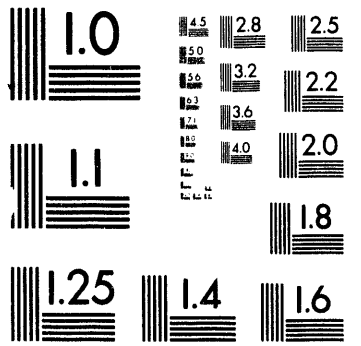
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AN OVERVIEW OF THE FEDERAL ENERGY MANAGEMENT TOOLKIT

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An Overview of the Federal Energy Management Toolkit

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Abstract

The federal government is the single largest energy user in the United States. The annual cost to the American taxpayer for supplying energy to buildings, facilities, and operations within the federal sector is $5 billion. Several estimates have been produced projecting that up to 40% of this annual cost could be saved through energy efficient actions.[1-3]

Pacific Northwest Laboratory (PNL)[(a)] and other DOE laboratories provide technical assistance to the Department of Energy (DOE) Federal Energy Management Program (FEMP) and other federal agencies to identify, evaluate, and prioritize the most cost-effective actions to improve energy efficiency and reduce energy costs at federal installations. A key feature of this program is the development and application of a comprehensive set of software tools, analyses, procedures, operations and maintenance approaches, and the transfer of knowledge through technical assistance and demonstration activities.

PNL and other federal laboratories are cooperating with FEMP and other federal agencies in applying these tools at over 50 federal sites containing over 60 central utility systems and more than 50,000 buildings and facilities. The overall approach employed by FEMP is fuel- and technology-neutral. This means that by applying the FEMP approach, the least-cost way to provide heat, cooling, and other energy services is identified without regard to whether or not the energy source is electricity, natural gas, or other fuel forms.

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-ACO6-76RLO 1830.

Background

A decade ago, the FEMP office was established within the DOE as the office to collect data on results of energy savings measures adopted by other federal agencies, to review and approve all plans to achieve the energy reduction goals, and to publish an annual report summarizing the results of the program. The FEMP office also supports the mission and objectives of DOE by providing federal agencies with a focal point for DOE program information and acting as a catalyst for interagency agreements to coordinate use of energy technology and tool development resources.

The role of FEMP has evolved through subsequent Executive Orders and laws. Recently the role of FEMP in federal energy management has been significantly elevated with the passage of the Comprehensive Energy Policy Act (EPAct) of 1992.[4] With increased responsibility, FEMP will continue to focus activities on its two key objectives:

- to facilitate improvement of energy management practices and decision making among federal agencies; and
- to coordinate and support the development and application of tools, techniques, and strategies to improve the energy efficiency and fuel flexibility in the federal sector, and transfer this technology to the private sector.

Historically, the overall strategy pursued by the FEMP office is to focus on those activities that maximize its limited resources. To do this, FEMP realized that there was a critical need for simple-to-use and effective tools to understand energy use at the building and facility level and to optimally identify solutions to increase energy efficiency and reduce costs.

Accordingly, FEMP has embarked on a comprehensive technology base support strategy that provides for the development and application of tools and methods needed to identify and assess energy efficiency potential and energy cost savings in federal facilities (for both the energy supply and end use), and to evaluate alternative improvement approaches. The program strategy is to provide a sound scientific basis for energy use improvement efforts that can be supported and implemented through several financing options available to the federal energy manager. This is coupled with technology demonstration and improving the skills of federal energy managers in the use of tools through a comprehensive training program.

Because many of FEMP's activities in this area cannot be funded completely through its own resources, the FEMP office cultivates cost-sharing approaches with other federal agencies that leverage their funds as well as its own to accomplish more comprehensive results.

Life-Cycle Costing

The tools and analysis capabilities developed and demonstrated by FEMP as part of its technology base support activities are all built upon the foundation of life-cycle-costing (LCC) as defined in 10 CFR Part 436.[5] The life-cycle cost of a potential action or investment is defined as the present value of all the costs associated with the investment over time and is calculated through the use of discounting using a federally mandated discount rate. Life-cycle costs include the current installed cost, the present value of annual energy costs, the present value of annual operations and maintenance (O&M) costs, and the present value of future replacement costs. Any action or investment selected to improve the energy efficiency or reduce energy costs at a federal facility is required to be the lowest life-cycle cost of those alternative actions which meet the agency's mission requirements.

Life-cycle costing is therefore the cornerstone imbedded in all FEMP-supported software tools and analysis procedures where actions, alternatives or investments are recommended. The LCC software is available to federal energy managers through the National Institute of Standards and Technology (NIST). FEMP works through NIST to annually update the discount rate and fuel escalation rates, and distribute updates to federal users. FEMP also works with NIST staff to provide training to federal energy managers in the use of the software.

A Comprehensive Approach

FEMP has developed a comprehensive approach and structure for tool development that includes software, hardware and processes, and is cooperating with other federal agencies to support this development. In addition FEMP and other federal agencies have supported the development of standard protocols and procedures for applying the tools and undertaking analysis. Finally, FEMP has initiated demonstration programs to apply the tools and energy efficiency technologies at federal facilities. These tools and example applications in the federal sector are summarized below.

The Facility Energy Decision Screening System - Software Tools

The FEMP software tools are all embodied within the Facility Energy Decision Screening (FEDS) System. FEDS is a top-down systems analysis and energy resource acquisition approach that uses computer software to characterize the energy use in a single building or an entire facility and analyze options for all cost-effective energy efficiency projects. The family of software tools provides the information for federal energy managers to undertake comprehensive fuel-neutral integrated resource planning and acquisition at their sites. A selection of federal sites where one or more of the elements of the comprehensive FEDS System has been applied is shown in Figure 1.

FEDS Level-1 and Level-2

The focus of the FEDS System software tools is FEDS Level-1, a top-down, first-pass energy systems analysis and energy resource acquisition decision software for buildings and facilities; and Level-2, which allows specific engineering inputs

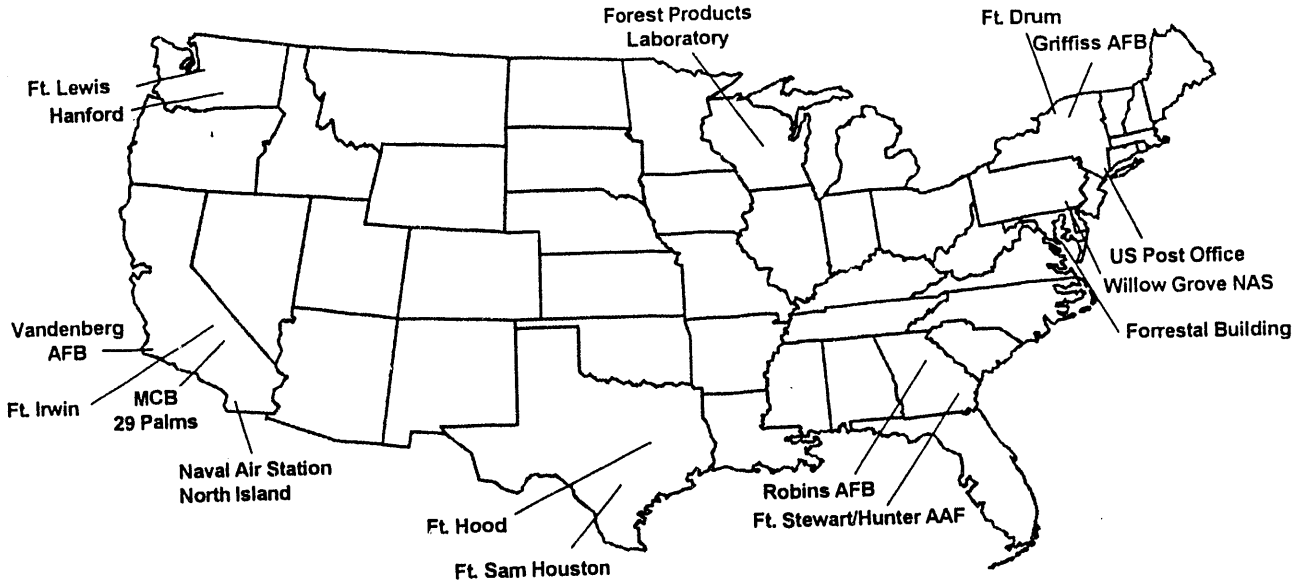

Figure 1. FEMP-Supported FEDS Tools Application at Federal Sites

and provides more detailed output. FEDS Level-1 is a user-friendly, menu-driven PC-based software program that can be used by institution, agency, energy, or installation managers to prioritize investments in energy efficiency among several sites, and/or assess the potential for cost-effective energy efficiency projects at a single site or facility with limited metered energy-use data. It is used to target and prioritize the most promising building and end-use retrofit opportunities, and to estimate capital investment requirements and potential energy and cost savings.

The FEDS Level-1 analysis is based upon the optimal life-cycle cost-effective retrofits to the current system (considering building interactive effects) and estimates 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 requirements, and net present value of the retrofit. Data are provided by building type and by end-use (e.g., lighting, hot water, etc.) A FEDS Level-1 analysis will typically be followed by a FEDS Level-2 analysis, which allows detailed energy-system information input, returning detailed *project-by-project technology selection* and economic information.

FEDS Level-1 was released in October 1992, and a military buildings-specific version of FEDS Level-1 is planned for release in June 1993. FEDS Level-2 is planned for release in October 1993. The first releases for both levels will cover only building systems. The next release in early 1994 will cover other energy systems, including central heating and cooling plants and thermal loops.

Lighting Systems Screening Tool

Though a central part of the FEDS System of software, all lighting software tools (described below) are "bundled" into the FEMP Federal Relighting Initiative (FRI), which also includes procedures for identifying cost-effective relighting projects.[6] Currently, the FRI software tools are being applied in FEMP and/or agency-supported relighting projects at the Forrestal and Mary Switzer Buildings in Washington, D.C.; Robins Air Force Base in Georgia; Camp Pendleton in California; and the Internal Revenue Service Building in Martinsburg, West Virginia.

The lighting systems screening tool (LSST) is one of the three FRI relighting software tools. The LSST is a computer model that can be used to quickly and easily identify the energy conservation potential of a lighting system in a

specific building. It is normally used once the FEDS Level-1 (or Level-2) analysis has been applied at a site to ascertain if there is a substantial potential for lighting efficiency in a group or type of buildings. The information provided by LSST helps energy managers screen their building stock to focus on those facilities that have the highest lighting efficiency potential and may warrant more extensive investigation and analysis.

A manager using LSST can conduct two levels of evaluation: 1) a pre-audit that requires simple inputs (similar to those in FEDS) such as building location, size, type (e.g., office, warehouse), operating hours, average cost of electricity and any available utility incentive or rebate; and 2) a post-audit, which is performed after a building walk-through and requires specific inputs regarding the stock or standard fluorescent and small incandescent fixtures.

In a post-audit evaluation, LSST retrieves appropriate lighting system technologies and calculates results for each building, including current and retrofit energy use, the present value of energy savings, retrofit costs, and a ratio of the present value of energy savings to cost (called a "savings index"). The LSST is run one time for all candidate buildings which are sorted by the savings index. Finally, energy savings, present value of savings, and costs are summed across all buildings. The BETA Release Version 1.0 (March 3, 1992) can analyze a total of 35 buildings at one time.

Lighting Technology Screening Matrix

The second FEDS System/FRI tool is the Lighting Technology Screening Matrix (LTSM). This software was developed to provide the federal energy manager with a choice of cost-effective retrofit technologies once he or she had targeted a specific building through the LSST for further analysis. The LTSM can be used to quickly identify if there are any potential cost-effective retrofits for an existing building or to identify cost-effective technologies for a building to be constructed.

The LTSM is a DOS-based software tool that calculates the life-cycle cost of an existing lighting fixture and a large number of potential energy-efficient replacements, both for a one-to-one (fixture-for-fixture) replacement or a lumen-equivalent (equal light output) basis. The LTSM can be used to evaluate retrofits for many common configurations of fluorescent, incandescent, and exit lighting systems for any level (hour) of operation, blended electricity rate, discount rate, and utility rebate program.

The inputs to the LTSM include the following:

- Discount Rate
- State/Census Region
- End-use Sector (Commercial or Residential)
- Labor and Materials Multiplier
- Fixture to Analyze
- Annual Operating Hours
- Average Electrical Rate
- Analysis Period
- Retrofit or New Project
- Cost Multipliers (Override Defaults)
- Minimum Lumen Ratio
- Utility Rebate.

The outputs that the LTSM provides for the existing lighting system and each retrofit alternative are as follows:

Fixture name	Value of 1st year savings
Fixture code	Annualized ballast cost
Activity type	Annualized lamp cost
Lumen ratio	Annualized O&M cost
Watts	Annualized capital cost
Ballast life (yrs)	Annualized energy cost

Lamp life (yrs)	Annualized total cost
Installed cost	Life-cycle cost
Rebate value	Net present value
Annual kWh savings	Levelized energy cost

The current Version 1.0 of the LTSM was released on July 13, 1992. An enhanced Version 2.0 with updated costs and additional technologies (including high-intensity discharge lamps) is due for release in early summer 1993.

Federal Energy Relighting Expert

The third of the FEDS System/FRI software tools still under development is the Federal Energy Relighting Expert (FLEX). FLEX is designed to be an interactive expert system for relighting project screening. The goal of FLEX is to go beyond just recommending appropriate technologies, to actually providing a room-by-room design for installation of those technologies.

FLEX contains the same graphical user interface as FEDS and will allow a federal energy manager who does not an have extensive lighting or computer background to actually design a lighting retrofit given existing lighting characteristics.

FLEX is designed to import lighting system characteristics data from the Existing Lighting Characterization forms developed for the FRI for building surveys. Based on this input and the life-cycle cost algorithms, FLEX provides analyses of alternative designs for lighting systems by employing rules to make qualitative recommendations in the areas of maintenance practices, operation and controls, and efficient system hardware. The software also accounts for the interactive effects of a lighting retrofit on building heating/cooling.

FLEX is being developed for FEMP by the National Renewable Energy Laboratory with support from the Lawrence Berkeley Laboratory, Lighting Research Institute, ADM Associates and other private and utility partners. The current Version 1.3 of FLEX allows for a building survey and for comparison of alternative designs for fluorescent, incandescent, and high-intensity discharge (HID) fixtures. The expert system version of FLEX will be available in early summer 1993.

A Simplified Energy Analysis Method

A Simplified Energy Analysis Method (ASEAM) has been a part of the FEMP toolbox for over seven years. It is used primarily by the federal energy manager to provide savings-to-investment ratios for energy efficiency improvements and projects for end-use technologies such as those identified as being cost-effective in a FEDS Level-1 or Level-2 analysis. This buildings-level DOS-based model uses the standard ASHRAE bin-temperature calculation method for thermal modeling of building and building systems. Projects evaluated for cost-effectiveness could include selecting insulation levels and window-glazing retrofits, selecting the optimal heating and cooling systems and evaluating control technologies (e.g., motion detectors, set-back thermostats).

ASEAM is a menu-driven PC-DOS-based software. It is currently being modified to have the same user interface as FEDS Level-1 and Level-2 software. In addition, future developments include rewriting ASEAM in C (Version 4.0) and an ASEAM-to-DOE-2 model input file generator and autocalibration (Version 5.0) to facilitate examination of energy conservation opportunities for which bin-temperature modeling may be inadequate but which can be more readily handled with DOE-2. Future development of the FEDS software will enable FEDS to read ASEAM input files.

FEMP provides an engineer/programmer's guide that documents the inner workings and technical basis of the code to assist those wishing to review or refine various features of the public domain code.

The Facility Energy Decision Screening System--Hardware and Process Tools

The complementary tools to the FEDS System software are the hardware and process tools for

federal energy managers. These include the application of metering, monitoring and testing equipment to develop baseline data and verify energy savings, standard-systematic approaches for data collection and analysis, demonstration and evaluation of O&M practices, and field testing and evaluation of new energy efficiency technology.

The development, peer-review and oversight of this set of tools are coordinated by FEMP through the Federal Energy Resources Management (FERM) Coordination Committee. The FERM is chaired by FEMP and comprised of representatives from the Army, Navy, Air Force, and Civilian Agencies supported by an Executive Secretary from PNL. The Committee meets semiannually, issues a semiannual report on activities,[7,8] and is responsible for:

- Development (where appropriate) and centralized distribution of published/written information regarding tools (software/hardware), procedures (testing and analysis), applications, and results (reports, articles, lessons learned) relating to meeting the goals of the EPAct.

- Development (where appropriate) and technical peer review of surveying, metering and testing capabilities and standard approaches to analysis with the goal of enhancing the cost-effectiveness of empirical data collection and thereby streamlining the development of projects that meet the EPAct criteria.

- Understanding new approaches/methods/procedures applied by other federal agencies/installations to tackle energy efficiency, and transferring this information (through multiple means) among the agencies, installations and energy managers.

Metering, Monitoring and Testing

Metering, monitoring and testing hardware development and field application is supported by FEMP in cooperation with other federal agencies to provide empirical data on energy flows in buildings and facilities. The information can be used as: 1) baseline data input into a FEDS Level-1 or Level-2 analyses, the LTSM or FLEX software; 2) to make decisions on operations and maintenance or equipment retrofit: and 3) to assess savings from the installation of cost-effective energy efficiency technologies.

Testing equipment is furnished and/or cost-shared by FEMP and maintained at PNL and the Naval Energy and Environmental Support Activity (NEESA). The equipment is typically shipped to the site and installed by trained specialists. Many times equipment is left onsite and data are collected for several months using site personnel or telephone transmission. New equipment is regularly acquired or enhanced, and if necessary, developed for particular test applications. Once a test is completed, a test report is prepared with recommendations supported by life-cycle-cost analyses.

Testing capabilities and applications include:

- substation and electrical distribution system metering[9]

- baselining and verification of energy savings from retrofit technologies[10,11]

- central plant and thermal distribution system evaluation[12,13]

- power factor and power quality determination

- lighting levels and lighting systems energy use measurements[14]

- HVAC system sizing and control strategy evaluation[15]

- chiller delivery efficiency determination

- motor, pump and compressor efficiency determination

- main power plant electric power use

- infrared thermography

- ventilation rates and indoor air quality measurements.[16,17]

A selection of current data collection sites for FEMP and other federal agencies are shown in Figure 2.

Procedures and Protocols

To support the testing and metering activities, FEMP, in cooperation with other federal agencies (primarily the U.S. Army Forces Command), supports the development of standard procedures and protocols for conducting field testing. The purpose for developing standard procedures is to enhance and improve the general capability of currently used methods of testing and metering and to improve the consistency of data collection, analysis and reporting.

A test procedure for building energy end-use metering has become an ASTM standard procedure,[18] and a procedure for building heating, ventilation and air conditioning system evaluation is in final balloting as a standard ASTM test procedure. Other test procedures that have been developed and field tested and/or peer-reviewed include:

- Hot and chilled water distribution system evaluation
- Evaluating illuminance levels in facilities
- Steam distribution system evaluation
- Electrical distribution system evaluation
- Boiler efficiency evaluation
- Chiller performance testing
- Evaluating lighting retrofit technologies--power, harmonics and lighting levels
- Ventilation measurements[19]
- Substation metering
- Infrared thermography

Energy Analysis Methods

Facilities modernization often involves detailed site-specific analysis of energy supply and energy systems that requires a more rigorous system-specific analysis for future design than is

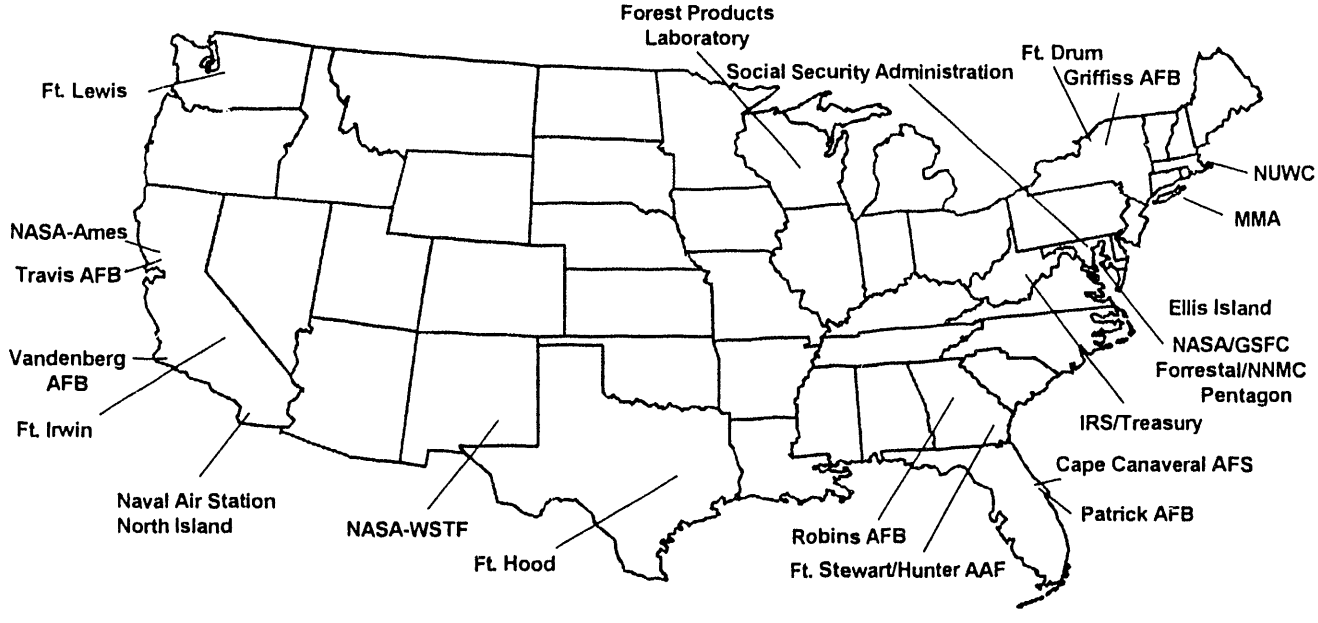

Figure 2. FEMP-Supported Metering/Testing Activities at Federal Sites

capable with a FEDS Level-1 or Level-2 software analysis. Therefore, FEMP, in cooperation with other federal agencies, supports the development and application of standard methods of analysis that incorporate the tenants of the LCC integrated with agency- or site-specific requirements such as mission security or environmental impact considerations.

The analysis methods range from evaluating options for providing energy services (e.g., heating, cooling, hot water, etc.) for new and retrofit construction, to selecting appropriate energy metering strategies, to determining the least cost and most reliable fuel supply. As an example, the analysis process for evaluating and selecting the most life-cycle cost-effective natural gas fuel supply option at a federal site is organized and undertaken according to the flowchart shown in Figure 3.

Other analysis methods that have been developed and recently applied include:

- Analysis of the value of a site's electrical transmission and distribution system.[20]
- Analysis of central plant energy supply options (e.g., cogeneration), and energy supply and rates to minimize life-cycle costs and environmental impact while still maintaining site energy security.[21,22]
- Analysis of utility rate structure, cost of service and metering strategy and system selection for automated (remote) meter reading system for all utilities (energy, water, wastewater).[23,24]

Operations and Maintenance Strategies and Tools

The potential energy savings from cost-effective O&M strategies can be as much as

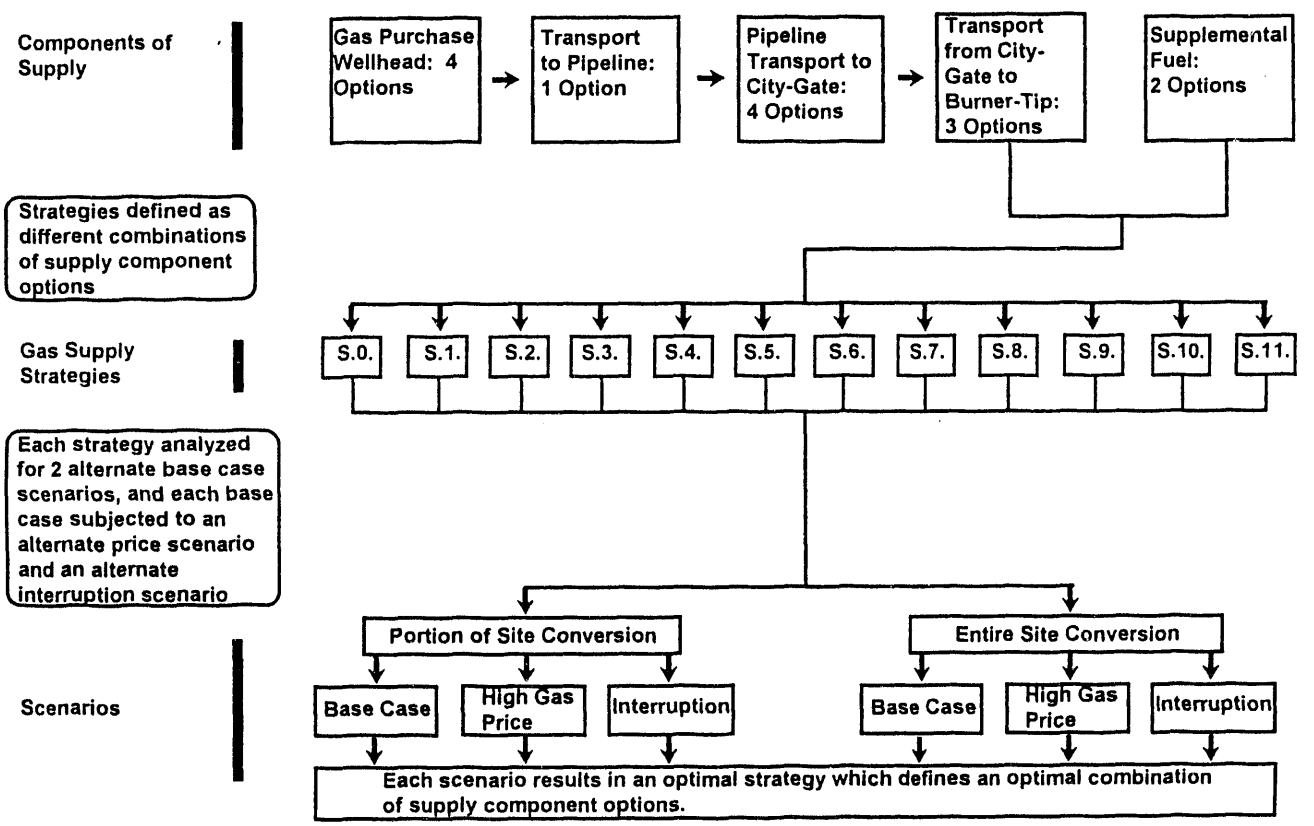

Figure 3. Typical Analyses Process for Determining National Gas Supply

20-30% in buildings and facilities. Therefore, FEMP, working with other federal agencies, has assisted in the development of O&M strategies by developing tools and practices to increase reliability and reduce operating and energy costs in central systems, facilities and buildings. These strategies are developed taking into consideration the uniqueness of the federal sector. They include:

- A Decision Support for Operations and Maintenance (DSOM) system designed to increase central plant efficiency and reliability while reducing life-cycle O&M costs. The system utilizes a computerized artificial intelligence (AI) power plant monitoring and diagnostic system that is designed to enhance a carefully restructured operating infrastructure.[25]

- Evaluating, correcting and recommending appropriate control strategies for HVAC systems, chillers, boilers and distribution systems.[8]

- Optimizing mechanical systems (e.g, compressed air, hot water distribution) through remote monitoring and control strategies.[7]

- Instituting a site-wide steam trap improvement program designed to supply appropriate acoustic test equipment for steam trap maintenance and provide training to staff in its use. The energy savings impact of the program in a selected steam is performed as part of the program.[8]

Energy Efficiency Technology Demonstration and Evaluation

As a final part of the FEDS System of tools and processes for an integrated approach to energy efficiency, FEMP, in cooperation with the Department of Defense and the DOE Geothermal Energy Office, is actively engaged in field demonstrations and evaluations of new energy efficiency technologies. These technologies are selected and evaluated in the FEMP test beds demonstration program (TBDP). The TBDP is a demonstration conducted at a federal facility or installation of a mature U.S. energy-related technology having no significant penetration in the federal sector. Through this demonstration, the performance of the technology in the federal environment can be documented, thereby reducing the time for widespread application of that new technology within the federal sector.

Through a unique partnership with a federal agency and installation, the utility serving the installation, the manufacturer of the technology, FEMP, and other organizations associated with these interests, new technologies can be cooperatively installed, evaluated and showcased. The partnership of these interests is formally secured through a Cooperative Research and Development Agreement (CRADA).

The TBDP includes a high-level data collection, analysis, reporting and management system to support the deployment efforts associated with the future use of new energy efficient technology in the federal sector.

The first FEMP test bed is the demonstration and evaluation of rooftop gas engine-driven cooling technology at the Willow Grove Naval Air Station.[26] Future test beds are planned to demonstrate a residential gas engine-driven heat pump at Fort Sam Houston, and (at sites to be determined) advanced thermal energy storage controls, geothermal (water- and ground-coupled) heat pump, and high-performance windows.

Toolkit Transfer

FEMP actively supports the transfer of all elements of the toolkit. Copies of all software and manuals are provided free to federal energy managers. Also, working in concert with the federal laboratories and contractors, FEMP offers several workshops annually. ASEAM, LCC, FEDS, and FRI workshops are specifically targeted for, and tailored to, the needs of the federal energy manager.

FEMP is committed to enhance and refine the "toolbox" as well as solicit the requirements and needs of federal energy managers as they develop

and implement strategies to comply with the goals of the EPAct. In addition, as required by the EPAct, FEMP is developing a comprehensive strategy to join with other federal and private agencies to effectively and efficiently train federal energy managers in use of the tools and processes focusing on a "hands-on" approach. Through a combination of user-friendly tools, training technical support and demonstrations, federal energy managers will be able to more readily identify cost-effective energy efficiency projects for implementation.

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