Conf-941218--11

PNL-SA-23975

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December 1994

Presented at the
World Energy Engineering Congress Conference
December 7-9, 1994
Atlanta, Georgia

Prepared for
the U.S. Department of Energy
under Contract DE-AC06-76RLO 1830

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ABSTRACT

The energy savings and demand reduction opportunities at the Army's National Training Center at Fort Irwin, California, were evaluated. The Fort Irwin analysis made use of the recently developed Facility Energy Decision Screening (FEDS) System Level-2 software tool. FEDS is a systematic, technology-neutral, and fuel-neutral approach to evaluating energy savings opportunities at large facilities. FEDS analyzes most major building end uses (e.g., heating, cooling, lighting, ventilation, and service hot water), including interactive effects (e.g., the effect of a lighting technology on heating and cooling loads). FEDS output provides specific cost, energy (and demand) charges, and life-cycle cost (LCC) information, by cost-effective energy resource opportunities (EROs). The remaining end uses common to large facilities (e.g., motors, transmission and distribution, vehicles) are analyzed using manual calculation methods.

The present value (PV) of the installed cost of all EROs constituting the minimum LCC efficiency resource (i.e., cost-effective) at Fort Irwin is approximately \$23.9 million in 1994 dollars (1994\$). The PV of the energy and demand, operations and maintenance (O&M), and replacement savings associated with this investment is approximately \$87.3 million, for an overall NPV of \$63.6 million.

This paper will describe the FEDS process and present detailed results of the comprehensive energy resource assessment conducted at Fort Irwin.

WHAT IS FEDS?

The number of conceivable energy conservation measures, fuel-switching opportunities, and renewable energy projects at a federal site is very large. The Pacific Northwest Laboratory (PNL) uses two methods to select, evaluate, and prioritize these energy resource opportunities (EROs). The first is the Facility Energy Decision Screening (FEDS) Model. FEDS is a multilevel software tool designed to provide a comprehensive approach to fuel-neutral, technology-independent, integrated (energy) resource planning and acquisition. FEDS currently has two levels--Level-1 and Level-2. Level-1 is a menu-driven DOS-based software program designed for facility energy managers as a screening tool. Level-1 assesses the likelihood of cost-effective energy projects based on high-level facility inputs and numerous assumptions. The output of Level-1 is used to assess an facility's overall energy conservation potential from the perspectives of potential energy savings, potential cost savings, and estimated investment requirement.

Level-2 is also a DOS-based software program that can be used by facility energy managers to identify, characterize, and assess individual energy projects. However, Level-2 goes to the next level of detail, providing specific information on energy and cost savings, as well as the estimated investment requirement for specific technology retrofits. Level-2 is the appropriate analysis to follow positive Level-1 results; typically, a Level-2 input file can be initiated from a Level-1 input file. Level-2 allows the user to enter facility-specific data inputs to replace the inferred default values from Level-1. These inputs form "building sets," which are groups of buildings similar in use, age, construction type, fuel use, fuel availability, or other definable characteristics. By developing building sets based on detailed facility data, Level-2 tailors the analysis to the facility and provides more accurate and detailed economic findings.

At this point in the software development, Level-1 and Level-2 analyze most major building end uses (heating, cooling, lighting, ventilation, and service hot water) including their interactive effects (e.g., the effect of a lighting technology on heating and cooling loads), providing specific cost, energy (and demand changes), and LCC information, by cost-effective technology.

The second method PNL uses addresses those end uses not analyzed by the FEDS software. This analytical approach is a three-step manual-calculation (hereafter referred to as "Manual") process which has been developed by PNL to make energy resource opportunity (ERO) selection, evaluation, and prioritization manageable. The steps are

- Preliminary Screening. Select promising EROs from a master list, considering the site's mission, building stock, end-use equipment characteristics, utility characteristics, climate, energy costs, and other local conditions that affect ERO viability, and recommendations from site staff.

- Cost and Performance Analysis. Establish, with a reasonable degree of accuracy, the technical and economic feasibility of each ERO that passed the preliminary screening. Perform an analysis comparing the operating and economic performance of the existing equipment and the ERO. Where applicable, include impacts on energy security and the environment in the analysis.

- Life-Cycle Cost Analysis and Prioritization. Perform an LCC analysis and rank EROs by net present value (NPV), so that a package with the optimal return on investment can be defined. If any utility cost-sharing or rebate programs exist, they can be included within this evaluation step.

All federal agencies are required to evaluate the LCC of alternative technologies when making energy investments. The LCC analysis and prioritization step used in both the Level-2 and manual methods is required by, and complies with, federal law [1]. An LCC evaluation computes the total long-run costs of alternative actions and identifies the action that maximizes the NPV of the energy investment.

FORT IRWIN CHARACTERISTICS

Fort Irwin is a roughly 1,000 square mile U.S. Army Forces Command (FORSCOM) facility situated in the Mojave Desert approximately 37 miles northeast of Barstow, California, and south of Death Valley. The main cantonment area is located near the southeastern portion of Fort Irwin. The Fort's primary mission is to operate the National Training Center (NTC). The NTC is a support facility for training of troops normally stationed at other posts throughout the United States. A total of twelve 28-day training rotations are scheduled each year. The Fort mission results in erratic energy consumption because a large portion of the Fort population is transient, moving on- and off-site as dictated by the training schedules.

The climate at Fort Irwin is classified as "high desert," with an average annual rainfall of 2.5 in., most of which falls between December and February. Summer maximum temperatures are around 104°F, and winter minimum temperatures are around 29°F. Annual heating and cooling degree-days (base 65°F) are 2,547 and 2,272, respectively.

Building Characterization

Roughly 842 commercial buildings (not including schools) with a floor area of 3,439,606 ft^2 are reported in the Fort Irwin Real Property Data Base (RPL). An additional 732 housing buildings (1636 units, not including General's Quarters) with a reported area of 2,961,830 ft^2 contribute to the Fort's total building area of 6,401,436 ft^2.

Based on the RPL, the facilities at Fort Irwin may be divided into 36 building types. These building types are created by combining facilities of different facility description codes (as provided in the RPL) into larger categories with similar energy usage. This procedure minimizes the number of building types while preserving any unique or unusual building characteristics that have an effect on energy consumption.

Family housing (2.9 million ft^2) is the single largest category by square footage at Fort Irwin, followed by barracks, administration, motor pools, warehouses, manufacture administration, and general shops. These building types account for more than 80% of the total building stock at Fort Irwin.

Commercial buildings are a mix of older wood frame construction and newer stone/brick construction, with some metal frame and curtain wall construction. Family housing is primarily wood frame construction with varying levels of insulation in the walls or ceilings.

Electric Utility Service Characterization

Electric service to Fort Irwin is provided by Southern California Edison (SCE). Distribution on the site consists of five 12-kV transmission lines from two substations. Both the transmission and distribution systems are overhead line systems for most of the commercial areas. Most of the family housing areas are supplied by underground lines.

The Fort Irwin electric system has approximately 610 transformers, with a total estimated nameplate capacity of more than 35,000 kVA. The losses associated with transformer operation are estimated at an average level of 272 kW, for a total yearly loss of 2,382 MWh.

Table 3 presents a breakdown and summary of both the energy and demand savings for the first year and full implementation of the cost-effective energy resource at Fort Irwin.

For EROs analyzed by FEDS Level-2, lighting EROs represent the greatest efficiency resource, accounting for more than $17.3 million of the total $63.8 million NPV and $4.4 million of the total $24.7 million installed cost. The remaining ERO categories have NPVs ranging from $6.1 million to $0.9 million, except for cooling and heating EROs, which are only marginally cost-effective with NPVs of $108,500 and $32,400, respectively.

For non-building EROs, vehicles represent the greatest efficiency resource, accounting for $10.1 million of the total $63.8 million NPV and more than $2 million of the total $24.7 million installed cost. The remaining non-building ERO categories have NPVs ranging from $9.4 million to $314,000.

For building EROs (analyzed by Level-2), the estimated annual electricity consumption at Fort Irwin is 89,100 MWh. Estimated electric demand is 30,100 kW. Full implementation of all electric EROs results in a reduction of 14,500 MWh and 3,600 kW. This represents a reduction of approximately 16% over total electricity consumption and 12% over site-wide demand. The estimated annual propane consumption at Fort Irwin is 209,100 MBtu. Full implementation of all propane EROs results in net conservation of 71,000 MBtu, which represents a net conservation of 34% of total consumption. The end uses of chilled water and district hot water were not broken out by fuel. The estimated annual chilled water use is 2 million ton-hours. Full implementation of all chilled water EROs results in a reduction of 331,000 ton-hours, or 16% of total consumption. The estimated annual district hot water use 9,200 MBtu. Full implementation of all district hot water EROs results in a reduction of 7,700 MBtu, or 83% of total consumption.

For non-building EROs, the estimated annual electricity consumption at Fort Irwin is 79,800 MWh. Estimated electric demand is 399,000 kW-month (sum of the peak demands for each month). Full implementation of all electric EROs results in a reduction of 12,200 MWh and 58,000 kW-month, representing a reduction of approximately 15% over total electricity consumption and 14% over site-wide demand. The estimated annual fossil fuel consumption (natural gas, No. 2 fuel oil, propane, gasoline, and diesel) at Fort Irwin is 823,800 MBtu. This total excludes any diesel and gasoline used for vehicles not addressed through EROs. Full implementation of all fossil fuel EROs results in conservation of 187,000 MBtu and a new load of 68,800 MBtu, for a net reduction of 118,600 MBtu. This represents conservation of 23% of total consumption, a new load of 8%, for an overall decrease of 14% in fossil fuel use.

ENERGY PROJECT IMPLEMENTATION AT FORT IRWIN

To meet its target of reducing overall energy consumption by 30% by the year 2005 (1985 baseline), Fort Irwin has developed a five-year plan and is actively pursuing base-wide energy conservation. Sources of funding for implementing these energy conservation projects include the Department of Army's Energy and Conservation Investment Program (MILCON/ECIP) and the Federal Energy Management Program (FEMP). Another potential source of funds is the utility-sponsored demand-side management (DSM) programs. The FEDS Level-2 results are used to prioritize the most cost-effective energy projects by evaluating the projects' life-cycle costs, investment requirements, and the energy savings opportunities.

Five-Year Energy Plan

Fort Irwin has developed an extended five-year energy plan that provides a timeline for implementation of energy conservation projects and identifies potential funding mechanisms. Individual energy projects identified by the FEDS process have been folded into this plan. The five-year plan is extremely dynamic, responding to the annual cycle of available funds or changes in utility DSM programs.

The detailed spreadsheet format of the FEDS Level-2 output allows for a relatively easy identification of individual energy projects that can be implemented as time-phased projects targeted to available funding sources. Specific projects can be identified by disaggregating the results either by building or end-use category or by a specific retrofit technology applied across multiple end uses.

As part of this process, the FEDS results were used to identify five energy projects that were submitted for FY95 FEMP funding. These projects, shown in Table 4, met the program requirements for simple payback and savings-to-investment ratio.

Residential HVAC Evaluation

The FEDS process was also used to evaluate alternative scenarios for heating and cooling of the existing family housing. There are 1,637 family housing units, all with basically the same propane furnace and central air conditioning systems. The options evaluated included air-source heat pump, ground-source heat pump, LPG furnace and central air, natural gas furnace and central air, and gas-fired heat pump (still under development but included for comparison purposes).

Although natural gas is not currently available at Fort Irwin, HVAC options are included to compare the operating cost of natural gas and propane. The natural gas rate used in the analysis is an estimate based on information provided by Fort personnel and representatives of possible natural gas providers.

This ERO was analyzed manually because the Level-2 software cannot yet fully analyze EROs involving heat pumps (either air- or ground-source) or fuel switching from LPG to natural gas when natural gas is not available to the building. Therefore, all residential HVAC options were analyzed manually, using only the savings from the individual pieces of equipment.

The technical assumptions are as follows:

- The existing LPG furnaces have an average size of 50 KBtu/h (input) and efficiency of 70.5% AFUE. The existing air conditioners have an average size of 2.5 tons and efficiency of 8.0 SEER.

- The replacement equipment efficiencies are shown in Table 5.

- Existing energy consumption was calculated using previously developed energy use intensities (EUIs) [2]: 2.91 kWh/ft^2-yr for cooling and 26.37 kBtu/ft^2-yr for heating. For an average house size of 1,800 ft^2, the energy consumption is 5,238 kWh for cooling and 47.5 MBtu for heating per unit.

- Retrofit energy consumption is based on the actual equipment size and estimated run hours of each replacement unit to meet the same load as the existing equipment. The replacement equipment sizes are different from the existing equipment size in almost all cases because actual equipment was chosen for the retrofit options. Equipment sizes are given in Table 6.

- Operating hours for the existing equipment are based on the EUIs and equipment capacities as described above. Operating hours for the retrofit equipment are calculated from the existing equipment hours modified by the replacement equipment efficiencies and capacities.

The cost assumptions are as follows:

- The replacement equipment installed costs are shown in Table 7.

- O&M costs are $75/yr for all air- and ground-source heat pump options, $85/yr for all furnace and air conditioner options (including the existing), and $105/yr for the gas-fired heat pump option.

- The cost of natural gas is assumed to be $3.50/MBtu.

Of the five options, the gas-fired heat pump was the winning technology (i.e., had the highest NPV) for this ERO. However, because natural gas is not now available at Fort Irwin (and it is unknown if the unit can be converted to LPG), this option is not viable at the Fort. In addition, present or future air quality laws may restrict the use of individual natural gas engines at each housing unit, and the residential gas-fired heat pump technology is still only in the testing stages and is therefore not available.

The runner-up HVAC technology is the high-efficiency ground-source heat pump. Full implementation of this ERO has an initial cost of $7,086,917, with a savings-to-investment ratio of 1.7 and discounted payback of 9.9 years.

It is estimated that the most cost-effective implementation of this ERO will result in an *increase* in annual electric energy consumption of 299,851 kWh but an accompanying decrease in propane use of 77,702 MBtu, for a total annualized energy cost savings of $479,316 and electric demand savings of 15,226 kW-month at an annualized value of $234,468.

The gas-fired heat pump is the only option that would require significant additional maintenance; the oil, oil filter and spark plug must be replaced yearly at an estimated cost (materials and labor) of $105 per unit. Replacing the furnace and air conditioner with a heat pump should result in minor O&M savings of approximately $16,370/yr.

CONCLUSION

Potential energy conservation measures, fuel-switching opportunities, and renewable energy projects at facilities the size of Fort Irwin are innumerable. A practical method to systematically assess all possible combinations of energy resource opportunities is needed to make the selection, evaluation, and prioritization of individual energy projects a manageable task. The FEDS process and Level-2 software do just that.

A FEDS assessment of Fort Irwin was recently completed. Significant energy and energy-cost savings opportunities were identified that would reduce building electric energy consumption by 16% and propane consumption by 34%. For non-building EROs, electric energy consumption would be reduced by 15%; fossil-fuel consumption would decline by 14%.

Individual energy projects identified using the FEDS process have been folded into a 5-year energy plan currently being implemented at Fort Irwin. It is anticipated that the FEDS assessment will be repeated in 1996 to reevaluate the energy conservation opportunities, given implementation of some of the recommended projects, revised energy costs, and other changing conditions at Fort Irwin.

REFERENCES

[1] 10 CFR 436. 1992. U.S. Department of Energy, "Federal Energy Management and Planning Programs." *U.S. Code of Federal Regulations.*

[2] Richman, E.E., J.M. Keller, A.L. Dittmer, and D.L. Hadley. 1994. *Fort Irwin Integrated Resource Assessment Volume 2: Baseline Detail.* PNL-9064 Vol. 2, Pacific Northwest Laboratory, Richland, Washington.

[3] Means. 1992. *MEANS Building Construction Cost Data: 1992 15th Annual Edition.* R.S. Means Company, Inc. Kingston, Massachusetts.

TABLE 1: ANNUAL ENERGY CONSUMPTION AND ENERGY COST

Energy Type	Annual Consumption	Annual Consumption (MBtu)	Percent of Total Energy	Annual Cost (1994$)	Percent of Total Cost
Electricity	72,860 MWh	248,645	11.9	6,271,513	52.8
Propane	2,369,487 gal	225,101	10.8	1,120,293	9.5
Gasoline	446,098 gal	55,762	2.7	370,261	3.1
Diesel	3,718,042 gal	515,692	24.7	2,491,088	21.0
JP-4	770,500 gal	184,646	8.9	577,875	4.9
JP-8	1,367,750 gal	853,954	41.0	1,025,813	8.7
Totals	—	2,083,800	100.0	11,856,843	100.0

TABLE 2: SUMMARY OF THE COST-EFFECTIVE EROS (1994$) [a]

ERO Category	Present Value of Installed Cost	Present Value of Energy and Demand Savings	Present Value of O&M Savings	Present Value of Replacement Savings	Present Value of Total Savings	Total Net Present Value
Lights (Level-2)	4,393,028	17,464,385	0	4,184,358	21,648,743	17,255,714
Vehicles	2,047,000	5,662,859	6,475,790	0	12,138,649	10,091,649
Envelope	1,400,907	11,619,936	0	-789,727	10,830,209	9,429,302
Roof (Level-2)	2,005,349	8,131,276	0	0	8,131,276	6,125,922
Fam. Hsg. HVAC	7,086,917	12,291,871	281,903	-241,994	12,331,780	5,244,863
Lighting Controls	180,827	2,512,676	719,268	0	3,231,943	3,051,116
Motors	1,362,331	4,051,014	-4,133	-504,490	3,542,390	2,180,059
HVAC	279,627	2,565,025	0	-126,243	2,438,782	2,159,155
Trans. & Dist.	2,543,519	2,242,172	-109	2,147,346	4,389,410	1,845,890
Hot Water (Level-2)	188,447	1,743,372	0	0	1,743,372	1,554924
Wall (Level-2)	907,261	1,840,887	0	0	1,840,887	933,622
Central Chillers	354,000	1,273,017	-25,831	0	1,247,186	893,186
DHW & A/C	118,124	1,001,673	-32,719	-53,507	915,446	797,322
Wells	210,500	718,156	-4,305	51,131	764,981	554,481
A/C	90	539,429	-1,550	0	537,879	537,789
Heating	235,202	700,930	0	22,215	723,146	487,944
Controls	150,400	532,652	0	-68,127	464,525	314,125
Cooling (Level-2)	165,900	274,395	0	0	274,395	108,496
Heating (Level-2)	13,016	45,366	0	0	45,366	32,352
Totals[b]	23,908,628	72,211,089	7,408,314	4,620,963	87,2474,447	63,625,347

Notes:
(a) Data of this level of detail is not normally available from FEDS Level-2. All values from the Level-2 software are approxiamate, and are shown only to represent the magnitude of the savings from each end use.
(b) These totals are the sum of the manual EROs and the output from the Level-2 software. They will not necessarily be the sum of the numbers above.

TABLE 3: SUMMARY OF ENERGY AND DEMAND SAVINGS FROM EROS

ERO Category	First Year Energy Savings (MBtu)	First Year Demand Savings (kW-mo)	Full Implement Energy Savings (MBtu)	Full Implement Demand Savings (kW-mo)	Annualized Energy and Demand Savings (1994 $)
Lights (Level-2)	NA	NA	34,815	2,487	1,014,144
Fam. Hsg. HVAC	76,678	15,226	76,678	15,226	713,785
Envelope	21,862	17,099	21,862	17,099	674,766
Roof (Level-2)	NA	NA	45,939	621	472,181
Vehicles	14,638	-180	14,638	-180	328,840
Hot Water (Level-2)	NA	NA	40,609	20	242,457
Motors	7,814	7,343	7,814	7,343	235,241
HVAC	15,058	1,690	15,058	1,690	148,950
Lighting Controls	5,992	0	5,992	0	145,910
Trans. & Dist.	2,203	3,708	6,076	7,223	130,202
Wall (Level-2)	NA	NA	10,653	123	106,898
Central Chillers	1,099	2,110	1,099	2,110	73,924
DHW & A/C	4,345	2,198	4,345	2,198	58,167
Wells	0	1,097	0	1,097	41,703
Heating	4,682	727	4,713	742	40,703
Cooling (Level-2)	NA	NA	962	143	35,400
A/C	935	1,129	935	1,129	31,324
Controls	1,508	2,186	1,508	2,186	30,931
Heating (Level-2)	NA	NA	-71	0	3,976
Totals:	156,813	54,331	293,623	61,256	4,529,501

TABLE 4: ENERGY PROJECTS IDENTIFIED FOR FEMP FUNDING

Project/Description	Initial Cost	Savings-to-Investment Ratio	Discounted Payback
Cross-connect chillers: Provide the capability to cross-connect chiller equipment between two central energy plants. During periods of low loads, this would allow operation with only one chiller, improving overall plant efficiency.	$354,000	3.5	4.9 years
Reset chilled/concenser water temperature: Reset the chilled water and condenser water temperatures 2-4° higher/lower. Large water-cooled chilleres are typically set for 45°F chilled water temperature and 95°F concensor water temperature. Most systems can operate at higher/lower temperatures without impacting cooling performance.	$1,000	5975	0.0 years
Install A/C desuperheaters: Install desuperheaters on air-cooled air conditioners in selected commercial buildings. This would improve overall A/C efficiency by about 15% and would supply the majority of the hot water needs during the cooling season.	$118,000	7.8	2.2 years
Replace existing residential domestic water heaters: Replace existing domestic hot water heaters, wrap tanks and piping with insulation and lower tank temperature.	$270,000	6.4	1.6 years
Replace space heaters with LPG infa-red heaters: Replace conventional space heaters with LPG infra-red heaters in selected maintenance shops and motor pool buildings.	$30,000	6.3	2.8 years

TABLE 5: EFFICIENCY RATINGS OF REPLACEMENT HVAC EQUIPMENT

Replacement Equipment	Cooling Eff.	Heating Eff.
Min. Compliance Air-source Heat Pump	10.0 SEER	7.0 HSPF
High Eff. Air-source Heat Pump	15.4 SEER	8.3 HSPF
Avg. Eff. Ground-source Heat Pump	13.3 EER	2.8 COP
High Eff. Ground-source Heat Pump	16.0 EER	3.5 COP
Min. Compliance Furnace and A/C	10.0 SEER	78.0 % AFUE
High Eff. Furnace and A/C	15.7 SEER	92.6 % AFUE
Gas-Fired Heat Pump	1.1 COP	1.3 COP

Note: (1) Efficiencies for the LPG and natural gas furnace and central air conditioner options are assumed the same; the only difference for these two options is the price of fuel.

(2) Additional notes on ground-source heat pumps: 1) There are no efficiency standards for ground-source heat pumps, so an average efficiency unit was chosen to represent the minimum compliance case, 2) Since the ground temperature remains fairly constant, the given efficiencies are assumed to represent seasonal values (EER = SEER).

TABLE 6: REPLACEMENT EQUIPMENT SIZES

Replacement Equipment	Cooling Cap. (KBtu/h)	Heating Cap. (KBtu/h)
Minimum Compliance Air-Source Heat Pump	28.2	27.4
High-Efficiency Air-Source Heat Pump	29.0	29.0
Average-Efficiency Ground-Source Heat Pump	30.2	20.8
High-Efficiency Ground-Source Heat Pump	31.2	21.2
Minimum Compliance Furnace and A/C	28.6	40.0
High-Efficiency Furnace and A/C	30.8	37.0
Gas-Fired Heat Pump	36.0	53.5

TABLE 7: INSTALLED COST OF REPLACEMENT EQUIPMENT

Replacement Equipment	Material (1994 $)	Labor (1994 $)
Minimum Compliance Air-Source Heat Pump	$2,180	$559
High-Efficiency Air-Source Heat Pump	$5,175	$559
Average-Efficiency Ground-Source Heat Pump	$3,000	$559
High-Efficiency Ground-Source Heat Pump	$3,770	$559
Minimum Compliance Furnace and A/C	$1,483	$468
High-Efficiency Furnace and A/C	$4,725	$468
Gas-Fired Heat Pump	$5,000	$750

Note: Material costs are from manufacturers' catalogs and sales representatives. Labor costs are from R. S. Means [3]. All costs include 15% overhead and profit. Material and labor costs for the ground-source heat pump excavation and piping are included in the material cost column above.