have developed do not run, and you get error messages that lead you to believe that your platform may be inadequate.

They may be recalled using the **Open case** option from the *File* menu and edited to create your own case.

Sample-1.fac Case File

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 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.

Sample-2.fac Case File

The example in this case file is of two 50,000 ft^2 office buildings, six 50,000 ft^2 warehouses, ten 2,000 ft^2 single family (detached) residences, and three multifamily (five or more unit) buildings with an average floor area of 26,667 ft^2. 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 all-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 service water heaters. All of the warehouses 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 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 multifamily buildings were constructed in 1984. One of the buildings (24,000 ft^2) is all electric, with electric resistance heating and electric water heaters. The other two buildings (28,000 ft^2 each) are heated with natural gas and have gas water heaters. All three buildings cool with window air conditioners. Ten percent of the lighting is fluorescent and 90% is incandescent. The buildings are occupied from 5 pm to 7 am on the weekdays and continuously occupied during the weekends.

Screens and Functions

This section provides a brief overview of the FEDS screens and user options. Information is available within FEDS 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.

Screen Navigation and Operation

FEDS 5.0 is a menu-driven Windows application whose operation will be familiar to Windows users. 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, e.g., selecting individual 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 exclusive, that is, selecting one item will deselect a previously selected item.
- 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 will select the item.

- List objects: In the *FEDS Installation Inputs* and the *Building Set Inputs: General Information* screens there are list objects. These allow you to access different areas of the program to input site-specific information. A double left mouse click (or SPACEBAR) will bring up the selected submenu. NOTE: This is the only place where a double mouse click should be used.

Special Buttons

These three buttons are located on all submenus. <**Save**> will save the information you have entered and leave the cursor in that screen. <**Cancel**> will erase any information that has not been previously saved and take you to the previous screen. <**Save-Done**> saves the information you have entered and takes you to the previous screen.

For each *building set* and technology in a building set, there is a separate group of screens (called a *record*). <**Add**> creates a new blank record. <**Copy**> creates a copy of an existing record. <**Delete**> removes an existing record and all associated data.

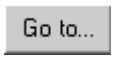
These buttons allow you to quickly move between building set and technology records:

moves to the first record;

moves back one record;

moves forward one record;

moves to the last record in the set.



pops up a pick list of all records; a double left mouse click on the desired record or single left mouse click on the desired record followed by clicking on <**Continue**> moves you to that record. Selecting any of these options will automatically save the current screen data before moving on to the next.

This button selects the *maximum detail* display mode for the *installation* level and individual building set record screens. See Display Modes.

Help

FEDS Help is available from the Help menu. Helpful information about each input is also available via the <**F1**> key. 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**>. 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.

Special Indicators and Locking

Inputs that have a blue arrow pointing at them belong to the *minimum set* and have not yet been satisfied. For a new *building set* or technology *record*, all minimum set items must be provided in order to successfully determine the *inferences* and run the model. All minimum set items are not inferred by FEDS and, thus, do not have the locking feature associated with them. Once a valid input is provided for a minimum set item and saved successfully, the blue arrow will disappear, indicating that the requirement has been met. For further information about minimum set values, see Minimum Set Screening.

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**>. Such 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.

Recommended Inputs: Inputs without the blue minimum set 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 miscellaneous 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 provide this information.

Display Modes

There are two modes available for displaying data:

***Minimum set* display**: When a new case is created, or a new *building set* is added, only those input cells that are required for FEDS to run (i.e., the minimum set) will be displayed. This significantly reduces the number of screens and inputs that appear, reducing the time and effort required to gather and input data and run the model. Using the minimum set input, FEDS requires the minimum possible information for making a reasonable first-cut estimate at the energy resource efficiency potential. For more details see Minimum Set Screening.

***Maximum detail* display**: Once all minimum set data have been entered at the *installation* level or for a particular building set and *inferences* have been updated successfully, the <**Maximum Detail**> button will be enabled. Clicking on this button will trigger the input data to be displayed in maximum detail. In addition to all minimum set inputs, nearly all parameter values which are inferable by FEDS are displayed. This gives you the ability to examine FEDS inferred values, lock those that are correct and change any values to more closely resemble the actual facility, thereby increasing the accuracy of the output (see Transitioning to Maximum Detail for more details).

NOTE: Once any maximum detail value is locked, the building set containing the lock cannot return to minimum set display. If no values are locked, upon exiting the building set and returning, the display will be once again set to minimum set (with the <**Maximum Detail**> button enabled). Again, the maximum detail display is selected separately for each building set and the installation level. Therefore, it is possible to have a portion of your building sets at maximum detail (i.e., those in which you have made non-minimum set inputs) and some at minimum set. To keep track of the display mode for the building sets, click on the <**Go to...**> button. Building sets displayed at maximum detail will be indicated by [MAX] and those at minimum set by [min].

Installation Level Inputs

After entering FEDS 5.0, you see the FEDS *Installation* Inputs screen. This screen displays the case filename and prompts you for general information about the installation, such as its name and location. From this screen, you may select any of the installation level inputs or move to the *building set* inputs. You may also initiate case and program functions using the menu bar or icons.

Additional Installation Inputs

The following selections are the list objects on the FEDS *Installation* Input screen. To choose, double-click on the item name.

Energy *consumption* inputs: 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.

Non-electric energy price inputs: Fuel price information for all non-electric fuels available at the installation, including oil (distillate and residual), natural gas, coal, purchased steam, site-generated steam, purchased hot water, site-generated 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 at *maximum detail*) 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.

Marginal electricity price inputs: These data include detailed electric rate structure information for flat and time-of-day rates and demand ratchets.

Central plant inputs: Asks for the predominant fuel type used for each type of central plant, if any. The selection of predominant fuel types defaults the availability of all self-generated fuel types site-wide in the same way that the price inputs do for all other fuels. If "not applicable" is selected, then that self-generated fuel is defaulted as not available on the site.

Financial parameter and screening inputs: 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.

Soil and water characteristics: This screen (which appears only in maximum detail display) stores the hydrogeologic information 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.

Case Options

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

New case: Allows you to create a new case. See Create New Case.

Open case: 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 and Converting Older FEDS Case Files.

Save case: 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.

Program Options

The following program options may be accessed from the menu bar or command icons.

Update installation inferences: Updates the installation level inferable (non-minset) values. Infers all information on soil and water characteristics and alter cost data screens.

Update all inferences: Updates FEDS inferences for the installation and all *building set* data. Updating inferences also catches any input errors and makes sure that the minimum set of input is provided.

Advanced options: Provides access to the *Advanced Options* screens, where various program options may be set, including excluding building sets and restricting retrofits from optimization, altering project cost data, and specifying whether to generate the optimal or top three retrofits.

Run FEDS: Initiates baseline energy *consumption* and optimization calculations. Depending on the size and complexity of the case, this may take up to ten

minutes to an hour to complete. If successful, a “{casename}.opt” file will be created.

Generate reports: Allows you to choose up to four formats of output report to produce. It also allows you to print text-based reports directly from within FEDS. For more information, see FEDS Output.

Exit: Shuts down the FEDS application.

Building Set Inputs

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. See Breaking Building Types into Building Sets for more information.

Clicking the <**Go to Building Set Inputs**> button on the *FEDS Installation Inputs* screen sends you to the first *Building Set Inputs: General Information* screen. Each building set has its own *General Information* screen so while there will only be one Installation General screen per case, the number of *Building Set* screens is essentially unlimited. They contain and access inputs describing the building set geometry, occupancy, construction, and energy use characteristics.

Minimum Set Inputs

The following inputs are required for each *building set*:

- Building Type: These include 16 civilian (commercial and residential), 26 military, and two special building types, which are listed in Table 2.1. 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.

- 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.

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
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
FEDS Special Building Types	
Commissary – Sales	Commissary – Warehouse

Table 2.1. FEDS Building Types

Maximum Detail Inputs

At *maximum detail*, FEDS gives you access to the data inferred at minimum set. In addition to more detailed information in the existing minimum set input screens, the following screens are also available at maximum detail display:

- Seasonal Occupancy: Specifies the months that the *building set* is occupied and unoccupied.
- Building Geometry: The number of zones and floors and percentage of wall area that is glass.
- Envelope Inputs: Construction materials and thermal characteristics of roof, floor, walls, and windows. Detailed descriptions of FEDS wall and roof types are available in Appendix F.
- Ventilation System: Control mode and specific system parameters, including vent motor specification.
- Service Hot Water: Daily *consumption*, distributed and loop system types and associated parameters.
- Miscellaneous Equipment: Equipment densities and utilization factors for all other miscellaneous loads. Categories include refrigeration, food preparation, and other (computer/office equipment, motors, etc.)
- Motors: Electric motor parameters and operating characteristics.

See Transitioning to Maximum Detail for more information about specific data inputs.

Dual-Use Buildings Sets

Within each display mode, you are asked to specify the number of use areas in the *building set*. If no choice is made, one use area is assumed. Selecting "2" enables you to model building sets with two distinct uses (use areas). An

example of a dual-use building set 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 building 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
- Occupancy: operating schedules and occupant densities
- 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.*
- Miscellaneous equipment types, *capacity* densities and utilization factors
- Motor types, size, utilization and *load* factors
- When dual use is selected within the *minimum set* display mode, the following additional inputs will appear, joining the minimum data set:
- Use-Area Inputs: For each use area, you must specify use-area type, category, and portion of the building set in that use area.
- Use-Area 1 Service Hot Water system type: You must specify either loop or distributed system for Use-Area 1 only (all Use-Area 2 systems are distributed).

Linked Building Sets

A special feature that exists exclusively in *maximum detail* display is the ability to link pairs of building sets. This allows you to model buildings that are adjacent to one another, sharing either wall or floor/roof space (such as a warehouse with a small office built onto one side). The difference between linked 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 having their own separate *HVAC* systems.

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 orientation, and click <**Save-Done**>.

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* for each set must be locked to 0 (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 abolish the link to the remaining set.

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 2.2 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. In such cases, the maximum number of records applies to the sum of technologies in both cases. Note that there are no technology records for the ventilation end use. FEDS requests only the control and operational information for the ventilation system.

End Use	Maximum Per
Lighting	30
Heating	10
Cooling	10
Ventilation	N/A
Service Hot Water	10
Miscellaneous Equipment	10
Motors	15

Table 2.2. Maximum Technology Records by End Use

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 are electric baseboards and radiators. 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 "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 desiccant dehumidification. At *maximum detail*, when the ventilation control mode is constant operation, the user can enter design and operating inputs for the desiccant system. Regeneration of the desiccant is possible using any FEDS fuel including waste heat.

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 at *maximum detail* display mode. 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.

2. This will bring up the *Pair Heat/Cool Technologies* screen.

3. 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 <**Save-Done**>. Each technology must serve the same portion of the building set to be valid.

4. 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.

FEDS Process

Briefly, the FEDS analysis process will usually consist of the following steps:

1. Determine *building set* breakdown.
2. Complete an initial *minimum set* screening.
3. Gather additional data about the *installation*.
4. Select *maximum detail* display for selected building sets and modify inferred data.
5. Run model on final maximum detail input data.

Each of these steps is described in the next sections.

Step 1: Breaking Building Types into Building Sets

It is not only impractical but also unnecessary to model each building at a site individually. Especially for large installations, with hundreds or thousands of buildings, it is unthinkable to model each individual building separately. FEDS is designed to model groups of buildings that can be categorized together into sets. When beginning a FEDS screening, it is important to try to group buildings into as few sets as possible, with just enough to adequately represent what is there.

The following example illustrates how and why building types are broken into building sets. An *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, 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:

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 +
100,000 or more	

With six size categories and five vintage categories, there are potentially 30 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 file could 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.

Step 2: Minimum Set Screening

The objective of the FEDS *minimum set* input is to provide a top-level screening as a preliminary indication of what actions should be initiated; further analysis is required before a project is designed and implemented. When entering only the minimum set inputs, FEDS depends upon numerous assumptions about the "typical" Federal *installation*, with only minimal energy price and installation configuration information needed as input. Engineering parameters are not part of the minimum set.

FEDS uses the minimum set information 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.

Specific FEDS capabilities with minimum set input 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 of the existing technology and the *LCC* of the retrofit technology.

Using FEDS with only the minimum set input provides utility, institution, agency, energy, or installation managers with a simple 3-4 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 most likely parameter-value approach to the development of the building prototypes allows FEDS to perform detailed modeling of an installation while requiring only very limited information from a user (the minimum set). The results from a minimum set FEDS 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 only minimum set information, it is most appropriately applied to installations with large numbers of buildings.

Step 3: Gathering Additional Data

Results from the *minimum set* 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 money for additional data-gathering. This effort may be as minimal as confirming the heating and cooling equipment types and the construction types with a quick walk-through or drive-by or it may involve such detail as determining actual lighting densities by counting light fixtures.

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 minimum set 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 are included on the FEDS CD.

Step 4: Transitioning to Maximum Detail

Transition to *maximum detail*. The objective of FEDS maximum detail is to allow a knowledgeable user to override the default building and energy-using/generating equipment parameters that were inferred at *minimum set*. The maximum detail display may be activated individually for the *installation* level or for any *building set* by clicking on the <**Maximum Detail**> button on the FEDS Installation or *Building Set Inputs General Information* screens. However, a successful update of *inferences* at the minimum set is a prerequisite for maximum detail, and this button will remain disabled until an inference update is completed (see Display Modes).

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. Whatever additional data were collected 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 detailed inputs, this approach allows but does not require you to enter any site-specific information that is not readily available.

Following is a brief list of suggested areas to modify:

- *Solar normalization*: Select "0" (calculate solar gains by facing directions) if most buildings in the set are oriented similarly. Select "1" (ignore facing directions) for sets of buildings with different orientations.

- Occupancy inputs: You may specify occupied and unoccupied periods as well as seasonal occupancy, for the ability to model buildings that are used only part of the year.

- Fuel availability: When considering fuel-switching retrofits at minimum set, it is assumed that the fuels available to the installation are available to each building in the installation. Maximum detail allows you to change 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 minimum set inferences for the construction materials used for the walls, roof, floor, and windows. You may also specify different insulation R-values and thicknesses than those inferred at minimum set or simply specify the desired overall U-value for windows, walls, roof, and floor. 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, utilization levels for occupied and unoccupied periods, and lighting heat to space. Maximum detail gives access to nearly 500 existing lighting technology configurations. A list of the codes used to identify each of the lighting technology configurations for the FEDS model along with descriptions of the technology configurations are contained 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 (see Dual-Use Building Sets).

- Ventilation system: Fan and fan-motor capacities and efficiencies, as well as the ventilation system control mode, may be changed. Specific motor and desiccant 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.

- Miscellaneous equipment: You may change the inferences for miscellaneous equipment densities, utilization levels, and heat to space.

- 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.

Update inferences. Any additional information that you provide at maximum detail is used to recalculate (where appropriate) any dependent inferred values. Inferences for a particular building set may be updated by selecting <**Update Inferences**> from the *Building Set Inputs: General Information* screen. You may update all installation and building set inferences for the case by pressing the "Update All Inferences" icon on the FEDS Installation Inputs screen or selecting *Update All Inferences* from the *Options* menu.

Repeat. You may then 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.

Step 5: Running the Model

Once you have checked and modified your data and the data inferred by FEDS, it is recommended that you exclude all building sets from optimization (see Exclude Building Sets from Optimization) and then run FEDS to determine baseline *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 reports.

Once large discrepancies have been resolved, remove the *building set* exclusions and select "Run FEDS" from the *FEDS Installation Inputs* screen under the *Options* menu. 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 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 fixtures with new high-efficiency fluorescent 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.

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

Once FEDS has successfully completed its optimization, a file named "{casename}.opt" will be produced, and you are ready to generate output reports.

Advanced Options

This section provides an overview of the operation and effective use of the features known collectively as Advanced Options. Each of the advanced options screens may be accessed by selecting “Advanced Options” located under the *Options* menu on the *FEDS Installation Inputs* screen or by clicking the *Advanced Options* icon. There are currently four Advanced Options available.

Advanced Options icon

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.

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.

Note: 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.

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.

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 <**Clear all**> buttons can aid in this process. Symbols to the left of the building set list identify sets that have been excluded from optimization ("X>") and sets with existing retrofit restrictions defined ("-->"). In Figure 4.2, sets 2, 4, and 5 have been excluded while sets 1, 7, and 9 each have at least one retrofit restriction currently defined.

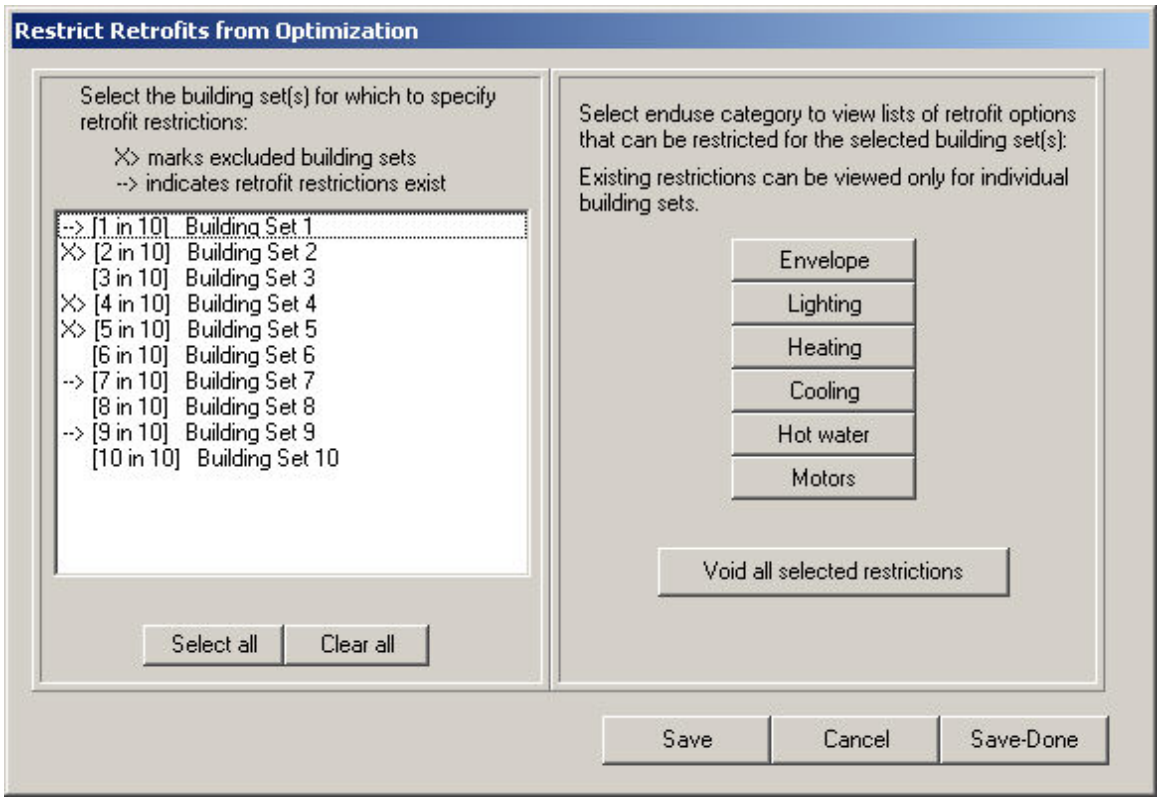
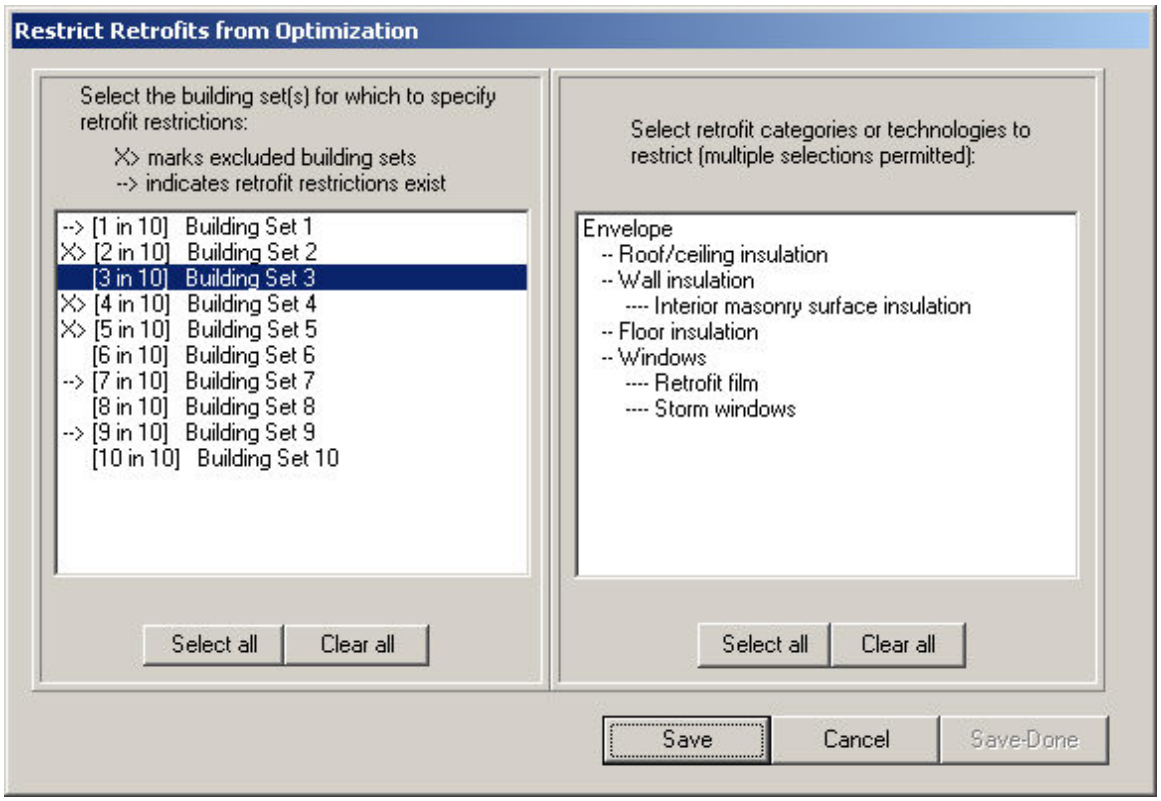


Figure 4.2 Restrict Retrofits from Optimization Screen

2. From the right half of the screen, select the end use category containing the retrofit(s) to eliminate from optimization. A new frame will appear containing a list of the restrictable retrofits for that end-use (see Figure 4.3).



FEDS 4.3 Envelope Retrofit Restriction Options

3. 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). Again, the <**Select all**> and <**Clear all**> buttons can assist in making selections.

4. 4. Pressing <**Save-Done**> at this point will save the specified restrictions and close the end-use window, bringing you back to the end-use buttons as shown in Figure 4.2. <**Cancel**> will take you back without saving any changes made since the last save.

5. 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 <**Save-Done**> or <**Cancel**>.

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

Viewing and Clearing Retrofit Restrictions

The complete set of restricted retrofits can only be viewed for individual building sets. This is accomplished by selecting a single building set and following the procedure for defining restrictions. When an individual set is chosen, all existing retrofit selections will appear highlighted on the end-use lists and specific retrofits may be added or deleted with a click of the mouse.

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 set is selected on the building set list.

<**Void all selected 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 <**Void all selected restrictions**> button.

Alter Cost Data

This option allows the user access to FEDS' internal cost data used in calculating the cost of retrofit equipment. The FEDS cost data consists of state averages, so altering these values allows users the ability to adjust for intra-state variations as well as for special rates and other factors to more accurately model the cost of retrofit projects in specific locales.

This option provides the ability to alter retrofit cost data at two levels:

FEDS Regional Cost Data

The *Regional Cost Data* screen (Figure 4.4) displays the cost data for each case including labor rates, materials cost multipliers (fractions of national average costs), sales tax rate, and *ECIP* design cost and 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 FEDS cost data for other regions may be viewed by selecting another state from the "State in which *installation* is located" list on the FEDS Installation Inputs screen, and updating the installation *inferences*. The "Other (global multiplier)" input on the *Regional Cost Data* screen is a value applied to the total cost of all retrofit projects considered during optimization. It should 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.

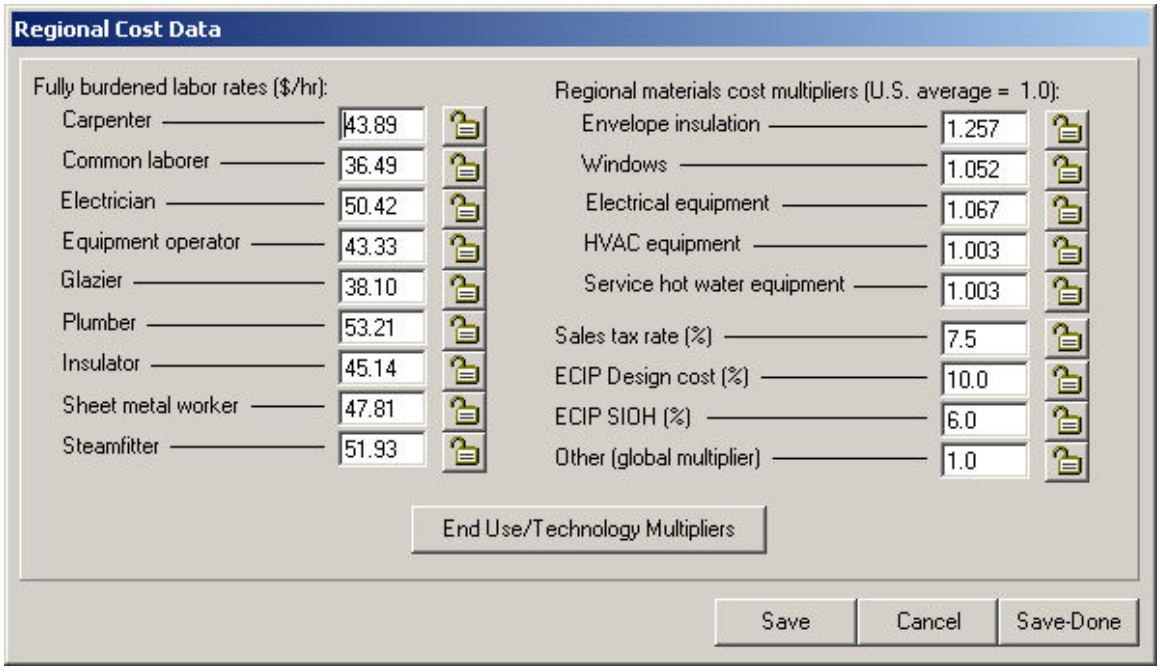


Figure 4.4 Regional Cost Data

End-Use/Technology 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. These can be accessed with the button on the bottom of the *Regional Cost Data* screen. 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 4.5.

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 cost 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.

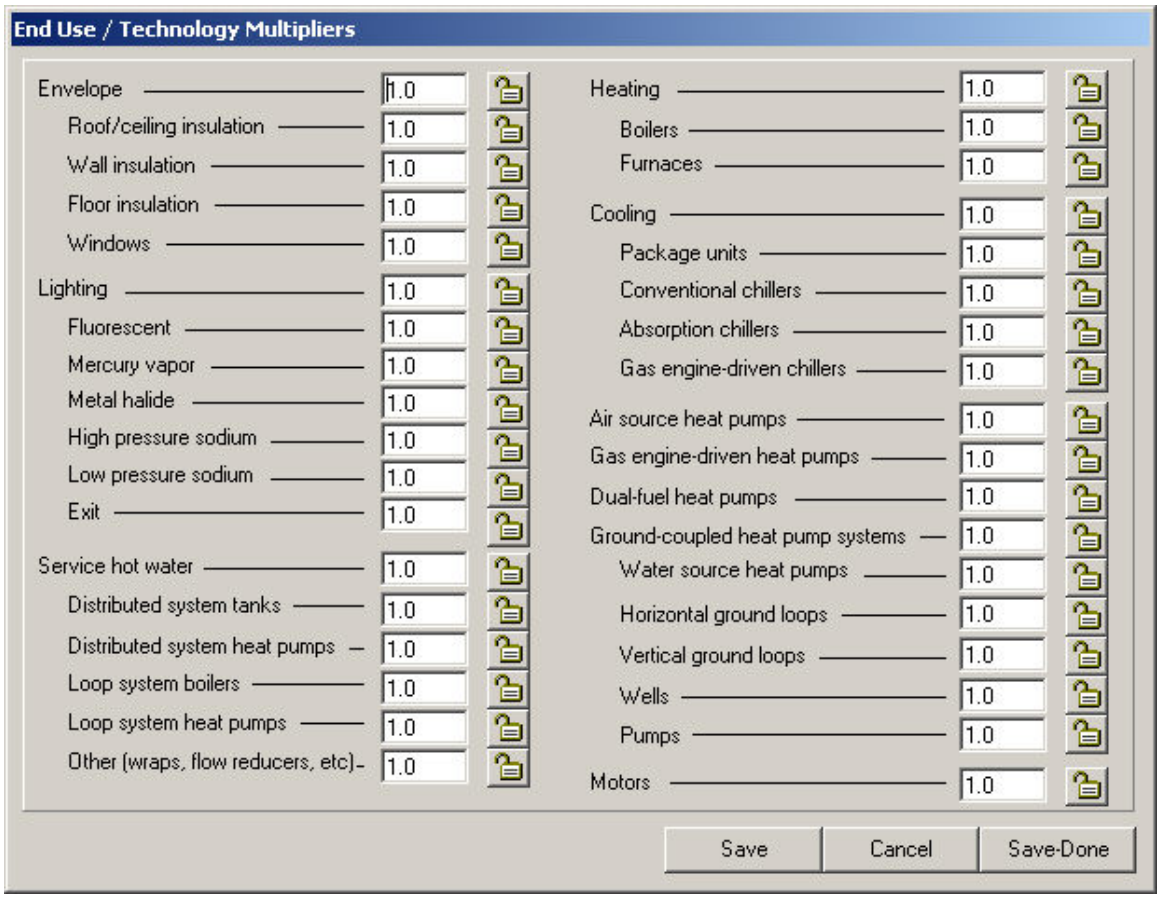


Figure 4.5 End Use/Technology Multipliers

Generate Top 3 Retrofits

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.

The *Retrofit Specification* screen (Figure 4.6) may be accessed with the <**Generate Top 3 Retrofits**> button from the *Advanced Options* driver screen. "Generate Minimum *LCC* Retrofit Only" is the default selection and will generate the one most life-cycle cost-effective retrofit. Choosing "Generate Top Three LCC Retrofits" will instruct FEDS to determine the top three retrofit options for each existing piece of equipment or envelope component. Note however that activating this feature will consume an additional 105 kbytes of disk space per *building set*.

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.

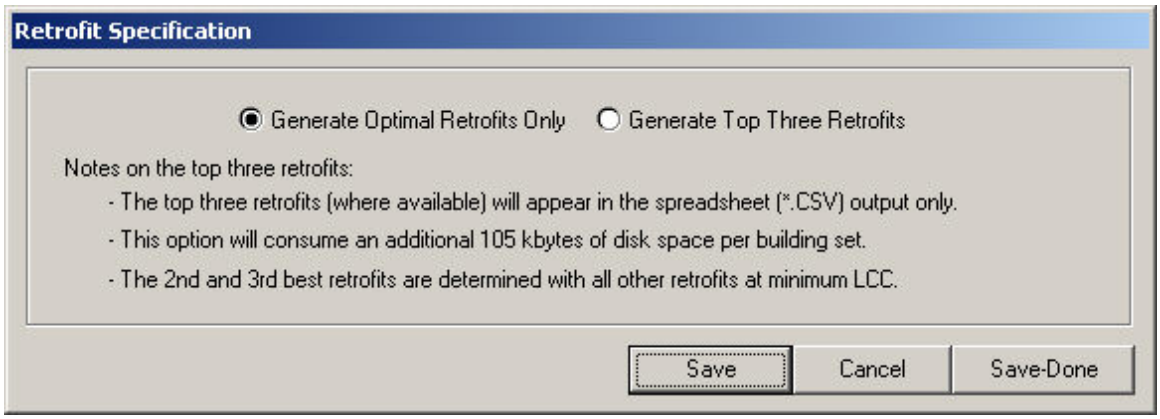


Figure 4.6 Retrofit Specification Screen

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.

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:

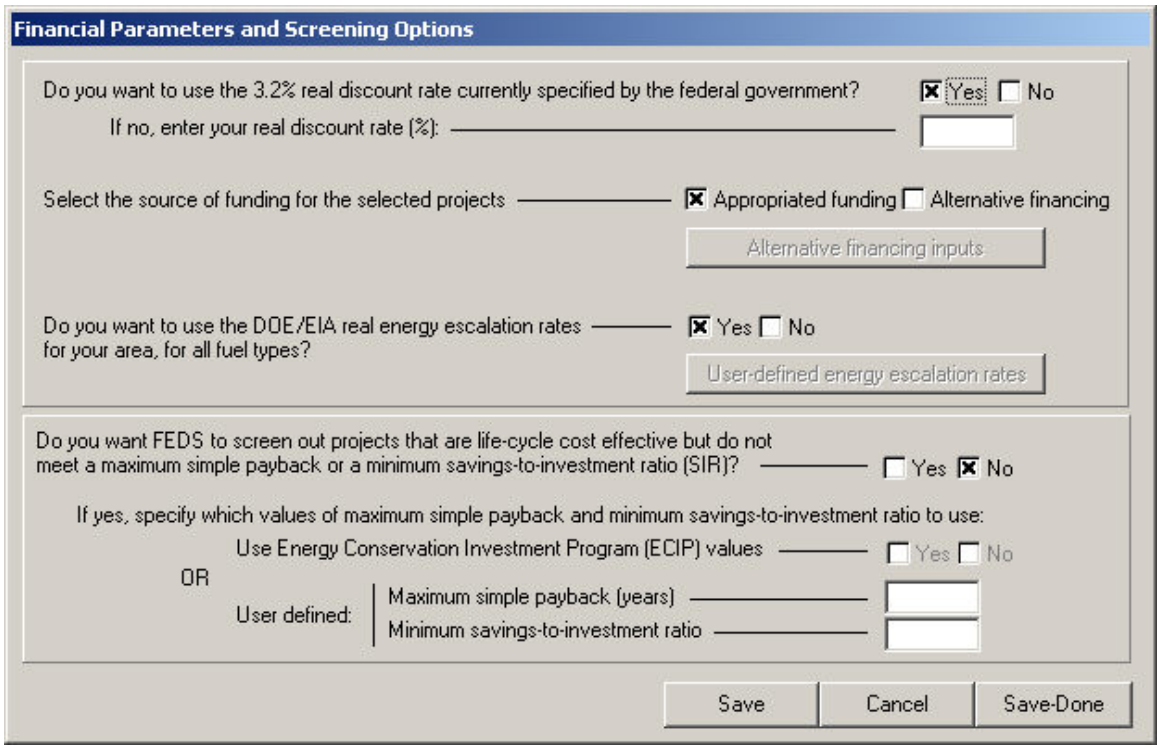
1. having the site continue to operate the baseline equipment and when it fails to replace it with the minimum life-cycle cost equipment, and

2. 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.

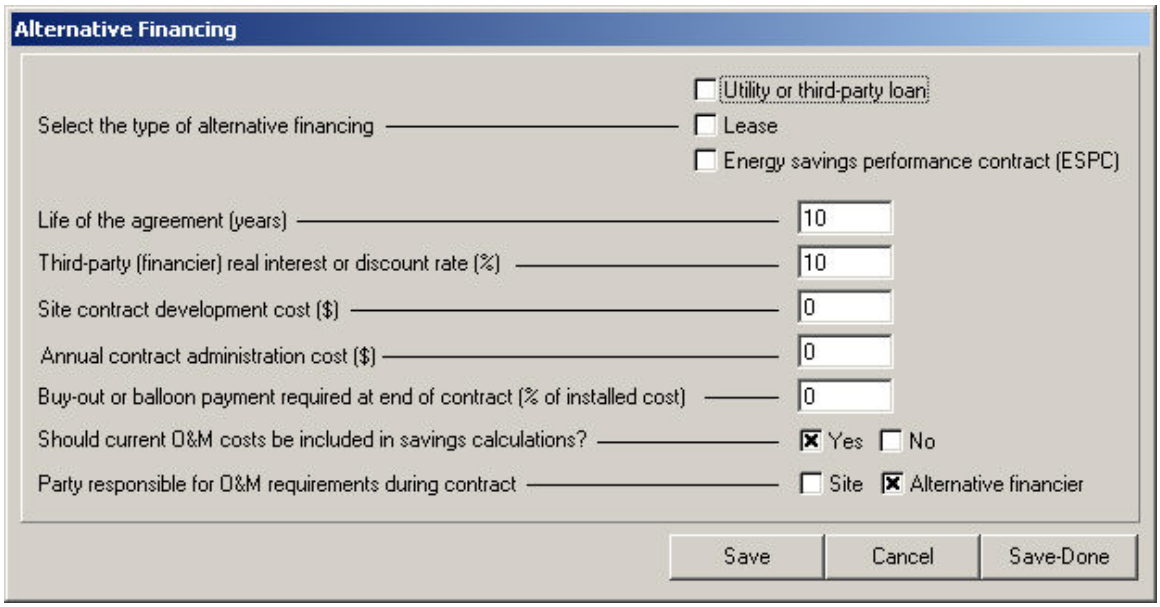
In a site financing run the comparison is the same except the site makes the retrofits. Hence the output of an alternative financing run and a site financing/appropriated funding run can be directly compared to determine which is the more favorable situation.

Alternative Financing Inputs

The alternative financing inputs may be accessed by selecting "Financial Parameters and Screening Options" from the FEDS *Installation* Inputs screen. The following screen will appear:



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:



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 or not 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.)

Alternative Financing {Casename}.txs Output

When an alternative financing case is run, Page 6 of the {Casename}.txs output presents a summary of the retrofit resource potential from both the alternative financier and site perspectives.

The first section of the example output shown in Figure 1 (Financier Perspective) is similar to the output that is provided when an appropriate funding run is made. The only difference is that under an alternative financing run, the output reflects the perspective of the financier rather than the site. This output is fully explained in FEDS Output.

The second section of the example corresponds to the site's perspective; each line of output is explained below.

```
                                        Alternative Finance Case / Somewhere, NB / Page 6

                              FEDS ANALYTICAL RESULTS

Summary of Retrofit Resource Potentials--Alternative Financier Perspective
-------------------------------------------------------------------------------
First year energy and demand dollar savings due to retrofits .      99,992
Present value of life-cycle energy, demand, and O&M savings ..     777,629
Total estimated investment required for retrofits ............     216,268
Present value of capital investments .........................     245,329
Net present value of retrofits ...............................     532,300
Estimated current installation energy use (MBtu) .............      38,792
Estimated post-retrofit installation energy use (MBtu) .......      34,356
Estimated installation annual energy savings (MBtu) ..........       4,435

Summary of Retrofit Resource Potentials-------------------Site Perspective
-------------------------------------------------------------------------------
Annualized value of change in net cash flow during project.....     11,629
Present value of change in net cash flow after project ........     39,281
Net present value of retrofits ...............................    201,030
Savings split (percentage of savings that site retains) .......          5
```

Figure 5.1 Example Output of {Casename}.txs File

Annualized value of change in net cash flow during project. This is the total annualized change in net cash flow throughout the project; it includes the benefits, avoided benefits, contract administration cost, and the annualized value of the contract setup cost.

Present value of change in net cash flow after project. This accounts for the years of service that the equipment will provide after the end of the contract and for which the alternative financier recovers the cost during the contract period. This value is the sum across all retrofits.

Net present value of retrofits. This is the primary decision criterion for the site to determine the benefit of entering into an alternative financing agreement. Positive values are better than doing nothing; however, these values should be compared to the appropriated funding values to see how much it is costing/benefiting the site to go with alternative financing.

Savings split (percentage of savings that site retains). This is the percentage of the annualized energy, demand, and *O&M* savings which the site accrues over the contract life.

Alternative Financing {Casename}.txd Output

When an alternative financing case is run, the {Casename}.txd output presents life-cycle cost savings data and a summary of the retrofit resource potential from both the alternative financier and the site perspective.

Similar to the .txs output, the first two columns of the *Life-Cycle Costs Savings* section are virtually the same output that is provided when an appropriated funding run is made. The difference is that under an alternative financing run the output is from the perspective of the financier rather than the site. This output is fully explained in Description of {Casename}.txd Output. The first four rows of the output in these two columns are impacted by the alternative financing inputs as discussed below.

Installed Cost. These are the present and annualized values of the installed cost, less the present and annualized values of the buyout.

Annual Maintenance. These are the present and annualized values of the annual maintenance cost. This value may or may not include the savings/costs associated with current or contract *O&M* depending on the user inputs regarding O&M. For example, if the user specifies that current O&M cost should not be included in the calculation and that the site will be responsible for the O&M, this value will be zero.

Non-Annual Maintenance. These are the present and annualized values of the non-annual maintenance cost. This value may or may not include the savings/costs associated with current or contract O&M depending on the user input regarding O&M.

Energy/Demand. The present and annualized values of the energy and demand savings realized during the contract period.

The third column of the *Life-Cycle Costs Savings* section (Site Present Values) summarizes the results from the site perspective; each line of output is explained below.

Installed Cost. This is the present value of the financier's annualized investment and the site's annualized buyout cost; the value is negative because it represents a cost.

Annual Maintenance. This is the present value of the financier's annualized maintenance cost savings.

Non-Annual Maintenance. This is the present value of the financier's non-annualized maintenance cost savings.

Energy/Demand. This is the present value of the financier's annualized energy and demand cost savings.

Total *LCC* Savings (*NPV*). This is the sum of the first four rows and represents the site net present value (NPV) over the contract period.

Avoided invest. This accounts for the years of service that the equipment will provide after the contract and for which the alternative financier recovers the cost during the contract.

Avoided benefit. This represents the present value of the annual benefits, for years after the remaining life of the existing equipment, that would have accrued to the site if the site had financed the initial and future capital replacements over the life of the contract. A negative value indicates that this is a cost or lost opportunity.

Site NPV. This is the present value of change in net cash flow throughout the life of the retrofits; it includes both the net benefits and the avoided investment. It does not include the contract administration or contract setup costs.

```
Technology Retrofit Information for Building Set #1:  (B) Office  (C)
Building Set Description  (D)
End Use: Lights  (E)
Use Area: Office  (F)
Existing Technology: FL1: FL 2X4 4F40T12 STD2  (G)
Percent of Building Set Served by this Technology: 50.00%
Retrofit Technology: FL244: FL 2X4 4F32T8 ELC4  (H)

                                   Existing                  Retrofit                Difference
Retrofit Technology
 Watts/fixture                        192  (N)                 114  (O)                    -78
 Operating hours/Year               2,952  (P)               2,952  (Q)                      0
 Fixtures in this Bldg. Set           194  (L)                 194  (M)                      0
 Vintage                             1978  (K)                 New
 Remaining Life (years)                25                       25

Technology Energy Use/Demand (this technology)
 Energy (user units)               109,958  (R) (kWh)  (S)   65,294  (T) (kWh)  (U)    -44,675
 Energy (MBtu)                         375                     223                       -152  (V)
 Electric Peak Demand (kW)              23                      14                        -10  (W)
 Coincident Pk Demand (kW)              23                      14                        -10

Building Set Energy Use/Demand (All technologies at minimum LCC except those being retrofit)
 Heating (MBtu)                        285                     307                         21
 Cooling (MBtu)                        369                     346                        -23
 Ventilation (MBtu)                    215                     209                         -6
 Lighting (MBtu)                     1,257                   1,105                       -152
 Misc. Equip. (MBtu)                   718                     718                          0
 Motors (MBtu)                           0                       0                          0
 Service Water Heating (MBtu)           26                      26                          0
  Total (MBtu)                       2,871                   2,710                       -161  (X)
  Peak Electric Demand (kW)            228                     216                        -12  (Y)

Air Pollution Emissions (All technologies at minimum LCC except those being retrofit)
 Sulfur Dioxide (lb)                2,038.3                 1,924.0                     -114.3
 Nitrogen Oxides (lb)                 947.4                   894.2                      -53.1
 Carbon Monoxide (lb)                 172.2                   162.6                       -9.7
 Carbon Dioxide (tons)                272.2                   257.0                      -15.3
 Particulate Matter (lb)                0.0                     0.0                        0.0
 Hydrocarbons (lb)                      0.0                     0.0                        0.0

Building Set Energy/Demand Cost--First Year
(All technologies at minimum LCC except those being retrofit)
This technology
 Energy                        $    10,997             $     6,529             $    -4,467  (Z)
 Annual Electric Demand        $     2,816             $     1,672             $    -1,144  (AA)
Balance of Building Set
(All technologies other than those being retrofit--includes systems and retrofit interactions)
 Energy                        $    73,117             $    72,868             $      -249  (AB)
 Annual Electric Demand        $    19,314             $    19,100             $      -214  (AC)

Life-Cycle Costs Savings    AF Present Values     AF Annualized Values          Site Present Values
 Installed Cost                $   -31,499  (AD)     $    -5,126  (AE)         $   -43,506  (AR)
 Annual Maintenance            $         0  (AF)     $         0  (AG)         $         0  (AS)
 Non-Annual Maintenance        $    -3,051  (AH)     $      -497  (AI)         $    -4,215  (AT)
 Energy/Demand                 $    36,236  (AJ)     $     5,897  (AK)         $    50,049  (AU)
    Total LCC Savings (NPV)    $     1,685  (AL)     $       274  (AM)         $     2,328  (AV)
    Simple Payback (years)            5.6  (AN)                   Avoided invest $    15,976  (AW)
    AIRR (percent/year)              10.6  (AO)                  Avoided benefit $   -40,831  (AX)
    SIR                               1.1  (AP)                         Site NPV $    59,134  (AY)

Installed Capital Cost:           $    31,499  (AQ)
```

Figure 5.2 Example Output of {Casename}.txd File (The characters in parentheses represent the spreadsheet column indicator where the data will reside after they are imported into a spreadsheet.)

Alternative Financing {Casename}.csv Output

When you select the “Spreadsheet format [*.csv]” option from the *Generate Reports* screen, an ASCII file (semi-colon delimited) will be produced, formatted for easy importation into 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 shaded characters in Figure 2. Those characters correspond to the column in which that information will appear in the spreadsheet. 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."

As you will note, several additional columns of output are provided for alternative financing cases and others that were previously shown from the site perspective are now shown from the alternative financier perspective. Specifically, columns AD though AQ are now from the alternative financier perspective and the additional columns (AR through AY) are from the site perspective.

Alternative Financing {Casename}.ecp Output

Because alternative financing and Energy Conservation Investment Program (*ECIP*) funding represent different funding alternatives *.ecp output is not available for cases run with alternative financing.

FEDS Output

Once the model has been successfully run on a case, output reports may be generated at any time. From the *Options* menu, select *Generate Reports*. A summary report of the *installation* and *building set* energy, demand, dollar, and air pollution emissions impacts ({casename}.txs) is always generated. Additionally, a detailed retrofit report ({casename}.txd) a spreadsheet format ({casename}.csv), and an *ECIP* report ({casename}.ecp) may be selected. Also see Formatting and Printing Reports.

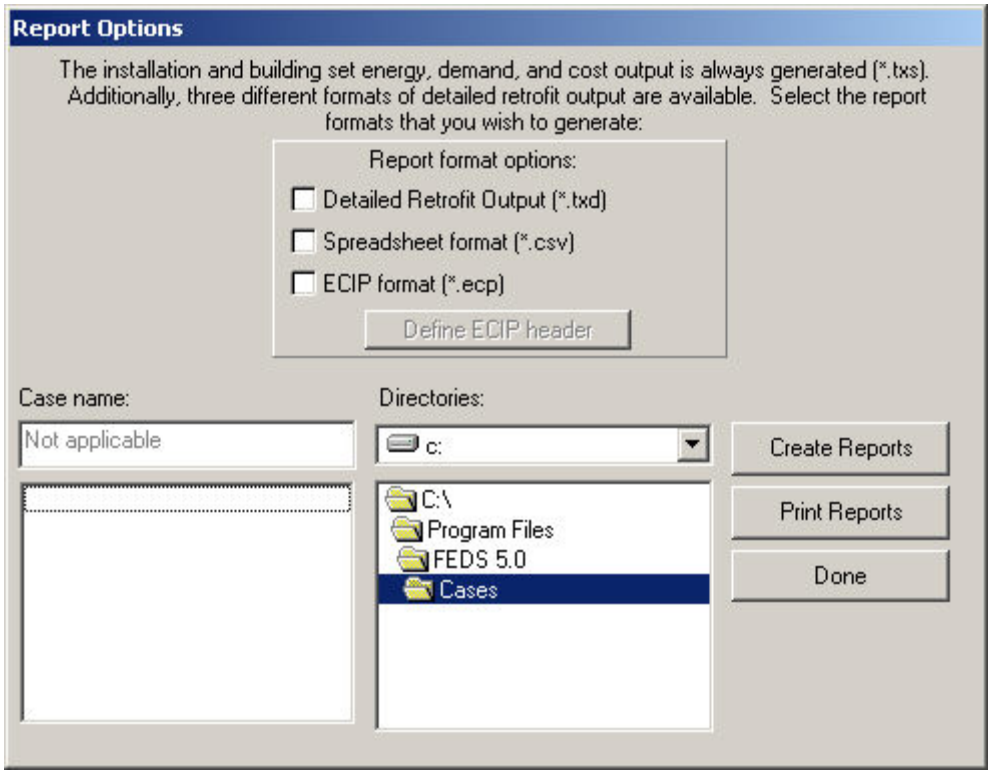


Figure 6.1 Report Options Screen

Description of {Casename}.txs Output

This report format contains a summary of the *installation* and building set energy, demand, and cost savings. It is automatically generated by FEDS every time any report format is selected. The output file is structured as follows:

Page 1: An echo of the site energy-use characterization that you have provided in the input file.

Page 2: An echo of the electricity price and schedule information that you have provided in the input file.

Page 3: An echo of the site building characteristics that you have provided in the input file. The echo includes the number of buildings, floor area, construction date, space heating technology, space cooling technology, and service water heating technology.

Page 4: An echo of additional site building characteristics that you have provided in the input file, including indoor lighting technology and building operating hours.

Page 5: An echo of the site economic data that you have provided 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 Advanced 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 Advanced Options.

Page 6: Following is a description of each line of output on Page 6.

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
Net present value of retrofits	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 6.2 Example Output of {Casename}.txs File

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 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 and O&M savings over the investment lifetime. The investment lifetime for equipment is the shorter of either 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 and O&M savings" is also the sum of the "net present value of retrofits" and the "present value of capital investments."

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.

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

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

Estimated current installation energy use (*MBtu*). This is the estimated total annual site energy use for buildings in MBtu prior to retrofit. This does not include process energy, electric distribution system losses, outdoor lighting, central plant energy *consumption*, or thermal loop losses. This value will not equal the annual energy consumption that you have entered. 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 10-year average data used by the model.

Estimated post-retrofit installation energy use (MBtu). This is the estimated total annual site energy use for buildings in MBtu.

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.

Page 9: Annual installation emissions by pollutant type (SO2, Nox, CO, CO2, particulates, and hydrocarbons). Values are provided for existing, post-retrofit, the difference, and the percentage change. For information on how the emissions impact was derived, review the emissions paper (in .pdf format) on the FEDS CD.

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

Page 11+: 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 installation average cost and, thus, will not necessarily match the value on page 14 of the output. There will be one page per building set.

Page 12+: 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 13+: 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 14+: 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.

Description of {Casename}.txd Output

This report format contains detailed information about 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 4.3 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. The impacts due to central fuel (district steam, hot water, or chilled water) savings are calculated in the same manner as for the *ECIP* output, as described in Description of {Casename}.ecp Output. For more detail on how the emissions values are tied to fuel use see the emissions paper (in .pdf format) on the FEDS CD.

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).

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

```
Technology Retrofit Information for Building Set #3: (B) Office (C)
Building Set Description (D)
End Use: Lights (E)
Use Area: Office (F)
Existing Technology: FL1: FL 2X4 4P4WT12 STD2 (G)
Percent of Building Set Served by this Technology: 80.00%
Retrofit Technology: FL237: FL 2X4 EP32T8 ELC3 REF (H)

Retrofit Technology                 Existing                  Retrofit                  Difference
 Watts/fixture                         192 (N)                    93 (O)                     -99
 Operating hours/Year                2,952 (P)                 2,952 (Q)                       0
 Fixtures in this Bldg. Set            776 (L)                   776 (M)                       0
 Vintage                              1977 (K)                   New
 Remaining Life (years)                 25                        25

Technology Energy Use/Demand (this technology)
                                    Existing                  Retrofit                  Difference
 Energy (user units)                439,873 (R) (KWh) (S)     213,064 (T) (KWh) (U)     -226,810
 Energy (MBtu)                        1,501                     727                       -774 (V)
 Electric Peak Demand (kW)               94                      45                        -48 (W)
 Coincident Pk Demand (kW)               94                      45                        -48

Building Set Energy Use/Demand (All technologies at minimum LCC except technology being retrofit)
                                    Existing                  Retrofit                  Difference
 Heating (MBtu)                       1,071                     1,224                       153
 Cooling (MBtu)                         673                       541                      -132
 Ventilation (MBtu)                     212                       185                       -27
 Lighting (MBtu)                      2,031                     1,256                      -774
 Misc. Equip. (MBtu)                  1,794                     1,794                         0
 Motors (MBtu)                            0                         0                         0
 Service Water Heating (MBtu)            55                        55                         0
  Total (MBtu)                        5,835                     5,055                      -780 (X)
 Peak Electric Demand (kW)              396                       330                       -66 (Y)

Air Pollution Emissions (All technologies at minimum LCC except technology being retrofit)
                                    Existing                  Retrofit                  Difference
 Sulfur Dioxide (lb)                 1,609.3                   1,323.7                     -285.6
 Nitrogen Oxides (lb)                1,518.4                   1,283.9                     -234.5
 Carbon Monoxide (lb)                   77.7                      72.6                       -5.1
 Carbon Dioxide (tons)                 250.6                     220.9                      -29.8
 Particulate Matter (lb)               203.5                     168.2                      -35.4
 Hydrocarbons (lb)                       0.5                       0.5                        0.1

Building Set Energy/Demand Cost--First Year
    (All technologies at minimum LCC except technology being retrofit)
This technology                     Existing                  Retrofit                  Difference
 Energy                          $    37,389               $    18,110               $   -19,279 (Z)
 Annual Electric Demand          $     2,253               $     1,091               $    -1,162 (AA)
Balance of Building Set
    (All technologies other than the one being retrofit--includes systems and retrofit interactions)
 Energy                          $    92,239               $    89,902               $    -2,337 (AB)
 Annual Electric Demand          $     6,974               $     6,609               $      -365 (AC)

Life-Cycle Costs Savings      Present Values          Annualized Values
 Installed Cost                  $  -191,224 (AD)        $   -12,370 (AE)
 Annual Maintenance              $         0 (AF)        $         0 (AG)
 Non-Annual Maintenance          $    59,394 (AH)        $     3,842 (AI)
 Energy/Demand                   $   386,387 (AJ)        $    24,996 (AK)
    Total LCC Savings (NPV)      $   254,557 (AL)        $    16,467 (AM)
    Simple Payback (years)              7.1 (AN)
    AIRR (percent/year)                 7.7 (AO)
    SIR                                 2.3 (AP)

Installed Capital Cost:          $   191,224 (AQ)
```

Figure 6.3 Example Output of {Casename}.txd File (The characters in parentheses represent the spreadsheet column indicator where the data will reside after they are imported into a spreadsheet.)

Description of {Casename}.csv Output

When you select the “Spreadsheet format [*.csv]” option from the *Generate Reports* screen, an ASCII file (semi-colon delimited) will be produced, formatted for easy importation into 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 shaded characters in Figure 6.3. Those characters correspond to the column in which that information will appear in the spreadsheet. 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 6.3, the “{casename}.csv” output will display three additional columns of information:

- *Installation* Name (Column A) - The installation name entered on the FEDS Installation Inputs screen will appear in the first column.

- Rank (Column I) - 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.

- End-use Retrofit Restrictions (Column J) - 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 apply "none" will be printed.

*Note: 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).*

Description of {Casename}.ecp Output

Selecting the “ECIP report” option will generate a life cycle cost analysis summary for the Energy Conservation Investment Program (*ECIP*). This file contains three pages of information for each retrofit project identified by FEDS. Figure 6.4 shows examples of output for the three pages of an ECIP 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.

Figure 6.4 Example Output of {Casename}.ecp File

ECIP Page 1 and Page 2 Output

Technology Retrofit Information for Building Set #3: Office
Office Building Set Description
End Use: Lights
Use Area: Office
Existing Technology: FL1: FL 2X4 4F40T12 STD2
Percent of Building Set Served by this Technology: 80.00%
Retrofit Technology: FL237: FL 2X4 3F32T8 ELC3 REF

Energy Project Summary Sheet

Installation:	Sample-2: Four Building Sets
Location:	Seattle, WA
Project Title:	Lighting Systems Office Building Set Description
Project Description:	FL237: FL 2X4 3F32T8 ELC3 REF
Project Number:	
Total Investment:	$ 221,820
MBtu/Yr Saved:	780
Discounted MBtu Savings:	$ 251,096
Discounted Demand Savings:	$ 16,857
Discounted Total Energy Savings:	$ 267,952
Discounted Total Non-Energy Savings:	$ 54,700
First Year Dollar Savings:	$ 27,745
Simple Payback in Years:	7.99
Discounted Total Net Savings:	$ 322,652
Savings To Investment Ratio (SIR):	1.45
Point Of Contact:	I.M. Somebody
Phone Number:	(123) 456-7890

ECIP Page 3 Output

Energy Life Cycle Cost Analysis Summary

Location: Seattle Region: 4 Project No:
Category: 6 Project Title: Lighting Systems FY: 96
Date: 31-Mar-96 Economic Life: 15 Prepared By: I.M. Somebody
State: WA

1. Investment Costs

			Funding Amount
A. Construction Cost	$ 191,224		
B. SIOH (6.00%)	$ 11,473		
C. Design Cost (10.00%)	$ 19,122		
D. Energy Credit Calc (1A+1B+1C)		$ 221,820	$ 221,820
E. Salvage Value of Existing Equipment		$ 0	
F. Public Utility Company Rebate		$ 0	
G. Total Investment (1D-(1E+1F))		$ 221,820	

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	$ 24.90	$ 893	$ 22,232	11.67	$ 259,437
B. Distillate Oil	$ 7.43	$ 0	$ 0	13.53	$ 0
C. Residual Oil	$ 0.00	$ 0	$ 0	13.51	$ 0
D. Natural Gas	$ 5.47	$ -113	$ -617	13.53	$ -8,341
E. Coal	$ 0.44	$ 0	$ 0	11.36	$ 0
F. Demand Savings			$ 1,527	11.04	$ 16,857
G. Subtotal		780	$ 23,143		$ 267,952

	Cost $/Mgal(1)	Savings Mgal/Yr(2)	Annual $ Savings(3)	Discount Factor(4)	Discounted Savings(5)
H. Water			$ 0	11.04	$ 0
I. Total			$ 23,143		$ 267,952

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

A. Annual Recurring(+/-)		$ 0
(1) Discount Factor	11.04	
(2) Discounted Savings/Cost (3A x3A1)		$ 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	$ 69,038			$ 54,700

C. Total Non-Energy Discounted Savings/Cost (3A2+3Bd4)	$ 54,700
4. First Year $ Savings (2I3+3A+(3Bd1/Yrs Econ Life))	$ 27,745
5. Simple Payback (1G/4)	7.99
6. Total Net Discounted Savings (2I5+3C)	$ 322,652
7. SIR (If < 1.25 Project Does Not Qualify) SIR = (6/1G)	1.45

Differences Between ECIP Output and Other FEDS Output

There are at least five reasons why the *ECIP* 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 ECIP results with the "*.txd" and "*.csv" results. The differences arise because the ECIP specification directs that some computations

be performed in a manner that is different from that used in computing the "*.txd" and "*.csv" output.

- The ECIP report reports only fuel savings for five fuels: electricity, distillate oil, residual oil, natural gas, and coal. Fuel savings are ignored completely for *LPG* (FEDS "other fuels"), and the three purchased fuels in the FEDS model (i.e., purchased steam, purchased hot water, and purchased chilled water). Fuel savings for self-generated steam, hot water, and chilled water are mapped back into the predominant fuel type for each self-generated fuel. If the predominant fuel type is one of the five ECIP fuels, then the savings that result from the mapping are added to the direct savings for that fuel, as reported in the "*.txd" and "*csv." Output. If the self-generated fuel maps back to a purchased fuel (e.g., chilled water generated from purchased steam) or LPG, they are ignored.

Ignoring these fuels can result in peculiar looking results. The savings shown on the ECIP output can be 0 (a savings in a non-ECIP fuel) or negative (switching from a non-ECIP fuel to an ECIP fuel), causing zeros or negative numbers to appear in some of the remainder of the ECIP output.

$$source\ fuel\ savings = \frac{self - generated\ fuel\ savings}{(central\ plant\ efficiency)(distribution\ system\ efficiency)}$$

- In mapping self-generated fuel savings (*MBtu*/yr) into one of the five ECIP fuels, the efficiency of the central plant must be estimated. This is done by dividing the source unit fuel cost by the generated unit fuel cost (i.e., the user-entered value for a self-generated fuel at the central plant boundary should be the source fuel cost divided by the central plant efficiency). No check is made by FEDS to see whether the values you have entered for the unit fuel prices of the self-generated fuel and its source fuel are realistic. Thus, it is possible that unreasonable values could result. In this case, the central plant efficiency is set to a reasonable value. The formula for mapping self-generated fuel savings into source fuel savings is as follows:

- Whereas the ECIP output uses central plant and distribution system efficiencies, the "*.txs," "*.txd," and "*.csv" output reports provide energy savings of central fuel inside the building; thus, they do not consider the central plant efficiency or distribution system efficiency. NOTE: The dollar value of self-generated and purchased fuel savings do include the distribution system efficiency in the "*.txs," "*.txd," and "*.csv" output reports.

- The analysis period used by the *LCC* model in FEDS is usually different from that used in the ECIP output. This affects the discounted savings

computed for the five ECIP fuels and for the non-recurring maintenance savings.

- The ECIP output uses a total investment cost, which includes an allowance for SIOH costs and design costs, in computing the *simple payback* and savings-to-investment ratio. These overhead and design costs are beyond those actually paid to the contractor. The "*.txd" and "*.csv" results include only the contractor's overhead and design costs; the ECIP SIOH and design costs are not included in computing the simple payback and savings-to-investment ratio in the "*.txd" and "*.csv".

- In the ECIP 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.

Formatting and Printing Reports

Once the reports have been generated (see FEDS Output), the ASCII text report files can be found in the FEDS\Cases subdirectory. At this point, you may either print the text-based reports directly from FEDS or open the text or spreadsheet reports in a word processing or spreadsheet application for editing, analysis, and publication.

To print any of the text-based reports ({casename}.txs, {casename}.txd, or {casename}.ecp) press the *Print Reports* button from *Report Options* screen. Locate and select the output report you wish to print and press **Open**. The report will be automatically printed to your default Windows printer, pre-formatted, in its entirety.

If you would like to change the format of the report or print only a select range of pages, you will need to open the report file in a word processor. The following formatting tips will ensure that the {casename}.txs and {casename}.txd reports display properly:

1. open your word processing program
2. open the file you wish to view or print
3. change the font to a fixed-pitch font such as Courier New
4. change the font size to 8pt
5. set the left and right margins to 0.5 inch each

Once these steps have been taken, the files should be ready to view or print.

The spreadsheet-based report ({casename}.csv) may only be opened and examined inside of a spreadsheet application. To view or print the spreadsheet report:

1. open your spreadsheet program
2. open the file you wish to view or print
3. adjust column widths to accommodate column headings, as needed

Once these steps have been taken, the file should be ready to manipulate in whatever ways you choose that your spreadsheet program allows (e.g., formatting, sorting, filtering, summing, etc.)

See FEDS Output for a detailed description of each report.

Appendix A - FEDS Technical Approach

FEDS 5.0 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 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.

Design Goals

FEDS was designed with two major 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.

Minimum Set Specific Design Goals

The FEDS *minimum set* provides a user-friendly tool for analyzing energy use and the potential for energy-efficiency retrofit projects at large 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 of an entire *installation*. 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.

Maximum Detail Specific Design Goals

Maximum detail display is intended to allow a user to identify specific projects that are cost-effective and appropriate to the *installation*. This is done by allowing a user to over-ride 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.

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 *minimum set* to single buildings less accurate than when it is used to model multi-building installations. Of course, accuracy is improved if actual parameter values are entered in the *maximum detail* display mode to override the inferred values.

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

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

Energy Modeling

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

- Lighting
- Electric motors

- Miscellaneous equipment
- Service hot water
- Heating
- Cooling
- Ventilation.

Lighting, motor, and miscellaneous equipment consumptions are calculated for the user-supplied occupancy schedule. 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.

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).

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.

Optimization

Optimization of the building energy system 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.

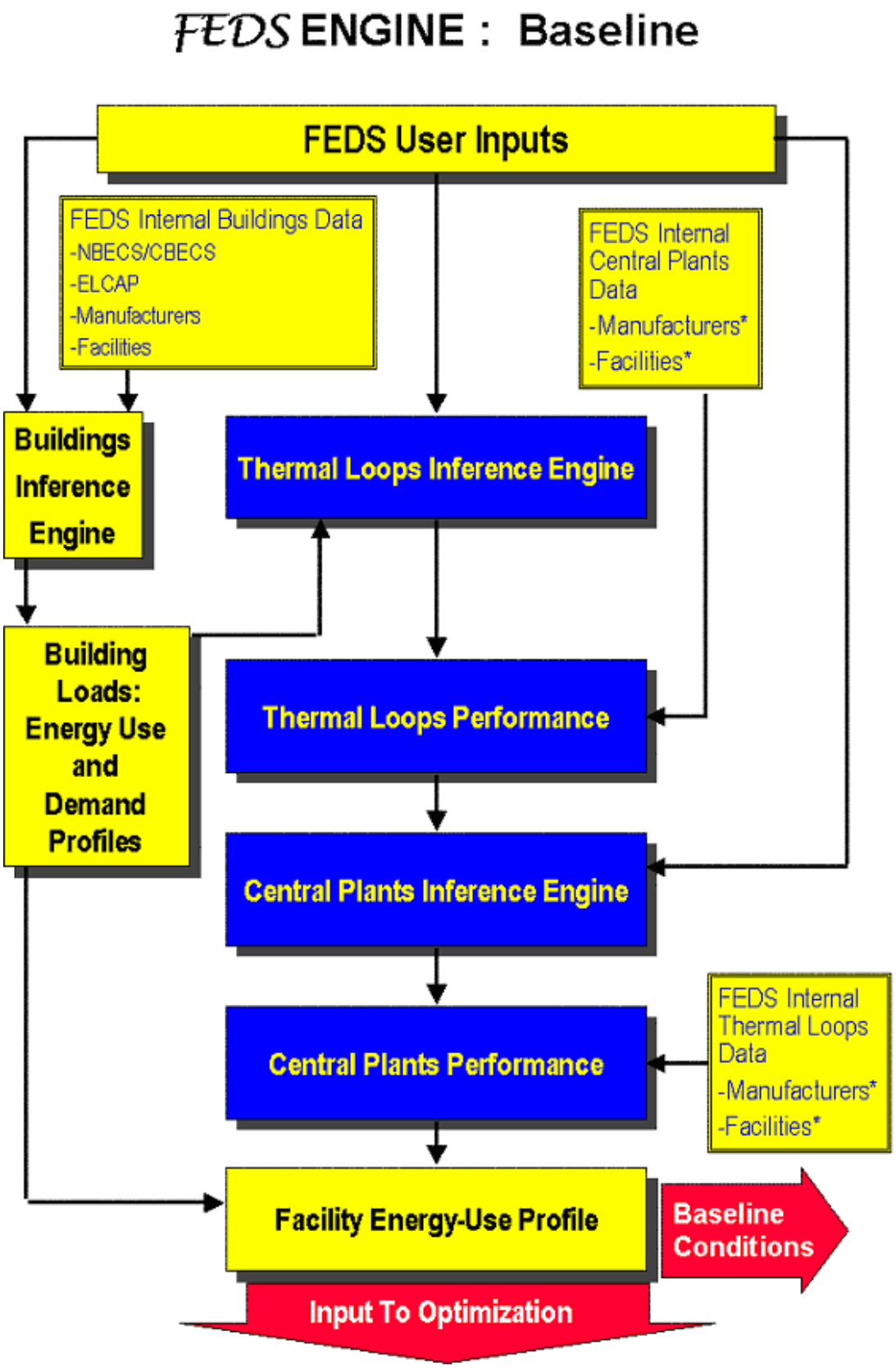


Figure A.1 FEDS Model Baseline Process

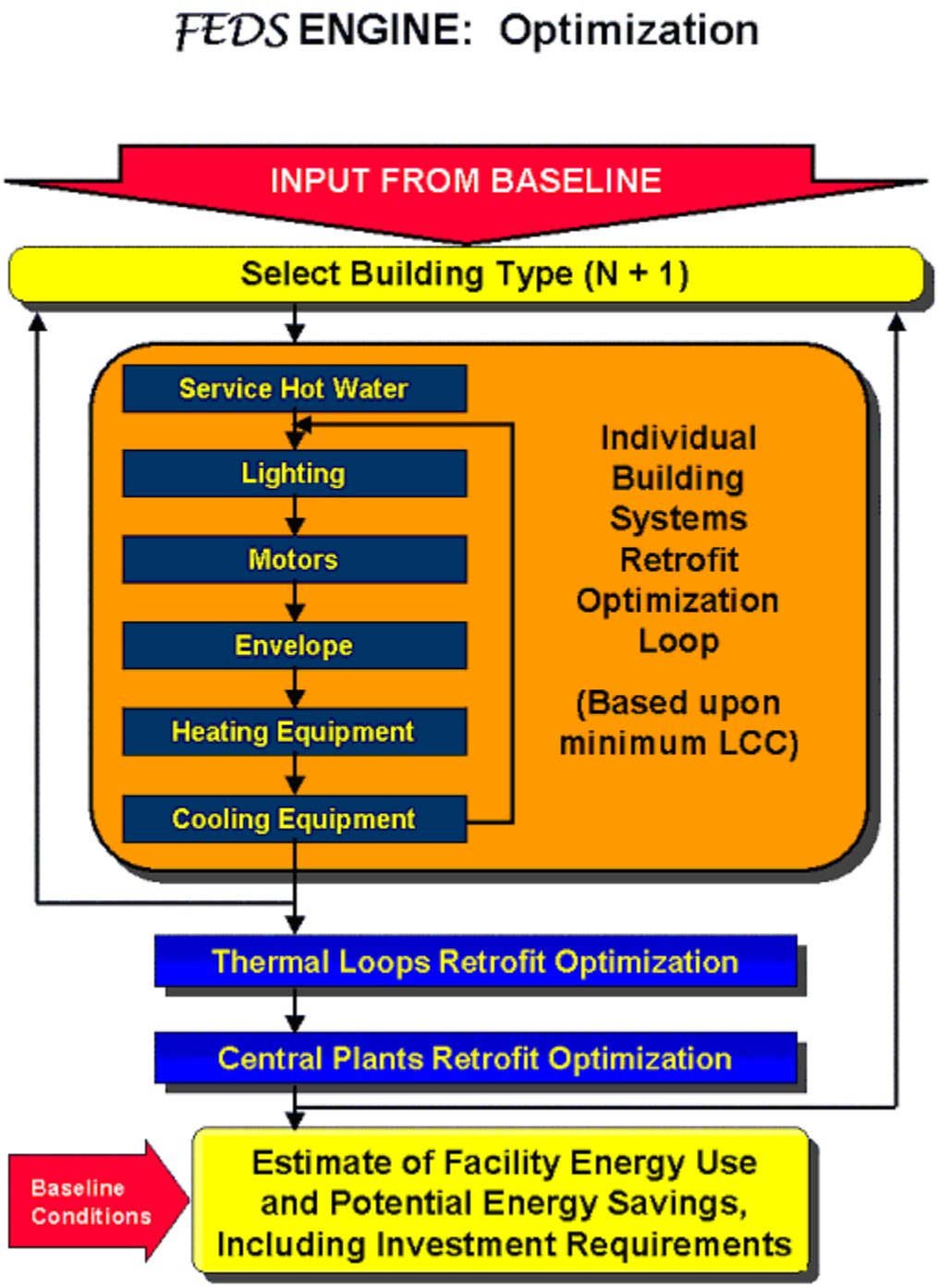


Figure A.2 FEDS Model Optimization Process

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.

Heating Retrofit Alternatives

FEDS is currently implemented only for buildings. Hence, the only retrofit of district heating systems is conversion to a building-level centralized system. Later, when central systems are implemented within the software, the analysis will also look at retrofitting a building-level system to a district system.

Electric Resistance

Retrofits to electric baseboard and electric fan coils are not available.

Replace electric furnaces with

- Newer conventional electric furnace
- Conventional distillate oil furnace
- Conventional gas furnace (80, 84, 90% efficiencies)

Replace electric boiler with

- New conventional distillate oil boiler (83, 84, 86.5% combustion efficiencies)
- New conventional residual oil boiler (82, 83.5, 86% combustion efficiencies)
- New conventional gas boiler (80, 81.5, 84% combustion efficiencies)
- Gas pulse condensing boiler (87, 91% combustion efficiencies)
- New conventional *LPG* boiler (80, 81.5, 84% combustion efficiencies)
- LPG pulse condensing boiler (87, 91% combustion efficiencies)

District Systems

Replace district steam with

- Conventional distillate oil boiler (83, 84, 86.5% combustion efficiencies)

- Conventional residual oil boiler (82, 83.5, 86% combustion efficiencies)
- Conventional gas boiler (80, 81.5, 84% combustion efficiencies)
- Gas pulse condensing boiler (87, 91% combustion efficiencies)
- Conventional LPG boiler (80, 81.5, 84% combustion efficiencies)
- LPG pulse condensing boiler (87, 91% combustion efficiencies)

Retrofits considered are switching from steam supplied by the thermal loop to steam supplied by a single-building boiler. Fuel-switching alternatives are considered only when the fuel is available to the building set.

Replace district hot water with

- Conventional distillate oil boiler (83, 84, 86.5% combustion efficiencies)
- Conventional residual oil boiler (82, 83.5, 86% combustion efficiencies)
- Conventional gas boiler (80, 81.5, 84% combustion efficiencies)
- Gas pulse condensing boiler (87, 91% combustion efficiencies)
- Conventional LPG boiler (80, 81.5, 84% combustion efficiencies)
- LPG pulse condensing boiler (87, 91% combustion efficiencies)

Oil/Gas/Coal/Other

Replace existing (oil, natural gas, coal, other fuel) boiler with

- New conventional distillate oil boiler (83, 84, 86.5% combustion efficiencies)
- New conventional residual oil biler (82, 83.5, 86% combustion efficiencies)
- New conventional gas boiler (80, 81.5, 84% combustion efficiencies)
- Gas pulse condensing boiler (87, 91% combustion efficiencies)
- New conventional LPG boiler (80, 81.5, 84% combustion efficiencies)
- LPG pulse condensing boiler (87, 91% combustion efficiencies)

Or add:

- Feedwater economizers

- Automatic electric damper

Fuel switching alternatives are only considered when the fuel is available to the *building set*. Performance of existing boiler depends on age, size, and fuel type.

Replace existing (oil, natural gas, other fuel) furnace with

- Conventional electric furnace
- Conventional distillate oil furnace
- Conventional gas furnace (80, 84, 90% efficiencies)
- Conventional other fuel (LPG) furnace (80, 84, 90% efficiencies)

Fuel-switching alternatives are only considered when the fuel is available to the building set. Performance of existing furnace depends on age, size, and fuel type.

Heat Pumps or Heat/Cool Pairs

Replace existing *heat/cool pair* (separate heat and cool equipment) with

- Individual heat and cool technologies
- Electric air source heat pump
- Natural gas engine-driven air source heat pump
- Dual-fuel air source heat pump with integrated natural gas backup heat
- Dual-fuel air source heat pump with integrated LPG backup heat
- Horizontal closed-loop ground-coupled heat pump system
- Vertical closed-loop ground-coupled heat pump system
- Open-loop ground-coupled heat pump system
- Packaged a/c unit with integral natural gas heat
- Packaged a/c unit with integral LPG heat
- Packaged a/c unit with natural gas heat and chlorine-free refrigerant
- Packaged a/c unit with LPG heat and chlorine-free refrigerant

Replace existing heat/cool pair (separate heat and cool equipment; heat is a furnace) with

- Individual heat and cool technologies
- Electric air source heat pump
- Natural gas engine-driven air source heat pump
- Dual-fuel air source heat pump with integrated natural gas backup heat
- Dual-fuel air source heat pump with integrated LPG backup heat
- Horizontal closed-loop ground-coupled heat pump system
- Vertical closed-loop ground-coupled heat pump system
- Open-loop ground-coupled heat pump system
- Packaged a/c unit with integral natural gas heat
- Packaged a/c unit with integral LPG heat
- Packaged a/c unit with natural gas heat and chlorine-free refrigerant
- Packaged a/c unit with LPG heat and chlorine-free refrigerant

Or add electric air source heat pump plus controls for dual-fuel operation.

Replace existing heat/cool pair (integrated heat and cool equipment) with

- Electric air source heat pump
- Natural gas engine-driven air source heat pump
- Dual-fuel air source heat pump with integrated natural gas backup heat
- Dual-fuel air source heat pump with integrated LPG backup heat
- Horizontal closed-loop ground-coupled heat pump system
- Vertical closed-loop ground-coupled heat pump system
- Open-loop ground-coupled heat pump system
- Packaged a/c unit with integral natural gas heat
- Packaged a/c unit with integral LPG heat
- Packaged a/c unit with natural gas heat and chlorine-free refrigerant
- Packaged a/c unit with LPG heat and chlorine-free refrigerant

Replace existing electric air source heat pump with

- Newer, more efficient electric air source heat pump
- Natural gas engine-driven air source heat pump
- Dual-fuel air source heat pump with integrated natural gas backup heat
- Dual-fuel air source heat pump with integrated LPG backup heat
- Horizontal closed-loop ground-coupled heat pump system
- Vertical closed-loop ground-coupled heat pump system
- Open-loop ground-coupled heat pump system

Or add furnace (gas, distillate oil, LPG) to existing heat pump plus controls for dual-fuel operation.

Replace existing natural gas engine-driven air source heat pump with

- Electric air source heat pump
- Newer, more efficient natural gas engine-driven air source heat pump
- Dual-fuel air source heat pump with integrated natural gas backup heat
- Dual-fuel air source heat pump with integrated LPG backup heat
- Horizontal closed-loop ground-coupled heat pump system
- Vertical closed-loop ground-coupled heat pump system
- Open-loop ground-coupled heat pump system

Replace existing dual-fuel air source heat pump (integrated backup heat) with

- Electric air source heat pump
- Natural gas engine-driven air source heat pump
- Newer, more efficient dual-fuel air source heat pump with integrated natural gas backup heat
- Newer, more efficient dual-fuel air source heat pump with integrated LPG backup heat
- Horizontal closed-loop ground-coupled heat pump system

- Vertical closed-loop ground-coupled heat pump system
- Open-loop ground-coupled heat pump system

Or adjust *crossover temperature* of existing dual-fuel heat pump

Replace existing dual-fuel air source heat pump (separate backup heat) with

- Electric air source heat pump
- Natural gas engine-driven air source heat pump
- Dual-fuel air source heat pump with integrated natural gas backup heat
- Dual-fuel air source heat pump with integrated LPG backup heat
- Horizontal closed-loop ground-coupled heat pump system
- Vertical closed-loop ground-coupled heat pump system
- Open-loop ground-coupled heat pump system

Or replace:

- Furnace of dual-fuel heat pump system with newer, more efficient furnace
- Heat pump of dual-fuel heat pump system with newer, more efficient air source heat pump

Or adjust crossover temperature of existing dual-fuel heat pump

Replace water source heat pump units of an existing ground-coupled heat pump system

Cooling Retrofit Alternatives

FEDS is currently only implemented for buildings. Hence, the only retrofit of district cooling systems is conversion to a building-level centralized system. Later, when central systems are implemented within the software, the analysis will look at retrofitting a building-level system to a district system.

Replace package units (cooled air output) with

- Newer, more efficient window/through-wall *AC* units (
- Newer, more efficient split system residential AC units (1.5 to 5.4 tons cooling)

- Newer, more efficient single zone packaged AC units (1.5 to 20 tons cooling)
- Newer, more efficient multi-zone packaged AC units (20 to 150 tons cooling)

Replace single building electric chiller (chilled water output) with

- Newer, more efficient electric chiller
- Single building natural gas engine-driven chiller
- Single building double-effect absorption chiller (steam, natural gas, or *LPG*)

Replace single building natural gas engine-driven chiller (chilled water output) with

- Single building conventional electric chiller
- Newer, more efficient natural gas engine-driven chiller
- Single building double-effect absorption chiller (steam, natural gas, or LPG)

Replace single building absorption chiller (fuels include: steam, high-temperature hot water, natural gas, and LPG – chilled water output) with

- Single building conventional electric chiller
- Single building natural gas engine-driven chiller
- Newer, more efficient single building double-effect absorption chiller (steam, natural gas, or LPG)

Replace district chilled water with

- Single building air-cooled electric chiller
- Single building air-cooled natural gas engine-driven chiller
- Single building air-cooled double-effect absorption chiller (steam, natural gas, or LPG)

Retrofits considered are switching from district chilled water to chilled water supplied by a single building chiller.

Heat Pumps or Heat/Cool Pairs

Refer to the discussion of heating retrofit alternatives for a list of possible retrofits for heat pumps and heat/cool pairs.

Envelope Retrofit Alternatives

The following retrofits are available for roof, walls, floor, and windows:

Roof/Ceiling Insulation (type depends on roof type)

- Attic Ceiling: Increase insulation by R-13
- Attic Ceiling: Increase insulation by R-19
- Attic Ceiling: Increase insulation by R-22
- Attic Ceiling: Increase insulation by R-30
- Attic Ceiling: Increase insulation by R-38
- Suspended Ceiling: Increase insulation by R-11
- Suspended Ceiling: Increase insulation by R-19
- Suspended Ceiling: Increase insulation by R-30
- Suspended Ceiling: Increase insulation by R-38
- Insulate Built-up Roof Surface (R-5) and Re-Roof
- Insulate Built-up Roof Surface (R-10) and Re-Roof
- Insulate Built-up Roof Surface (R-15) and Re-Roof
- Insulate Built-up Roof Surface (R-20) and Re-Roof

Wall Insulation (applicability of retrofit depends on wall construction material, presence of existing insulation, and space available)

- Blow-in Insulation to Fill Available Space
- Interior Masonry Surface: Increase insulation by R-4.1
- Interior Masonry Surface: Increase insulation by R-8.3
- Interior Masonry Surface: Increase insulation by R-10.3

- Interior Masonry Surface: Increase insulation by R-12.4

Floor Insulation (type depends on floor type)

- Insulate above Crawlspace: Increase insulation by R-11
- Insulate above Crawlspace: Increase insulation by R-19
- Insulate above Crawlspace: Increase insulation by R-30
- Insulate above Crawlspace: Increase insulation by R-38
- Insulate Perimeter of Slab on Grade: Increase insulation by R-4.1
- Insulate Perimeter of Slab on Grade: Increase insulation by R-6.2
- Insulate Perimeter of Slab on Grade: Increase insulation by R-8.3
- Insulate Perimeter of Slab on Grade: Increase insulation by R-12.4

Window Retrofits

- Add Storm Windows
- Add Retrofit Film
- Install Aluminum Frame Double Pane Window
- Install Aluminum Frame Double Pane Low-E Window
- Install Aluminum Frame Double Pane Super Low-E Window
- Install Aluminum Frame Double Pane Argon/Low-E Window
- Install Aluminum Frame Double Pane Argon/Super Low-E Window
- Install Thermal Break Aluminum Frame Double Pane Window
- Install Thermal Break Aluminum Frame Double Pane Low-E Window
- Install Thermal Break Aluminum Frame Double Pane Super Low-E Window
- Install Thermal Break Aluminum Frame Double Pane Argon/Low-E Window
- Install Thermal Break Aluminum Frame Double Pane Argon/Super Low-E Window

- Install Thermal Break Aluminum Frame Double Pane Heat Mirror Window
- Install Wood or Vinyl Frame Double Pane Window
- Install Wood or Vinyl Frame Double Pane Low-E Window
- Install Wood or Vinyl Frame Double Pane Super Low-E Window
- Install Wood or Vinyl Frame Double Pane Argon/Low-E Window
- Install Wood or Vinyl Frame Double Pane Argon/Super Low-E Window

Service Hot Water Retrofit Alternatives

All logical combinations of the retrofits listed below are also included:

Distributed Systems

Replace distributed tank system (electric, gas, oil, other fuels) with

- electric resistance water heater (R-16 insulation)
- electric resistance water heater (R-24 insulation)
- electric heat pump water heater
- 0.78-efficient distillate oil water heater
- 0.76-efficient gas water heater (residential only)
- 0.78-efficient gas water heater (commercial only)
- 0.80-efficient gas water heater (residential only)
- 0.82-efficient gas water heater (commercial only)
- 0.85-efficient gas water heater (residential only)
- 0.94-efficient gas water heater
- 0.76-efficient *LPG* water heater (residential only)
- 0.78-efficient LPG water heater (commercial only)
- 0.80-efficient LPG water heater (residential only)
- 0.82-efficient LPG water heater (commercial only)
- 0.85-efficient LPG water heater (residential only)

- 0.94-efficient LPG water heater
- electric water heater (R-16 insulation) with heat trap
- electric water heater (R-24 insulation) with heat trap
- 0.78-efficient distillate oil water heater with heat trap
- 0.76-efficient gas water heater with heat trap (residential only)
- 0.78-efficient gas water heater with heat trap (commercial only)
- 0.80-efficient gas water heater with heat trap (residential only)
- 0.82-efficient gas water heater with heat trap (commercial only)
- 0.85-efficient gas water heater with heat trap (residential only)
- 0.94-efficient gas water heater with heat trap
- 0.76-efficient LPG water heater with heat trap (residential only)
- 0.78-efficient LPG water heater with heat trap (commercial only)
- 0.80-efficient LPG water heater with heat trap (residential only)
- 0.82-efficient LPG water heater with heat trap (commercial only)
- 0.85-efficient LPG water heater with heat trap (residential only)
- 0.94-efficient LPG water heater with heat trap

Also:

- Insulate existing tank.
- Insulate pipe near water heater.
- nstall low-flow shower heads.
- Install faucet aerators.
- Decrease service hot water temperature (only possible for certain building types and only done in conjunction with flow reducers).

Loop Systems

Replace existing boiler in central tank circulating system (electric, oil, gas, coal, other fuels) with

- Conventional distillate oil boiler (83, 84, 86.5% combustion efficiencies)
- Conventional residual oil boiler (82, 83.5, 86% combustion efficiencies)
- Conventional gas boiler (80, 81.5, 84% combustion efficiencies)
- Gas pulse condensing boiler (87, 91% combustion efficiencies)
- Conventional LPG boiler (80, 81.5, 84% combustion efficiencies)
- LPG pulse condensing boiler (87, 91% combustion efficiencies)

Also:

- Insulate tank.
- Install low-flow shower heads.
- Install faucet aerators.

Replace existing heat exchanger in central tank circulating system (district steam or district high-temperature hot water) with

- Conventional distillate oil boiler (83, 84, 86.5% combustion efficiencies)
- Conventional residual oil boiler (82, 83.5, 86% combustion efficiencies)
- Conventional gas boiler (80, 81.5, 84% combustion efficiencies)
- Gas pulse condensing boiler (87, 91% combustion efficiencies)
- Conventional LPG boiler (80, 81.5, 84% combustion efficiencies)
- LPG pulse condensing boiler (87, 91% combustion efficiencies)

Also:

- Insulate tank.
- Install low-flow shower heads.
- Install faucet aerators.

Lighting Retrofit Alternatives

The Pacific Northwest National Laboratory has developed a large database of lighting technology configurations that are included in FEDS (over 500); these lighting technologies can be existing or 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.

Ventilation Retrofit Alternatives

Currently, ventilation retrofits are not available.

Miscellaneous Equipment Alternatives

Currently, miscellaneous equipment (plug-load) retrofits are not available.

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 1200) were derived from the database of over 18,000 motors contained within the MotorMaster+ 3.0 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-based summary report files for the sample cases have been installed to your FEDS\cases directory (default location is C:\Program Files\FEDS 5.0\cases). The files (sample-1.pdf and sample-2.pdf) 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://www.adobe.com/products/acrobat/readstep.html

Appendix D - Weather Station File Names and Locations

The weather station file names and locations used in FEDS are listed below.

State	File Name	Location	
AL	birminal	Birmingham	AL
	mobileal	Mobile	AL
	montgoal	Montgomery	AL
AK	adakak	Adak	AK
	annettak	Annette	AK
	bethelak	Bethel	AK
	bigdelak	Big Delta	AK
	gulkanak	Gulkana	AK
	homerak	Homer	AK
	juneauak	Juneau	AK
	kingsaak	King Salmon	AK
	kodiakak	Kodiak	AK
	mcgratak	McGrath	AK
	summitak	Summit	Ak
	yakutaak	Yakutat	AK
AR	fortsmar	Fort Smith	AR
	littlear	Little Rock	AR

AZ	phoeniaz	Phoenix	AZ
	prescoaz	Prescott	AZ
	tucsonaz	Tucson	AZ
	winsloaz	Winslow	AZ
	yumaaz	Yuma	AZ
CA	arcataca	Arcata	CA
	bakersca	Bakersfield	CA
	chinalca	China Lake	CA
	eltoroca	El Toro	CA
	fresnoca	Fresno	CA
	longbeca	Long Beach	CA
	losangca	Los Angeles	CA
	mountsca	Mount Shasta	CA
	oaklanca	Oakland	CA
	pointmca	Point Mugu	CA
	redbluca	Red Bluff	CA
	sacramca	Sacramento	CA
	sandieca	San Diego	CA
	sanfraca	San Francisco	CA
	santamca	Santa Maria	CA
	sunnyvca	Sunnyvale	CA

CO	coloraco	Colorado Springs	CO
	denverco	Denver	CO
	eagleco	Eagle	CO
	grandjco	Grand Junction	CO
	puebloco	Pueblo	CO
	hartfoct	Hartford	CT
DE	wilminde	Wilmington	DE
FL	apalacfl	Apalachicola	FL
	daytonfl	Daytona	FL
	jacksofl	Jacksonville	FL
	miamifl	Miami	FL
	orlandfl	Orlando	FL
	tallahfl	Tallahassee	FL
	tampafl	Tampa	FL
	westpafl	West Palm Beach	FL
GA	atlantga	Atlanta	GA
	augustga	Augusta	GA
	maconga	Macon	GA
	savannga	Savannah	GA
HI	barberhi	Barbers Point	HI
	honoluhi	Honolulu	HI

	lihuehi	Lihue	HI
IA	desmoiia	Des Moines	IA
	masoncia	Mason City	IA
	siouxcia	Sioux City	IA
ID	boiseid	Boise	ID
	lewistid	Lewiston	ID
	pocateid	Pocatello	ID
IL	chicagil	Chicago	IL
	molineil	Moline	IL
	springil	Springfield	IL
IN	indianin	Indianapolis	IN
	southbin	South Bend	IN
KS	dodgecks	Dodge City	KS
	goodlaks	Goodland	KS
	topekaks	Topeka	KS
KY	lexingky	Lexington	KY
	louisvky	Louisville	KY
LA	batonrla	Baton Rouge	LA
	lakechla	Lake Charles	LA
	neworlla	New Orleans	LA
	shrevela	Shreveport	LA

MA	bostonma	Boston	MA
MD	baltimmd	Baltimore	MD
	patuxemd	Patuxent	MD
ME	bangorme	Bangor	ME
	caribome	Caribou	ME
	portlame	Portland	ME
MI	alpenami	Alpena	MI
	detroimi	Detroit	MI
	flintmi	Flint	MI
	grandrmi	Grand Rapids	MI
	saultsmi	Sault Sainte Marie	MI
	travermi	Traverse City	MI
MN	duluthmn	Duluth	MN
	internmn	International Falls	MN
	minneamn	Minneapolis	MN
	rochesmn	Rochester	MN
MO	columbmo	Columbia	MO
	saintlmo	Saint Louis	MO
	springmo	Springfield	MO
MS	jacksoms	Jackson	MS
	meridims	Meridian	MS

MT	billinmt	Billings	MT
	cutbanmt	Cutbank	MT
	dillonmt	Dillon	MT
	glasgomt	Glasgow	MT
	greatfmt	Great Falls	MT
	helenamt	Helena	MT
	lewistmt	Lewistown	MT
	milescmt	Miles City	MT
	missoumt	Missoula	MT
NC	ashevinc	Asheville	NC
	capehanc	Cape Hatteras	NC
	charlonc	Charlotte	NC
	cherrync	Cherry Point	NC
	greensnc	Greensboro	NC
	raleignc	Raleigh	NC
ND	bismarnd	Bismarck	ND
	fargond	Fargo	ND
	minotnd	Minot	ND
NE	grandine	Grand Island	NE
	northpne	North Platte	NE
	omahane	Omaha	NE

	scottsne	Scottsbluff	NE
NH	NONE		
NJ	lakehunj	Lakehurst	NJ
	newarknj	Newark	NJ
NM	albuqunm	Albuquerque	NM
	claytonm	Clayton	NM
	roswelnm	Roswell	NM
	truthonm	Truth or Consequence	NM
	tucumcnm	Tucumcari	NM
NV	elkonv	Elko	NV
	elynv	Ely	NV
	lasvegnv	Las Vegas	NV
	lovelonv	Lovelock	NV
	renonv	Reno	NV
	tonopanv	Tonopah	NV
	winnemnv	Winnemucca	NV
	yuccafnv	Yucca Flats	NV
NY	albanyny	Albany	NY
	binghany	Binghamton	NY
	buffalny	Buffalo	NY
	massenny	Massena	NY

	newyocny	New York City	NY
	newyolny	La Guardia Airport	NY
	rochesny	Rochester	NY
	syracuny	Syracuse	NY
OH	akronoh	Akron	OH
	cincinoh	Cincinnati	OH
	cleveloh	Cleveland	OH
	columboh	Columbus	OH
	daytonoh	Dayton	OH
	toledooh	Toledo	OH
	youngsoh	Youngstown	OH
OK	oklahook	Oklahoma City	OK
	tulsaok	Tulsa	OK
OR	astorior	Astoria	OR
	medforor	Medford	OR
	northbor	North Bend	OR
	portlaor	Portland	OR
	redmonor	Redmond	OR
	salemor	Salem	OR
PA	allentpa	Allentown	PA
	avocapa	Avoca	PA

	eriepa	Erie	PA
	harrispa	Harrisburg	PA
	philadpa	Philadelphia	PA
	pittsbpa	Pittsburgh	PA
PI	wakeispi	Wake Island	PI
PR	sanjuapr	San Juan	PR
RI	providri	Providence	RI
SC	charlesc	Charleston	*SC*
	columbsc	Columbia	SC
	greenvsc	Greenville	SC
SD	huronsd	Huron	SD
	pierresd	Pierre	SD
	rapidcsd	Rapid City	SD
	siouxfsd	Sioux Falls	SD
TN	chattatn	Chattanooga	TN
	knoxvitn	Knoxville	TN
	memphitn	Memphis	TN
	nashvitn	Nashville	TN
TX	abilentx	Abilene	TX
	amariltx	Amarillo	TX
	austintx	Austin	TX

	brownstx	Brownsville	TX
	corpustx	Corpus Christi	TX
	delriotx	Del Rio	TX
	elpasotx	El Paso	TX
	fortwotx	Fort Worth	TX
	houstotx	Houston	TX
	kingsvtx	Kingsville	TX
	laredotx	Laredo	TX
	lubboctx	Lubbock	TX
	lufkintx	Lufkin	TX
	midlantx	Midland	TX
	portartx	Port Arthur	TX
	sanangtx	San Angelo	TX
	sananttx	San Antonio	TX
	shermatx	Sherman	TX
	wacotx	Waco	TX
	wichittx	Wichita Falls	TX
UT	brycecut	Bryce Canyon	UT
	cedarcut	Cedar City	UT
	saltlaut	Salt Lake City	UT
VA	norfolva	Norfolk	VA

	richmova	Richmond	VA
	roanokva	Roanoke	VA
VT	burlinvt	Burlington	VT
WA	olympiwa	Olympia	WA
	seattlwa	Seattle	WA
	spokanwa	Spokane	WA
	whidbewa	Whidbey Island	WA
	yakimawa	Yakima	WA
WI	eauclawi	Eau Claire	WI
	greenbwi	Green Bay	WI
	lacroswi	La Crosse	WI
	madisowi	Madison	WI
	milwauwi	Milwaukee	WI
WV	charlewv	Charleston	WV
WY	casperwy	Casper	WY
	cheyenwy	Cheyenne	WY
	rockspwy	Rock Springs	WY
	sheridwy	Sheridan	WY
BC	vancoubc	Vancouver	BC
AB	edmontab	Edmonton	AB
SW	NONE		

MB	winnipmb	Winnipeg	MB
ON	toronton	Toronto	ON
PQ	montrepq	Montreal	PQ
DC	washindc	Washington	DC

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. There are 3 different building classes within FEDS: civilian, military, and special. These classes describe the general characteristic of the buildings; a "military" building or use-area type may be the most appropriate choice for a "civilian" building or use-area and vise versa.

Civilian Building and Use-Area Types

The civilian building and *use-area* types are the same ones used by DOE in the *NBECS* 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: retails 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 is has living quarters for two, three, or four families or households

5 or More Unit Multifamily

Examples: apartment building

Characteristics: structure that is 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

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. 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: communication buildings, ADP, simulators, r&d electronics labs

Similar Civilian Type:

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:

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

Laundry

Examples: institutional/commercial laundries and dry cleaning plants

Similar Civilian Type:

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:

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

Production and/or Process

Examples: industrial buildings, foundries

Similar Civilian Type:

Characteristics: process dominated consumption

Recreation

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

Similar Civilian Type:

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

Schools and/or Training

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

Similar Civilian Type: Education

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

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

Storage

Examples: hazardous materials storage, ammunition storage

Similar Civilian Type:

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

Special Building Types

The special building class allows FEDS to model systems that are unique to a specific type of building. Two new building types have been added under the special *building set* class: commissary - sales and commissary - warehouse. In both of these building types FEDS 5.0 allows detailed modeling of refrigerated cases. All common case configurations can be modeled including: single and multi-deck, glass doored, roll-in, closed-service, walk in cooler, and self-contained units. The modeling accounts for all significant gains to the

refrigerated cases, case *consumption*, and sensible and latent interaction with the *HVAC* system.

Commissary – Sales

Examples: Commissary sales and administration area

Similar Types: Military Commissary and Administration

Characteristics: military commissary building with detailed refrigeration modeling and two use-areas (90% commissary and 10% administration)

Commissary – Warehouse

Examples: Commissary warehouse area

Similar Types: Military warehouse

Characteristics: military warehouse with detailed refrigeration modeling

Appendix F - FEDS Wall and Roof Types

FEDS Wall Types

Description	Wall Construction Type
Wood siding on wood frame	0
Masonry façade on wood frame	1
Masonry façade on masonry frame	2
Curtain wall	3
Prefabricated metal panels	4

Wood siding over wood frame – also includes plastic or metal siding.

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.

Curtain wall – steel frame with brick, stone, stucco, or other masonry exterior.

Prefabricated metal panels – outside walls which are factory fabricated aluminum or galvanized steel panel which are fastened to the building frame.

FEDS Roof Types

Description	Roof Construction Type
Built-up	0
Prefabricated metal panels	1
Shingles or shakes	2

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.

Prefabricated metal panels – light gauge metal roofing sheets (often corrugated).

Shingles or shakes – a series of overlapping rows of roofing material, including wood, plastic, fiber glass, baked clay, tile, slate, asbestos, asphalt, and aluminum.

Appendix G - Fixture Name Abbreviations

Exit Signs

Abbreviation	Description	
EX1	EXIT – INC (2X20)	Two 20-watt incandescent
EX2	EXIT – INC (2X15)	Two 15-watt incandescent
EX3	EXIT – FL 1-PL9	One 9-watt compact fluorescent
EX4	EXIT – FL 2-PL9	Two 9-watt compact fluorescent
EX5	EXIT – FL RET 1-PL9	One 9-watt compact fluorescent
EX6	EXIT – LED	Light emitting diode
EX7	EXIT – SELF LUMINOUS	Tritium gas self-luminous
EX8	EXIT – INC (2X25)	Two 25-watt incandescent
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	Light emitting capacitor (LEC)

Fluorescent Lamps

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.

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

Table 1. Fixture Dimensions

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 eights of an inch; e.g., a T12 lamp has a diameter of 12/8 or 1.5 inches. Table 2 lists the possible lamp types and their descriptions.

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),
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
F23T5	28-watt T5 lamp, 46-in. length
F14T5	14-watt T5 lamp, 22-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

Table 2. Lamp Types

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

Ballast Type	Description
STD1	Standard magnetic ballast designed for one lamp
STD2	Standard magnetic ballast designed for two lamps; for four-lamp

STD1,2	Combination of one lamp and two lamp standard magnetic
EEF1	Energy-efficient magnetic ballast designed for one lamp
EEF2	Energy-efficient magnetic ballast designed for two lamps; for four-
EEF1,2	Combination of one- and two-lamp energy-efficient magnetic
ELC1	Electronic ballast designed for one lamp
ELC2	Electronic ballast designed for two lamps; for four-lamp fixtures,
ELC1,2	Combination of one- and two-lamp electronic ballasts, for use with
ELC3	Electronic ballast designed for three lamps
ELC4	Electronic ballast designed for four lamps

Table 3. Ballast Type

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.

Compact Fluorescent Lamps

Abbreviation	Description	
CF1	CFL 7 INTEGRAL UNIT	7-watt compact fluorescent lamp
CF2	CFL 9 INTEGRAL UNIT	9-watt compact fluorescent lamp
CF3	CFL 11 INTEGRAL UNIT	11-watt compact fluorescent lamp
CF4	CFL 15 INTEGRAL UNIT	15-watt compact fluorescent lamp
CF5	CFL 18 INTEGRAL UNIT	18-watt compact fluorescent lamp
CF6	CFL 20 INTEGRAL UNIT	20-watt compact fluorescent lamp
CF7	CFL 23 INTEGRAL UNIT	23-watt compact fluorescent lamp

CF8	CFL 25 INTEGRAL UNIT	25-watt compact fluorescent lamp
CF9	CFL 26 INTEGRAL UNIT	26-watt compact fluorescent lamp
CF10	CFL 27 INTEGRAL UNIT	27-watt compact fluorescent lamp
CF11	CFL 30 INTEGRAL UNIT	30-watt compact fluorescent lamp
CF12	CFL 15 GLOBE UNIT	15-watt compact fluorescent globe
CF13	CFL 18 GLOBE UNIT	18-watt compact fluorescent globe
CF14	CFL 5 + BLST UNIT	5-watt compact fluorescent lamp and
CF15	CFL 7 + BLST UNIT	7-watt compact fluorescent lamp and
CF16	CFL 9 + BLST UNIT	9-watt compact fluorescent lamp and
CF17	CFL 2-9 + BLST UNIT	Two 9-watt compact fluorescent lamps
CF18	CFL 11 + BLST UNIT	11-watt compact fluorescent lamp and
CF19	CFL 13 + BLST UNIT	13-watt compact fluorescent lamp and
CF20	CFL 2-13 + BLST UNIT	Two 13-watt compact fluorescent
CF21	CFL 15 + BLST UNIT	15-watt compact fluorescent lamp and
CF22	CFL 20 + BLST UNIT	20-watt compact fluorescent lamp and
CF23	CFL 7 CEIL FIXT	7-watt compact fluorescent hardwired
CF24	CFL 11 CEIL FIXT	11-watt compact fluorescent hardwired
CF25	CFL 15 CEIL FIXT	15-watt compact fluorescent hardwired
CF26	CFL 2-11 CEIL FIXT	Hardwired ceiling fixture w/two 11-watt
CF27	CFL 2-15 CEIL FIXT	Hardwired ceiling fixture w/two 15-watt
CF28	CFL 7 WALL FIXT	7-watt compact fluorescent hardwired

CF29	CFL 11 WALL FIXT	11-watt compact fluorescent hardwired
CF30	CFL 15 WALL FIXT	15-watt compact fluorescent hardwired
CF31	CFL 2-11 WALL FIXT	Hardwired wall fixture w/two 11-watt
CF32	CFL 2-15 WALL FIXT	Hardwired wall fixture w/two 15-watt
CF33	CFL 7 CAN	7-watt compact fluorescent hardwired
CF34	CFL 11 CAN	11-watt compact fluorescent hardwired
CF35	CFL 15 CAN	15-watt compact fluorescent hardwired

High-Pressure Sodium Lamps

Abbreviation	**Description**	
HS1	HPS 35 POLE	35-watt high-pressure sodium
HS2	HPS 50 POLE	50-watt high-pressure sodium
HS3	HPS 70 POLE	70-watt high-pressure sodium
HS4	HPS 100 POLE	100-watt high-pressure sodium
HS5	HPS 150 POLE	150-watt high-pressure sodium
HS6	HPS 200 POLE	200-watt high-pressure sodium
HS7	HPS 250 POLE	250-watt high-pressure sodium
HS8	HPS 310 POLE	310-watt high-pressure sodium
HS9	HPS 400 POLE	400-watt high-pressure sodium
HS10	HPS 1000 POLE	1000-watt high-pressure sodium
HS11	HPS 35 PEND	35-watt high-pressure sodium
HS12	HPS 50 PEND	50-watt high-pressure sodium

HS13	HPS 70 PEND	70-watt high-pressure sodium
HS14	HPS 100 PEND	100-watt high-pressure sodium
HS15	HPS 150 PEND	150-watt high-pressure sodium
HS16	HPS 200 PEND	200-watt high-pressure sodium
HS17	HPS 250 PEND	250-watt high-pressure sodium
HS18	HPS 310 PEND	310-watt high-pressure sodium
HS19	HPS 400 PEND	400-watt high-pressure sodium
HS20	HPS 1000 PEND	1000-watt high-pressure sodium
HS21	HPS 35 WALL	35-watt high-pressure sodium wall
HS22	HPS 50 WALL	50-watt high-pressure sodium wall
HS23	HPS 70 WALL	70-watt high-pressure sodium wall
HS24	HPS 100 WALL	100-watt high-pressure sodium
HS25	HPS 150 WALL	150-watt high-pressure sodium
HS26	HPS 200 WALL	200-watt high-pressure sodium
HS27	HPS 250 WALL	250-watt high-pressure sodium
HS28	HPS 310 WALL	310-watt high-pressure sodium
HS29	HPS 400 WALL	400-watt high-pressure sodium
HS30	HPS 35 FLD	35-watt high-pressure sodium
HS31	HPS 70 FLD	70-watt high-pressure sodium
HS32	HPS 50 CAN	50-watt high-pressure sodium can
HS33	HPS 70 CAN	70-watt high-pressure sodium can

HS34	HPS 100 CAN	100-watt high-pressure sodium
HS35	HPS 150 REP FOR MV	150-watt high-pressure sodium
HS36	HPS 215 REP FOR MV	215-watt high-pressure sodium
HS37	HPS 220 REP FOR MV	220-watt high-pressure sodium
HS38	HPS 360 REP FOR MV	360-watt high-pressure sodium
HS39	HPS 880 REP FOR MV	880-watt high-pressure sodium
HS40	HPS 940 REP FOR MV	940-watt high-pressure sodium
HS41	HPS 150 REP FOR MV	150-watt high-pressure sodium
HS42	HPS 215 REP FOR MV	215-watt high-pressure sodium
HS43	HPS 220 REP FOR MV	220-watt high-pressure sodium
HS44	HPS 360 REP FOR MV	360-watt high-pressure sodium
HS45	HPS 880 REP FOR MV	880-watt high-pressure sodium
HS46	HPS 940 REP FOR MV	940-watt high-pressure sodium
HS47	HPS 150 REP FOR MV	150-watt high-pressure sodium
HS48	HPS 215 REP FOR MV	215-watt high-pressure sodium
HS49	HPS 220 REP FOR MV	220-watt high-pressure sodium
HS50	HPS 360 REP FOR MV	360-watt high-pressure sodium
HS51	HPS 880 REP FOR MV	880-watt high-pressure sodium
HS52	HPS 940 REP FOR MV	940-watt high-pressure sodium
HS53	HPS 70 IS PEND	70-watt high-pressure sodium
HS54	HPS 100 IS PEND	100-watt high-pressure sodium

HS55	HPS 150 IS PEND	150-watt high-pressure sodium
HS56	HPS 250 IS PEND	250-watt high-pressure sodium
HS57	HPS 400 IS PEND	400-watt high-pressure sodium
HS58	HPS 70 IS WALL	70-watt high-pressure sodium
HS59	HPS 100 IS WALL	100-watt high-pressure sodium
HS60	HPS 150 IS WALL	150-watt high-pressure sodium
HS61	HPS 250 IS WALL	250-watt high-pressure sodium
HS62	HPS 400 IS WALL	400-watt high-pressure sodium
HS63	HPS 70 IS POLE	70-watt high-pressure sodium
HS64	HPS 100 IS POLE	100-watt high-pressure sodium
HS65	HPS 150 IS POLE	150-watt high-pressure sodium
HS66	HPS 250 IS POLE	250-watt high-pressure sodium
HS67	HPS 400 IS POLE	400-watt high-pressure sodium
HS68	HPS 35 WL PEND	35-watt high-pressure sodium
HS69	HPS 50 WL PEND	50-watt high-pressure sodium
HS70	HPS 100 WL PEND	100-watt high-pressure sodium
HS71	HPS 35 WL WALL	35-watt high-pressure sodium
HS72	HPS 50 WL WALL	50-watt high-pressure sodium
HS73	HPS 100 WL WALL	100-watt high-pressure sodium
HS74	HPS 35 WL POLE	35-watt high-pressure sodium
HS75	HPS 50 WL POLE	50-watt high-pressure sodium

HS76	HPS 100 WL POLE	100-watt high-pressure sodium
HS77	HPS 150 REP FOR MH	150-watt high-pressure sodium
HS78	HPS 215 REP FOR MH	215-watt high-pressure sodium
HS79	HPS 220 REP FOR MH	220-watt high-pressure sodium
HS80	HPS 360 REP FOR MH	360-watt high-pressure sodium
HS81	HPS 880 REP FOR MH	880-watt high-pressure sodium
HS82	HPS 940 REP FOR MH	940-watt high-pressure sodium
HS83	HPS 150 REP FOR MH	150-watt high-pressure sodium
HS84	HPS 215 REP FOR MH	215-watt high-pressure sodium
HS85	HPS 220 REP FOR MH	220-watt high-pressure sodium
HS86	HPS 360 REP FOR MH	360-watt high-pressure sodium
HS87	HPS 880 REP FOR MH	880-watt high-pressure sodium
HS88	HPS 940 REP FOR MH	940-watt high-pressure sodium
HS89	HPS 150 REP FOR MH	150-watt high-pressure sodium
HS90	HPS 215 REP FOR MH	215-watt high-pressure sodium
HS91	HPS 220 REP FOR MH	220-watt high-pressure sodium
HS92	HPS 360 REP FOR MH	360-watt high-pressure sodium
HS93	HPS 880 REP FOR MH	880-watt high-pressure sodium
HS94	HPS 940 REP FOR MH	940-watt high-pressure sodium
HS95	HPS 70 POLE ELC	70-watt high-pressure sodium
HS96	HPS 70 PEND ELC	70-watt high-pressure sodium

HS97	HPS 70 WALL ELC	70-watt high-pressure sodium wall
HS98	HPS 70 FLD ELC	70-watt high-pressure sodium
HS99	HPS 70 CAN ELC	70-watt high-pressure sodium can
HS100	HPS 100 POLE ELC	100-watt high-pressure sodium
HS101	HPS 100 PEND ELC	100-watt high-pressure sodium
HS102	HPS 100 WALL ELC	100-watt high-pressure sodium
HS103	HPS 100 CAN ELC	100-watt high-pressure sodium

Incandescent Lamps

Abbreviation	Description	
IN1	INC 40 CEIL	40-watt incandescent ceiling fixture
IN2	INC 2-40 CEIL	Incandescent ceiling fixture w/two 40-watt
IN3	INC 3-40 CEIL	Incandescent ceiling fixture w/three 40-watt
IN4	INC 4-40 CEIL	Incandescent ceiling fixture w/four 40-watt
IN5	INC 60 CEIL	60-watt incandescent ceiling fixture
IN6	INC 2-60 CEIL	Incandescent ceiling fixture w/two 60-watt
IN7	INC 3-60 CEIL	Incandescent ceiling fixture w/three 60-watt
IN8	INC 75 CEIL	75-watt incandescent ceiling fixture
IN9	INC 2-75 CEIL	Incandescent ceiling fixture w/two 75-watt
IN10	INC 3-75 CEIL	Incandescent ceiling fixture w/three 75-watt
IN11	INC 100 CEIL	100-watt incandescent ceiling fixture
IN12	INC 2-100 CEIL	Incandescent ceiling fixture w/two 100-watt

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	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
IN21	INC 3-40 WALL	Incandescent wall fixture w/three 40-watt
IN22	INC 4-40 WALL	Incandescent wall fixture w/four 40-watt
IN23	INC 60 WALL	60-watt incandescent wall fixture
IN24	INC 2-60 WALL	Incandescent wall fixture w/two 60-watt
IN25	INC 75 WALL	75-watt incandescent wall fixture
IN26	INC 2-75 WALL	Incandescent wall fixture w/two 75-watt
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

Low-Pressure Sodium Lamps

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
LS6	LPS 180 PEND	180-watt low-pressure sodium pendant
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

Metal Halide Lamps

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
MH34	MH 150 HE PEND	150-watt metal halide high-efficiency
MH35	MH 175 HE PEND	175-watt metal halide high-efficiency
MH36	MH 250 HE PEND	250-watt metal halide high-efficiency
MH37	MH 400 HE PEND	400-watt metal halide high-efficiency
MH38	MH 1000 HE PEND	1000-watt metal halide high-efficiency
MH39	MH 70 HE WALL	70-watt metal halide high-efficiency wall
MH40	MH 150 HE WALL	150-watt metal halide high-efficiency wall
MH41	MH 175 HE WALL	175-watt metal halide high-efficiency wall
MH42	MH 250 HE WALL	250-watt metal halide high-efficiency wall
MH43	MH 400 HE WALL	400-watt metal halide high-efficiency wall
MH44	MH 1000 HE WALL	1000-watt metal halide high-efficiency wall
MH45	MH 70 HE POLE	70-watt metal halide high-efficiency pole
MH46	MH 150 HE POLE	150-watt metal halide high-efficiency pole
MH47	MH 175 HE POLE	175-watt metal halide high-efficiency pole
MH48	MH 250 HE POLE	250-watt metal halide high-efficiency pole
MH49	MH 400 HE POLE	400-watt metal halide high-efficiency pole
MH50	MH 1000 HE POLE	1000-watt metal halide high-efficiency pole
MH51	MH 32 POLE ELC	32-watt metal halide pole fixture
MH52	MH 50 PEND ELC	50-watt metal halide pendant fixture

MH53	MH 32 WALL ELC	32-watt metal halide wall fixture
MH54	MH 50 POLE ELC	50-watt metal halide pole fixture
MH55	MH 50 PEND ELC	50-watt metal halide pendant fixture
MH56	MH 50 WALL ELC	50-watt metal halide wall fixture
MH57	MH 50 CAN ELC	50-watt metal halide can fixture
MH58	MH 70 POLE ELC	70-watt metal halide pole fixture
MH59	MH 70 PEND ELC	70-watt metal halide pendant fixture
MH60	MH 70 WALL ELC	70-watt metal halide wall fixture
MH61	MH 70 CAN ELC	70-watt metal halide can fixture
MH62	MH 100 POLE ELC	100-watt metal halide pole fixture
MH 63	MH 100 PEND ELC	100-watt metal halide pendant fixture
MH64	MH 100 WALL ELC	100-watt metal halide wall fixture
MH65	MH 150 HE POLE	150-watt metal halide high-efficiency pole
MH66	MH 150 HE PEND	150-watt metal halide high-efficiency
MH67	MH 150 HE WALL	150-watt metal halide high-efficiency wall

Mercury Vapor Lamps

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 - Fixture Codes

Fixture	Fixture Name		Fixture	Fixture Name
CF1	CFL 7 INTEGRAL UNIT ELC		FL252	FL 1X8 4F96T8 ELC2 REF
CF2	CFL 9 INTEGRAL UNIT ELC		FL253	FL 1X8 2F96T8 ELC2 REF
CF3	CFL 11 INTEGRAL UNIT ELC		FL254	FL 1X8 1F96T8 ELC1 REF
CF4	CFL 15 INTEGRAL UNIT ELC		FL255	FL 1X8 3F96T8 ELC1,2
CF5	CFL 18 INTEGRAL UNIT ELC		FL256	FL 2X2 2F14T5 ELC2
CF6	CFL 20 INTEGRAL UNIT ELC		FL257	FL 2X2 4F14T5 ELC4
CF7	CFL 23 INTEGRAL UNIT ELC		FL258	FL 1X4 1F28T5 ELC1
CF8	CFL 25 INTEGRAL UNIT ELC		FL259	FL 1X4 2F28T5 ELC2
CF9	CFL 26 INTEGRAL UNIT ELC		FL260	FL 2X4 2F28T5 ELC2
CF10	CFL 27 INTEGRAL UNIT ELC		FL261	FL 2X4 3F28T5 ELC3
CF11	CFL 30 INTEGRAL UNIT		FL262	FL 2X4 4F28T5 ELC4
CF12	CFL 15 GLOBE UNIT		FL263	FL 2X2 2F14T5 ELC2 REF
CF13	CFL 18 GLOBE UNIT		FL264	FL 2X2 4F14T5 ELC4 REF
CF14	CFL 5 + BLST UNIT		FL265	FL 1X4 1F28T5 ELC1 REF
CF15	CFL 7 + BLST UNIT		FL266	FL 1X4 2F28T5 ELC2 REF
CF16	CFL 9 + BLST UNIT		FL267	FL 2X4 2F28T5 ELC2 REF
CF17	CFL 2-9 + BLST UNIT		FL268	FL 2X4 3F28T5 ELC3 REF
CF18	CFL 11 + BLST UNIT		FL269	FL 2X4 4F28T5 ELC4 REF
CF19	CFL 13 + BLST UNIT		HS1	HPS 35 POLE

CF20	CFL 2-13 + BLST UNIT		HS2	HPS 50 POLE
CF21	CFL 15 + BLST UNIT		HS3	HPS 70 POLE
CF22	CFL 20 + BLST UNIT		HS4	HPS 100 POLE
CF23	CFL 7 CEIL FIXT		HS5	HPS 150 POLE
CF24	CFL 11 CEIL FIXT		HS6	HPS 200 POLE
CF25	CFL 15 CEIL FIXT		HS7	HPS 250 POLE
CF26	CFL 2-11 CEIL FIXT		HS8	HPS 310 POLE
CF27	CFL 2-15 CEIL FIXT		HS9	HPS 400 POLE
CF28	CFL 7 WALL FIXT		HS10	HPS 1000 POLE
CF29	CFL 11 WALL FIXT		HS11	HPS 35 PEND
CF30	CFL 15 WALL FIXT		HS12	HPS 50 PEND
CF31	CFL 2-11 WALL FIXT		HS13	HPS 70 PEND
CF32	CFL 2-15 WALL FIXT		HS14	HPS 100 PEND
CF33	CFL 7 CAN		HS15	HPS 150 PEND
CF34	CFL 11 CAN		HS16	HPS 200 PEND
CF35	CFL 15 CAN		HS17	HPS 250 PEND
EX1	EXIT – INC (2X20)		HS18	HPS 310 PEND
EX2	EXIT – INC (2X15)		HS19	HPS 400 PEND
EX3	EXIT – FL 1-PL9		HS20	HPS 1000 PEND
EX4	EXIT – FL 2-PL9		HS21	HPS 35 WALL
EX5	EXIT – FL RET 1-PL9		HS22	HPS 50 WALL

EX6	EXIT – LED		HS23	HPS 70 WALL
EX7	EXIT – SELF LUMINOUS		HS24	HPS 100 WALL
EX8	EXIT – INC (2X25)		HS25	HPS 150 WALL
EX9	EXIT – FLEX TUBE 8		HS26	HPS 200 WALL
EX10	EXIT – LED RETRO KIT		HS27	HPS 250 WALL
EX11	EXIT – PANEL		HS28	HPS 310 WALL
EX12	EXIT – PANEL RETRO KIT		HS29	HPS 400 WALL
FL1	FL 2X4 4F40T12 STD2		HS30	HPS 35 FLD
FL2	FL 2X4 3F40T12 STD1,2		HS31	HPS 70 FLD
FL3	FL 2X4 2F40T12 STD2		HS32	HPS 50 CAN
FL4	FL 1X4 2F40T12 STD2		HS33	HPS 70 CAN
FL5	FL 1X4 2F40T12 STD1		HS34	HPS 100 CAN
FL6	FL 2X2 2F40T12U STD2		HS35	HPS 150 REP FOR MV
FL7	FL 2X4 4F40T12 STD2 REF		HS36	HPS 215 REP FOR MV
FL8	FL 2X4 3F40T12 STD1,2 REF		HS37	HPS 220 REP FOR MV
FL9	FL 2X4 2F40T12 STD2 REF		HS38	HPS 360 REP FOR MV
FL10	FL 1X4 2F40T12 STD2 REF		HS39	HPS 880 REP FOR MV
FL11	FL 1X4 1F40T12 STD1 REF		HS40	HPS 940 REP FOR MV
FL12	FL 2X2 2F40T12U STD2 REF		HS41	HPS 150 REP FOR MV
FL13	FL 2X4 4F40T12 EEF2		HS42	HPS 215 REP FOR MV
FL14	FL 2X4 3F40T12 EEF1,2		HS43	HPS 220 REP FOR MV

FL15	FL 2X4 2F40T12 EEF2		HS44	HPS 360 REP FOR MV
FL16	FL 1X4 2F40T12 EEF2		HS45	HPS 880 REP FOR MV
FL17	FL 1X4 1F40T12 EEF1		HS46	HPS 940 REP FOR MV
FL18	FL 2X2 2F40T12U EEF2		HS47	HPS 150 REP FOR MV
FL19	FL 2X4 4F40T12 EEF 2 REF		HS48	HPS 215 REP FOR MV
FL20	FL 2X4 3F40T12 EEF1,2 REF		HS49	HPS 220 REP FOR MV
FL21	FL 2X4 2F40T12 EEF2 REF		HS50	HPS 360 REP FOR MV
FL22	FL 1X4 2F40T12 EEF2 REF		HS51	HPS 880 REP FOR MV
FL23	FL 1X4 1F40T12 EEF1 REF		HS52	HPS 940 REP FOR MV
FL24	FL 2X2 2F40T12U EEF2 REF		HS53	HPS 70 IS PEND
FL25	FL 2X4 4F40T12 ELC2		HS54	HPS 100 IS PEND
FL26	FL 2X4 3F40T12 ELC1,2		HS55	HPS 150 IS PEND
FL27	FL 2X4 2F40T12 ELC2		HS56	HPS 250 IS PEND
FL28	FL 1X4 2F40T12 ELC2		HS57	HPS 400 IS PEND
FL29	FL 1X4 1F40T12 ELC1		HS58	HPS 70 IS WALL
FL30	FL 2X2 2F40T12U ELC2		HS59	HPS 100 IS WALL
FL31	FL 2X4 4F40T12 ELC2 REF		HS60	HPS 150 IS WALL
FL32	FL 2X4 3F40T12 ELC1,2 REF		HS61	HPS 250 IS WALL
FL33	FL 2X4 2F40T12 ELC2 REF		HS62	HPS 400 IS WALL
FL34	FL 1X4 2F40T12 ELC2 REF		HS63	HPS 70 IS POLE
FL35	FL 1X4 1F40T12 ELC1 REF		HS64	HPS 100 IS POLE

FL36	FL 2X2 2F40T12U ELC2 REF		HS65	HPS 150 IS POLE
FL37	FL 2X4 4F32T8 EEF2		HS66	HPS 250 IS POLE
FL38	FL 2X4 3F32T8 EEF1,2		HS67	HPS 400 IS POLE
FL39	FL 2X4 2F32T8 EEF2		HS68	HPS 35 WL PEND
FL40	FL 1X4 2F32T8 EEF2		HS69	HPS 50 WL PEND
FL41	FL 1X4 1F32T8 EEF1		HS70	HPS 100 WL PEND
FL42	FL 2X2 2F32T8U EEF2		HS71	HPS 35 WL WALL
FL43	FL 2X4 4F32T8 EEF2 REF		HS72	HPS 50 WL WALL
FL44	FL 2X4 3F32T8 EEF1,2 REF		HS73	HPS 100 WL WALL
FL45	FL 2X4 2F32T8 EEF2 REF		HS74	HPS 35 WL POLE
FL46	FL 1X4 2F32T8 EEF2 REF		HS75	HPS 50 WL POLE
FL47	FL 1X4 1F32T8 EEF1 REF		HS76	HPS 100 WL POLE
FL48	FL 2X2 2F32T8U EEF2 REF		HS77	HPS 150 REP FOR MH
FL49	FL 2X4 4F32T8 ELC2		HS78	HPS 215 REP FOR MH
FL50	FL 2X4 3F32T8 ELC1,2		HS79	HPS 220 REP FOR MH
FL51	FL 2X4 2F32T8 ELC2		HS80	HPS 360 REP FOR MH
FL52	FL 1X4 2F32T8 ELC2		HS81	HPS 880 REP FOR MH
FL53	FL 1X4 1F32T8 ELC1		HS82	HPS 940 REP FOR MH
FL54	FL 2X2 2F32T8U ELC2		HS83	HPS 150 REP FOR MH
FL55	FL 2X4 4F32T8 ELC2 REF		HS84	HPS 215 REP FOR MH
FL56	FL 2X4 3F32T8 ELC1,2 REF		HS85	HPS 220 REP FOR MH

FL57	FL2X4 2F32T8 ELC2 REF		HS86	HPS 360 REP FOR MH
FL58	FL 1X4 2F32T8 ELC2 REF		HS87	HPS 880 REP FOR MH
FL59	FL 1X4 1F32T8 ELC1 REF		HS88	HPS 940 REP FOR MH
FL60	FL 2X2 2F32T8U ELC2 REF		HS89	HPS 150 REP FOR MH
FL61	FL 1X8 4F96T12 STD2		HS90	HPS 215 REP FOR MH
FL62	FL 1X8 2F96T12 STD2		HS91	HPS 220 REP FOR MH
FL63	FL 1X8 1F96T12 STD1		HS92	HPS 360 REP FOR MH
FL64	FL 1X8 4F96T12 STD2 REF		HS93	HPS 880 REP FOR MH
FL65	FL 1X8 2F96T12 STD2 REF		HS94	HPS 940 REP FOR MH
FL66	FL 1X8 1F96T12 STD1 REF		HS95	HPS 70 POLE ELC
FL67	FL 1X8 4F96T12 EEF2		HS96	HPS 70 PEND ELC
FL68	FL 1X8 2F96T12 EEF2		HS97	HPS 70 WALL ELC
FL69	FL 1X8 1F96T12 EEF1		HS98	HPS 70 FLD ELC
FL70	FL 1X8 4F96T12 EEF2 REF		HS99	HPS 70 CAN ELC
FL71	FL 1X8 2F96T12 EEF2 REF		HS100	HPS 100 POLE ELC
FL72	FL 1X8 1F96T12 EEF1 REF		HS101	HPS 100 PEND ELC
FL73	FL 1X8 4F96T12 ELC2		HS102	HPS 100 WALL ELC
FL74	FL 1X8 2F96T12 ELC2		HS103	HPS 100 CAN ELC
FL75	FL 1X8 1F96T12 ELC1		IN1	INC 40 CEIL
FL76	FL 1X8 4F96T12 ELC2 REF		IN2	INC 2-40 CEIL
FL77	FL 1X8 2F96T12 ELC2 REF		IN3	INC 3-40 CEIL

FL78	FL 1X8 1F96T12 ELC1 REF		IN4	INC 4-40 CEIL
FL79	FL 2X4 4F40T12ES STD2		IN5	INC 60 CEIL
FL80	FL 2X4 3F40T12ES STD1,2		IN6	INC 2-60 CEIL
FL81	FL 2X4 2F40T12ES STD2		IN7	INC 3-60 CEIL
FL82	FL 1X4 2F40T12ES STD2		IN8	INC 75 CEIL
FL83	FL 1X4 1F40T12ES STD1		IN9	INC 2-75 CEIL
FL84	FL 2X2 2F40T12UES STD2		IN10	INC 3-75 CEIL
FL85	FL 2X4 4F40T12ES STD2 REF		IN11	INC 100 CEIL
FL86	FL 2X4 3F40T12ES STD1,2		IN12	INC 2-100 CEIL
FL87	FL 2X4 2F40T12ES STD2 REF		IN13	INC 25 TABLE LAMP
FL88	FL 1X4 2F40T12ES STD2 REF		IN14	INC 40 TABLE LAMP
FL89	FL 1X4 1F40T12ES STD1 REF		IN15	INC 60 TABLE LAMP
FL90	FL 2X2 2F40T12UES STD2		IN16	INC 75 TABLE LAMP
FL91	FL 2X4 4F40T12ES EEF2		IN17	INC 100 TABLE LAMP
FL92	FL 2X4 3F40T12ES EEF1,2		IN18	INC 25 WALL
FL93	FL 2X4 2F40T12ES EEF2		IN19	INC 40 WALL
FL94	FL 1X4 2F40T12ES EEF2		IN20	INC 2-40 WALL
FL95	FL 1X4 1F40T12ES EEF1		IN21	INC 3-40 WALL
FL96	FL 2X2 2F40T12UES EEF2		IN22	INC 4-40 WALL
FL97	FL 2X4 4F40T12ES EEF2 REF		IN23	INC 60 WALL
FL98	FL 2X4 3F40T12ES EEF1,2		IN24	INC 2-60 WALL

FL99	FL 2X4 2F40T12ES EEF2 REF		IN25	INC 75 WALL
FL100	FL 1X4 2F40T12ES EEF2 REF		IN26	INC 2-75 WALL
FL101	FL 1X4 1F40T12ES EEF1 REF		IN27	INC 100 WALL
FL102	FL 2X2 2F40T12UES EEF2		IN28	INC 150 PEND
FL103	FL 2X4 4F40T12ES ELC2		IN29	INC 200 PEND
FL104	FL 2X4 3F40T12ES ELC1,2		IN30	INC 300 PEND
FL105	FL 2X4 2F40T12ES ELC2		IN31	INC 40 CAN
FL106	FL 1X4 2F40T12ES ELC2		IN32	INC 60 CAN
FL107	FL 1X4 1F40T12ES ELC1		IN33	INC 75 CAN
FL108	FL 2X2 2F40T12UES ELC2		IN34	INC 100 CAN
FL109	FL 2X4 4F40T12ES ELC2 REF		IN35	INC 40 FLD
FL110	FL 2X4 3F40T12ES ELC1,2		IN36	INC 60 FLD
FL111	FL 2X4 2F40T12ES ELC2 REF		IN37	INC 75 FLD
FL112	FL 1X4 2F40T12ES ELC2 REF		IN38	INC 100 FLD
FL113	FL 1X4 1F40T12ES ELC1 REF		IN39	INC 150 FLD
FL114	FL 2X2 2F40T12UES ELC2		IN40	INC 200 FLD
FL115	FL 1X8 4F96T12ES STD2		IN41	INC 250 FLD
FL116	FL 1X8 2F96T12ES STD2		IN42	INC 500 FLD
FL117	FL 1X8 1F96T12ES STD1		LS1	LPS 18 PEND
FL118	FL 1X8 4F96T12ES STD2 REF		LS2	LPS 35 PEND
FL119	FL 1X8 2F96T12ES STD2 REF		LS3	LPS 55 PEND

FL120	FL 1X8 1F96T12ES STD1 REF		LS4	LPS 90 PEND
FL121	FL 1X8 4F96T12ES EEF2		LS5	LPS 135 PEND
FL122	FL 1X8 2F96T12ES EEF2		LS6	LPS 180 PEND
FL123	FL 1X8 1F96T12ES EEF1		LS7	LPS 18 POLE
FL124	FL 1X8 4F96T12ES EEF2 REF		LS8	LPS 35 POLE
FL125	FL 1X8 2F96T12ES EEF2 REF		LS9	LPS 55 POLE
FL126	FL 1X8 1F96T12ES EEF1 REF		LS10	LPS 90 POLE
FL127	FL 1X8 4F96T12ES ELC2		LS11	LPS 135 POLE
FL128	FL 1X8 2F96T12ES ELC2		LS12	LPS 180 POLE
FL129	FL 1X8 1F96T12ES ELC1		LS13	LPS 18 WALL
FL130	FL 1X8 4F96T12ES ELC2 REF		LS14	LPS 35 WALL
FL131	FL 1X8 2F96T12ES ELC2 REF		LS15	LPS 55 WALL
FL132	FL 1X8 1F96T12ES ELC1 REF		LS16	LPS 90 WALL
FL133	FL 2X4 4F40T12HO STD2 REF		LS17	LPS 135 WALL
FL134	FL 2X4 3F40T12HO STD1,2		LS18	LPS 180 WALL
FL135	FL 2X4 2F40T12HO STD2 REF		MH1	MH 50 PEND
FL136	FL 1X4 2F40T12HO STD2 REF		MH2	MH 70 PEND
FL137	FL 1X4 1F40T12HO STD1 REF		MH3	MH 100 PEND
FL138	FL 2X4 4F40T12HO EEF2		MH4	MH 175 PEND
FL139	FL 2X4 3F40T12HO EEF1,2		MH5	MH 250 PEND
FL140	FL 2X4 2F40T12HO EEF2		MH6	MH 400 PEND

FL141	FL 1X4 2F40T12HO EEF2		MH7	MH 1000 PEND
FL142	FL 1X4 1F40T12HO EEF1		MH8	MH 1500 PEND
FL143	FL 2X4 4F40T12HO EEF2 REF		MH9	MH 50 WALL
FL144	FL 2X4 3F40T12HO EEF1,2		MH10	MH 70 WALL
FL145	FL 2X4 2F40T12HO EEF2 REF		MH11	MH 100 WALL
FL146	FL 1X4 2F40T12HO EEF2 REF		MH12	MH 175 WALL
FL147	FL 1X4 1F40T12HO EEF1 REF		MH13	MH 250 WALL
FL148	FL 2X4 4F40T12HO ELC2		MH14	MH 400 WALL
FL149	FL 2X4 3F40T12HO ELC1,2		MH15	MH 1000 WALL
FL150	FL 2X4 2F40T12HO ELC2		MH16	MH 1500 WALL
FL151	FL 1X4 2F40T12HO ELC2		MH17	MH 50 POLE
FL152	FL 1X4 1F40T12HO ELC1		MH18	MH 70 POLE
FL153	FL 2X4 4F40T12HO ELC2 REF		MH19	MH 100 POLE
FL154	FL 2X4 3F40T12HO ELC1,2		MH20	MH 175 POLE
FL155	FL 2X4 2F40T12HO ELC2 REF		MH21	MH 250 POLE
FL156	FL 1X4 2F40T12HO ELC2 REF		MH22	MH 400 POLE
FL157	FL 1X4 1F40T12HO ELC1 REF		MH23	MH 1000 POLE
FL158	FL 1X8 4F96T12HO STD2 REF		MH24	MH 1500 POLE
FL159	FL 1X8 2F96T12HO STD2 REF		MH25	MH 50 CAN
FL160	FL 1X8 1F96T12HO STD1 REF		MH26	MH 70 CAN
FL161	FL 1X8 4F96T12HO EEF2		MH27	MH 750 WALL

FL162	FL 1X8 2F96T12HO EEF2		MH28	MH 32 WALL
FL163	FL 1X8 1F96T12HO EEF1		MH29	MH 32 PEND
FL164	FL 1X8 4F96T12HO EEF2 REF		MH30	MH 750 POLE
FL165	FL 1X8 2F96T12HO EEF2 REF		MH31	MH 750 PEND
FL166	FL 1X8 1F96T12HO EEF1 REF		MH32	MH 32 POLE
FL167	FL 1X8 4F96T12HO ELC2		MH33	MH 70 HE PEND
FL168	FL 1X8 2F96T12HO ELC2		MH34	MH 150 HE PEND
FL169	FL 1X8 1F96T12HO ELC1		MH35	MH 175 HE PEND
FL170	FL 1X8 4F96T12HO ELC2 REF		MH36	MH 250 HE PEND
FL171	FL 1X8 2F96T12HO ELC2 REF		MH37	MH 400 HE PEND
FL172	FL 1X8 1F96T12HO ELC1 REF		MH38	MH 1000 HE PEND
FL198	FL 1X8 4F96T8 EEF2		MH39	MH 70 HE WALL
FL199	FL 1X8 2F96T8 EEF2		MH40	MH 150 HE WALL
FL200	FL 1X8 1F96T8 EEF1		MH41	MH 175 HE WALL
FL201	FL 1X8 4F96T8 EEF2 REF		MH42	MH 250 HE WALL
FL202	FL 1X8 2F96T8 EEF2 REF		MH43	MH 400 HE WALL
FL203	FL 1X8 1F96T8 EEF1 REF		MH44	MH 1000 HE WALL
FL204	FL 2X4 3F40T12HO STD1,2		MH45	MH 70 HE POLE
FL205	FL 2X4 2F40T12HO STD2		MH46	MH 150 HE POLE
FL206	FL 1X4 2F40T12HO STD2		MH47	MH 175 HE POLE
FL207	FL 1X4 1F40T12HO STD1		MH48	MH 250 HE POLE

FL208	FL 1X8 2F96T12HO STD2		MH49	MH 400 HE POLE
FL209	FL 1X8 1F96T12HO STD1		MH50	MH 1000 HE POLE
FL210	FL 1X8 3F96T12 STD1,2 REF		MH51	MH 30 POLE ELC
FL211	FL 1X8 3F96T12 EEF1,2 REF		MH52	MH 32 PEND ELC
FL212	FL 1X8 3F96T12 ELC1,2 REF		MH53	MH 32 WALL ELC
FL213	FL 1X8 3F96T8 EEF1,2 REF		MH54	MH 50 POLE ELC
FL214	FL 1X8 3F96T12HO STD1,2		MH55	MH 50 PEND ELC
FL215	FL 1X8 3F96T12HO STD1,2		MH56	MH 50 WALL ELC
FL216	FL 1X8 3F96T12HO EEF1,2		MH57	MH 50 CAN ELC
FL217	FL 1X8 3F96T12HO ELC1,2		MH58	MH 70 POLE ELC
FL218	FL 1X8 3F96T12HO EEF1,2		MH59	MH 70 PEND ELC
FL219	FL 1X8 3F96T12HO ELC1,2		MH60	MH 70 WALL ELC
FL220	FL 1X8 3F96T12ES STD1,2		MH61	MH 70 CAN ELC
FL221	FL 1X8 3F96T12ES STD1,2		MH62	MH 100 POLE ELC
FL222	FL 1X8 3F96T12ES EEF1,2		MH63	MH 100 PEND ELC
FL223	FL 1X8 3F96T12ES EEF1,2		MH64	MH 100 WALL ELC
FL224	FL 1X8 3F96T12ES ELC1,2		MH65	MH 150 HE POLE ELC
FL225	FL 1X8 3F96T12ES ELC1,2		MH66	MH 150 HE PEND ELC
FL226	FL 1X8 3F96T12 STD1,2		MH67	MH 150 HE WALL ELC
FL227	FL 1X8 3F96T12 EEF1,2		MV1	MERC 50 PEND
FL228	FL 1X8 3F96T12 ELC1,2		MV2	MERC 75 PEND

FL229	FL 1X8 3F96T8 EEF1,2		MV3	MERC 100 PEND
FL230	FL 2X4 3F40T12ES ELC3		MV4	MERC 175 PEND
FL231	FL 2X4 3F40T12ES ELC3 REF		MV5	MERC 250 PEND
FL232	FL 2X4 3F40T12 ELC3		MV6	MERC 400 PEND
FL233	FL 2X4 3F40T12 ELC3 REF		MV7	MERC 700 PEND
FL234	FL 2X4 3F40T12HO ELC3		MV8	MERC 1000 PEND
FL235	FL 2X4 3F40T12HO ELC3 REF		MV9	MERC 50 POLE
FL236	FL 2X4 3F32T8 ELC3		MV10	MERC 75 POLE
FL237	FL 2X4 3F32T8 ELC3 REF		MV11	MERC 100 POLE
FL238	FL 2X4 4F40T12ES ELC4		MV12	MERC 175 POLE
FL239	FL 2X4 4F40T12ES ELC4 REF		MV13	MERC 250 POLE
FL240	FL 2X4 4F40T12 ELC4		MV14	MERC 400 POLE
FL241	FL 2X4 4F40T12 ELC4 REF		MV15	MERC 700 POLE
FL242	FL 2X4 4F40T12HO ELC4		MV16	MERC 1000 POLE
FL243	FL 2X4 4F40T12HO ELC4 REF		MV17	MERC 50 WALL
FL244	FL 2X4 4F32T8 ELC4		MV18	MERC 75 WALL
FL245	FL 2X4 4F32T8 ELC4 REF		MV19	MERC 100 WALL
FL246	FL 1X8 4F96T12HO STD2		MV20	MERC 175 WALL
FL247	FL 2X4 4F40T12HO STD2		MV21	MERC 250 WALL
FL248	FL 1X8 4F96T8 ELC2		MV22	MERC 400 WALL
FL249	FL 1X8 2F96T8 ELC2		MV23	MERC 700 WALL

FL250	FL 1X8 1F96T8 ELC1		MV24	MERC 1000 WALL
FL251	FL 1X8 3F96T8 ELC1,2			

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
- window/through-wall air conditioning units
- fan coil units using single-building conventional 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 conventional 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 conventional 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 conventional 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

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 does hourly calculations only 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: At minimum set, it is assumed that all buildings have the “correct” lighting levels; hence, the percentage of illumination is required to add up to 100%. At *maximum detail*, you can enter 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 overlit or underlit). Similarly, you can increase or decrease the percentage of illumination for any technology to indicate that a space is underlit or overlit. For example, you might have entered at *minimum set* that 30% of the illumination was provided by incandescent and 70% by fluorescent. If the space is overlit by 30%, at maximum detail, you could enter 39% for incandescent and 91% for fluorescent.

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.

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 are entered on a per-building basis as if it were the only technology in the building. If there are multiple technologies in an individual building, then the capacities need to be extrapolated to the total building level. 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.

Technology Record Errors

"Exceeded list limit" The number of possible technologies for a particular end use has been exceeded. Reduce the number of technologies to a value less than or equal to the maximum number provided in Technology Records.

Inference Errors

Inferences are updated at two points: when you explicitly request an inference update and just before the optimizer is run. Updating inferences catches any input errors and makes sure that the *minimum set* of inputs is 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 errors messages typically identify the source of the error and the solution.

"Missing minset at level [default level, NOTE: not used], missing [description] [tech #]" **A minimum set input has not been entered. Make sure that all blue cells 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/unserved 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.

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).**

"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.**

Changes to Locked Inputs

Inputs that are locked in FEDS are by definition fixed and will not be changed. There are however, a couple of instances when you might see a change to a locked value.

Design Outdoor Ventilation Air: You entered a percentage for the design outside air, but after updating *inferences*, you notice that the number you entered is somewhat different. Because the total supply air depends on the amount of outside air, and you entered the outside air as a percentage of the total supply air, this is an iterative calculation and will not return the exact entered value. If you are not satisfied with the returned value, go to the Ventilation End Use Inputs screen, enter the percentage, and update inferences. Repeat this process until the percentage is satisfactory.

Lighting Use Area Fixture Density: You entered fixture counts for a dual use area *building set* and later change the use area percentages for use area one and two. Upon updating inferences, the supposedly locked lighting fixture counts are changed. This occurs because lighting fixture counts are stored on a fixture per square foot basis, and changing the square footage in each use area via the use area percentages (or by changing the total building set floor area for a single or dual use building set) the fixture count displayed on the lighting screen changes to reflect the change in floor area. While the only way to prevent this from happening is to not change the floor area and use area percentage inputs, it is important to be aware of this if you have input lighting in terms of fixture counts and subsequently need to change either of these parameters - revisit the lighting fixture density inputs and correct as necessary.

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. You created a new building set and did not visit the *Lighting Inputs*. The model assumed there were no lights in the building set. 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. You created a new building set 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:

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.

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.

Present Value

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

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

where:

PVj = Present value of cost element j

n = Analysis period

CFj,i = Cash flow for cost element j in year i (by convention, cash inflows have a positive sign and cash outflows a negative sign)

escj,i = Escalation rate for CFj,i if CF is first year cost (e.g., energy cost)

k = Discount rate.

Annualizing

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

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

where:

AVj = Annualized value of cost element j.

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.

Economic Figures of Merit

A number of 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*).

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

AVj,retrofit = Annualized value of cost element j for the retrofit existing technology

AVj,existing = Annualized value of cost element j for the existing technology.

Simple Payback

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

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:

ΔCFenergy = The difference between building's first year energy cost without the retrofit and with the retrofit (existing - retrofit)

ΔCFdemand = The difference between building's first year demand cost without the retrofit and with the retrofit (existing - retrofit)

ΔAVO&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

ΔAVnon-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.

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.

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

where:

SIR = Savings to investment ratio

PVInstalled Cost = PV of installed cost (a cash outflow and thus a negative number by convention).

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.

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

where:

AIRR = Adjusted internal rate of return.

Appendix L - Miscellaneous Resources

Data Collection Forms

FEDS MinSet Form.pdf and FEDS Audit Form.pdf have been installed to your FEDS\model directory (default location is C:\Program Files\FEDS 5.0\model). These are examples of data forms developed by FEDS users to collect building data used by FEDS. Two different versions are available: a single page *minimum set* version and a multi-page detail version, listing data that are applicable to each level. 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://www.adobe.com/products/acrobat/readstep.html

Emissions Paper

EmissionsPaper.pdf has been installed to your FEDS\model directory (default location is C:\Program Files\FEDS 5.0\model). This paper describes the methodology used to develop and apply emissions factors for the six air pollutants tracked within FEDS. It discusses not only the direct contribution from the combustion of fossil fuels, but also the development of state-level electricity impacts, based on the generation resource mix of each state.

The file is in pdf format and may be viewed by opening it with the Adobe Acrobat Reader. If you need to download the Acrobat Reader, visit http://www.adobe.com/products/acrobat/readstep.html.

Frequently Asked Questions

There is a page on the FEDS web site listing a number 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. Visit www.pnl.gov/feds/faqs.html.

Glossary

A

AC: air conditioning

ACH: air change per hour

AIRR: adjusted internal rate of return

ASHRAE: American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc.

aspect ratio: Ratio of a building's north facing length to the east facing length; used to specify geometric orientation

B

Btu: British thermal unit

building set: A group of like buildings that are modeled together in FEDS. Buildings with similar size, vintage, function, and occupancy schedule can be grouped into a building set.

C

capacity: The amount of energy, divided by the time, a piece of equipment would use if it were to run continuously at rated conditions.

CBECS: Commercial Buildings Energy Consumption Survey

CDD: cooling degree day

cfm: cubic feet per minute

CLF: cooling load factor

CLTD: cooling load temperature difference

consumption: The energy input required, after adjustments for efficiency, in order for the energy using equipment to meet the loads

COP: coefficient of performance

crossover temperature: The outdoor air temperature at which a dual-fuel heat pump switches operation from the heat pump to the backup technology.

D

day type: A modeling day in FEDS; weekday, Saturday, and Sunday.

demand ratchet: An electric demand billing method in which the billed demand is the minimum of the actual demand and some fraction of the peak demand in previous months.

distributed hot water system: A hot water system where the water is heated in the storage tank as in a home. Numerous tanks may be distributed about a large building each serving a small area.

DOE FEMP: The U.S. Department of Energy's Federal Energy Management Program

DX: direct expansion

E

ECIP: Energy Conservation Investment Program

EIA: Energy Information Administration

ELA: equivalent leakage area

EPACT: Energy Policy Act of 1992

ETP: equivalent thermal parameter

F

FEDS HVAC zones: Zones are portions of the building that are individually controlled by the HVAC system. Zones are assumed to be adiabatically isolated from each other.

FORSCOM: The U.S. Army Forces Command

G

gpm: gallons per minute

H

HDD: heating degree day

heat/cool pair: A pair consisting of a heating and cooling technology serving the same buildings of a building set. Together they may be considered for replacement with a heat pump.

HTS: heat contributed to space

HVAC: heating, ventilation, and air conditioning

I

inferences: Parameter values not entered by the user that are inferred from other inputs.

installation: The collection of building sets modeled in a FEDS run. This should be all the buildings on a single billing meter.

K

kWh: kilowatt-hour

L

LCC: life-cycle cost

linked building set: A geometric description of two buildings (sets) sharing a common (adiabatic) portion of wall or roof/ceiling area.

load: The required energy output for an end-use

loop hot water system: A hot water system where the water is typically heated external to the storage tank(s) and moved continuously through a large building (e.g., hotel or hospital) via a loop circulation system.

lpg: liquefied petroleum gas

M

maximum detail: User interface display mode in which all minimum set inputs and all inferable inputs (white input cells) of the model are shown and available for changing.

MBtu: million Btu

minimum set: User interface display mode in which only those inputs required for the model to run are shown; those inputs are distinguished by a blue input cell that must be entered by the user.

N

NAECA: National Appliance Energy Conservation Act

NBECS: Nonresidential Buildings Energy Consumption Survey

NFESC: U.S. Navy's Naval Facilities Engineering Service Center

NPV: net present value

O

O&M: operations and maintenance

OAT: outdoor air temperature

occupancy unit: Term used in service hot water modeling in calculations for determining the number of tanks, faucets, average consumption, and capacity requirements.

P

PNNL: Pacific Northwest National Laboratory

profile: A shorthand term that describes a vector of 24 values, indexed by hour of the day.

R

RC: resistance-capacitance

record: (technology or building set) - set of inputs/parameters describing a particular technology or building set

RECS: Residential Energy Consumption Survey

S

SC: shading coefficient

SHGF: solar heat gain factors

SHW: service hot water

simple payback: The ratio of the total installed cost to the first year savings

SIR: savings-to-investment ratio

solar normalization: A method in FEDS to avoid biasing the solar gains calculation (which is dependent on orientation) when the orientation is not known or there are multiple buildings of different orientations in a building set.

T

therm: 100,000 Btu

thermostat dead band: Number of degrees below (above) the thermostat set-point that the inside temperature must fall (rise) before the heating (cooling) system begins supplying heat (cool) again.

TMY: typical meteorological year

U

UA: overall thermal conductivity

USA-CERL: U.S. Army's Construction Engineering Research Laboratory

use-area: Part of a building dedicated to a particular use; may be different than the use the building was originally built for (building type); maximum of 2 use-areas per building.

W

WYEC: weather year for energy calculations

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