FINAL REPORT

Optimized Decision Support for Portfolio Energy Investment

ESTCP Project EW-201342

MARCH 2018

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Boeing

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ESAT (Energy Security Assessment Tool) is an innovative decision support technology which rapidly selects optimal energy project portfolios, cost effectively meets multiple energy goals, and assists with navigating multiple policies & mandates. It enables a decision maker to effectively explore the solution space of alternative portfolios, and easily and transparently incorporate evolving preferences. ESAT represents an integration of a Constraint Management System with a state-of-the-art visualization and analytics framework. This analytic environment successfully evaluates all project types of interest: energy efficiency, renewable energy, water conservation, and energy resilience. This approach simultaneously considers key financial and domain metrics, for example, Net Present Value (NPV), Savings to Investment Ratio (SIR), energy and water savings, and renewable energy generation.

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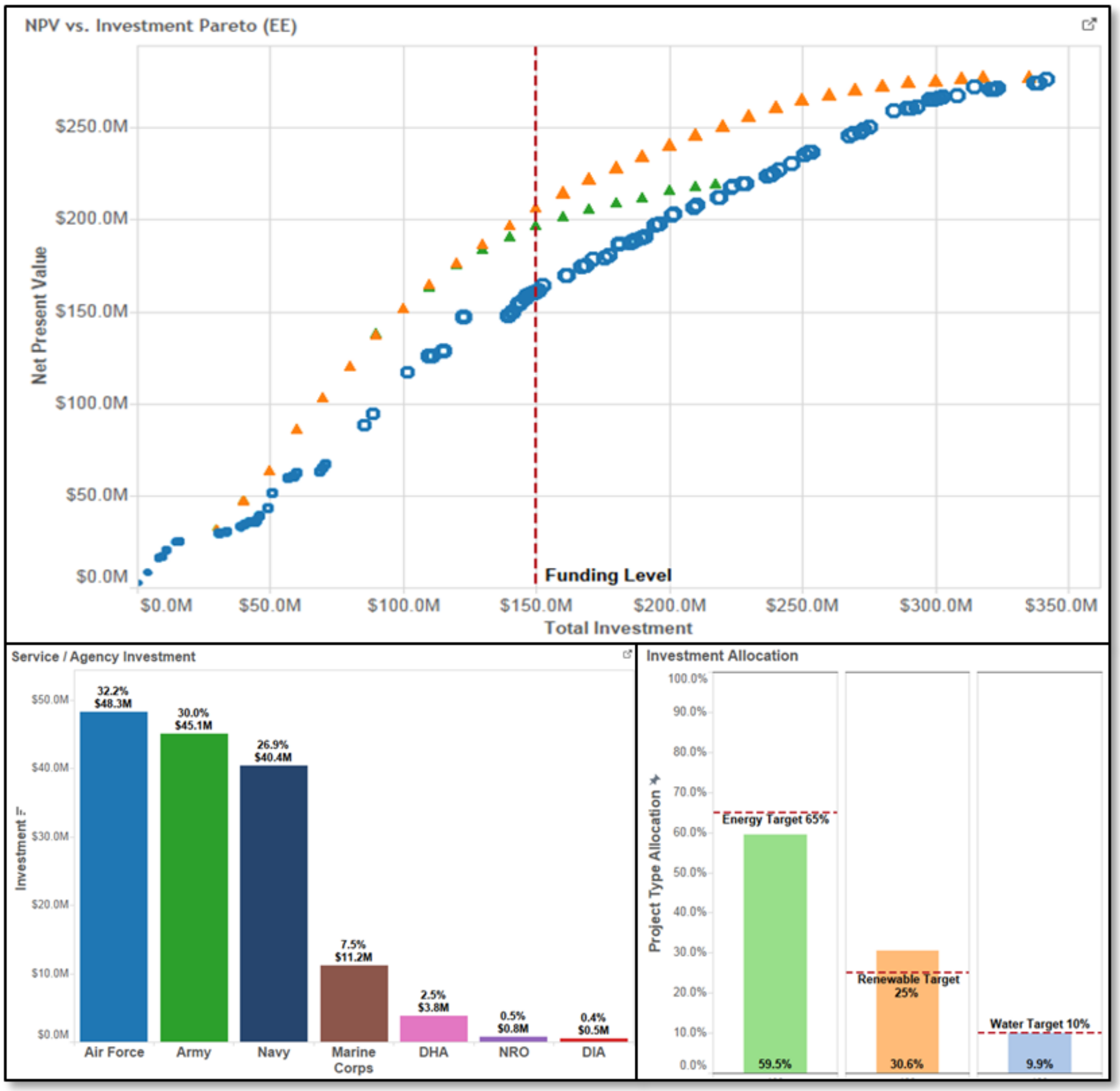
Energy Security Assessment Tool
Optimized Decision Support for Portfolio Energy Investment



Comprehensive Approach to Multi-Objective
Energy Portfolio Investment Analysis

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEC	Air Force Civil Engineering Center
AFCESA	Air Force Civil Engineer Support Agency
AIRR	Adjusted Internal Rate of Return
AMARG	Aerospace Maintenance and Regeneration Group
API	Application Programmer’s Interface
AZ	Arizona
BIR	Benefit to Investment Ratio
BLCCA	Building Life-Cycle Cost Analysis
CDR	Commander
CMS	Constraint Management System
CNIC	Commander Naval Installations Command
CNO	Chief of Naval Operations
CO2	Carbon Dioxide
DLA	Defense Logistics Agency
DOD	Department of Defense
DOE	Department of Energy
DON	Department of Navy
DS	Design Sheet™
DSIRE	Database of State Incentives for Renewables & Efficiency
ECIP	Energy Conservation Investment Program
EEM	Energy Efficiency Measure
EO	Executive Order
eROI	Energy Return on Investment
ESAT	Energy Security Assessment Tool
ESTCP	Environmental Security Technology Certification Program
FL	Florida
FEDS	Facility Energy Decision System
FEMP	Federal Energy Management Program
FSRM	Facilities Sustainment Restoration & Modernization
FY	Fiscal Year
GHG	Green House Gas
GSA	General Services Administration
GSU	Geographically Separated Units
GWh	Giga Watt hours
HASP	Health and Safety Plan
HOMER	Hybrid Optimization Model for Electric Renewables

Hrs	Hours
HVAC	Heating Ventilation Air Conditioning
ID	Identification
IDIQ	Indefinite Delivery Indefinite Quantity
IT	Information Technology
IPL	Integrated Project List
IPR	Interim Project Review
kg	Kilogram
kW	Kilowatt
kWh	Kilowatt-hour
LED	Light Emitting Diode
M	Million
MAJCOM	Major Command
MBTU	Millions British Thermal Units
MIP	Mixed Integer Programming
MW	Mega Watts
MMBTU	Millions British Thermal Units
MS	Microsoft
NASA	National Aeronautics and Space Administration
NIST	National Institute of Standards and Technology
NPV	Net Present Value
NREL	National Renewable Energy Laboratory
NRG	Air Force Energy Conservation Focus Energy Project Budget
OSD	Office of Secretary of Defense
PNNL	Pacific Northwest National Laboratory
QSA	Quality Score Average
REM	Resource Efficiency Manager
RI	Rhode Island
ROI	Return On Investment
RSA	Resilience Score Average
SIR	Savings to Investment Ratio
SP	Service Priority
SPR	Service Priority Rank
SRM	Sustainment Restoration and Modernization
TRL	Technology Readiness Level

US	United States
USA	United States Army
USACE	Unite States Army Corps of Engineers
USAF	United States Air Force
USMC	United States Marine Corps
USN	United States Navy
Yr	Year

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EXECUTIVE SUMMARY

ESAT is an innovative decision support technology which rapidly selects optimal energy project portfolios, cost effectively meets multiple energy goals, and assists with navigating multiple policies & mandates. It enables a decision maker to effectively explore the solution space of alternative portfolios, and easily and transparently incorporate evolving preferences. ESAT represents an integration of a Constraint Management System with a state-of-the-art visualization and analytics framework. This analytic environment successfully evaluates all project types of interest: energy efficiency, renewable energy, water conservation, and energy resilience. This approach simultaneously considers key financial & domain metrics, for example Net Present Value (NPV), Savings to Investment Ratio (SIR), energy and water savings, and renewable energy generation.

ESAT is broadly applicable to all Department of Defense fixed installations for energy investment decision support, with the capacity to impact DoD's $4B fixed installation annual energy costs. It is especially suited to situations where there are a large number of alterative projects to choose from, an oversubscribed budget, and the funding is distributed by a decision maker based on multiple criteria to support organizational goals. ESAT's underlying technology is also easily extensible to other project portfolio decision support areas, such as facility maintenance, sustainment support, technology investments, and other potential applications.

It has proved to be highly effective in improving the decision-making process relative to the legacy rank order approach, improving NPV by $12M-$30M, and ensuring that extensive decision criteria are met. Overall, the demonstration was very successful. Nine of the ten performance metrics were successfully met, while the tenth was partially met. A summary table is shown. No significant implementation issues were encountered during the demonstration.

Performance Objective	Success Criteria	Objective Met?
Analysis Effort	Excess savings due to optimized analysis over current practice exceed additional cost of analysis by 50%	Yes
Net Present Value	5% improvement in NPV compared to current practice	Yes
Energy Savings	Meet energy savings goals with either improved NPV or reduced investment level of 5%.	Yes
Cost Savings	5% improvement in annual energy cost savings when compared to current practice	Yes
Renewable Fraction	Improvement in renewable fraction over current practice	Yes
GHG (CO_2) Savings	Reduction in GHG over current plans/practice of 5%.	Yes
Energy Surety	Quantification of the tradeoff between islanding times and costs associated with an optimal selection of energy surety alternatives.	Partial
Analysis Schedule	Characterization of elapsed time to initial results & final results as a function of alternative scenarios	Yes
Insight Gained	Site management and energy team endorsements of the impact of this approach on their decision making	Yes
Budget Justification	Results incorporated into installation project proposals.	Yes

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1.0 INTRODUCTION

Boeing has developed a decision support technology, called “Energy Security Analysis Tool” (ESAT), which can be used for optimally determining the portfolio of energy projects to meet both installation-specific objectives and enterprise-wide goals and mandates. This report documents the results of demonstrating and validating this technology for installation-level and enterprise-level decision making at the Department of Defense (DoD) and quantifies the benefits of this technology over current practice.

1.1 BACKGROUND

Need: The Department of Defense’s energy strategy focuses on improving energy reliance, by increasing energy efficiency and use of renewable energy to reduce dependence on fossil fuels and vulnerability to supply disruption, both at the installation and enterprise levels. Decision makers at all levels are presented with an array of energy infrastructure improvement options from which they need to choose a subset, as well as, justify the budgets for acquiring and supporting these choices. The decision problem is complicated by multiple financial and energy performance objectives, annual budget constraints, complex financial incentives (at local, state, and federal level), intricate utility rate schedules, variability in renewable energy resources (e.g., for solar, wind, or geothermal), and stringent surety requirements. The decision maker has to *simultaneously* consider minimizing life cycle cost, initial investment and greenhouse gas (GHG) emissions, while maximizing energy savings, and examine tradeoffs between financial expenditure, implementation schedule, energy generation and savings, and surety.

Gap: Current practice, as reflected by methods employed at the centrally managed ECIP and NRG capital funding allocation programs, relies on straightforward prioritization or rank-ordering of projects by individual cost/benefit measures, such as payback period or savings to investment ratio (SIR), or a weighted combination of these. Such an approach is inadequate to the challenge of simultaneously considering multiple goals. For example, energy savings, energy surety, and GHG may all be impacted, but impacted differently by each of the potential energy projects being considered for implementation.

Challenge: Producing the optimal subset of projects to meet yearly budget constraints is a computationally-hard problem[1] and requires state of the art optimization algorithms to rapidly (within minutes) give the decision maker suggested best investment portfolios for any set of goals and constraints.

Desired Solution: A decision aid is needed for performing an *integrated* analysis of energy efficiency, renewable energy, energy storage, and energy resiliency/surety to help navigate the complex tradeoffs. The analysis tools must also produce charts and reports for the decision maker to assess performance, visualize trends, and examine tradeoffs and financial implications of implementing these projects. In the preliminary stages, the tradeoffs need to rapidly cover the widest possible range of alternatives. The model for these initial tradeoffs needs to be constructed, verified, and results analyzed quickly to give timely feedback appropriate for the given decision level – facility managers, regional managers, and DoD portfolio and enterprise managers.

[1] This problem is equivalent to a combinatorial NP-hard multiple bin-packing problem.

As the solution space is narrowed, there is a need to rapidly refine the models and perform subsequent analyses to the appropriate level of detail to justify budget profiles, include sensitivities to variations in assumptions, and understand the impact to schedule and cost.

Expected Benefits: Boeing's ESAT simultaneously optimizes life cycle cost, initial investment, GHG emissions, and energy savings, subject to constraints on annual budget, while also addressing renewable energy goals and energy resilience/surety metrics. ESAT provides decision makers the optimal tradeoff envelopes among expenditure, schedule, energy generation and savings, and resilience/surety. ESAT is broadly applicable to all DoD fixed installations for energy investment decision support and energy surety/mission assurance planning. Local, regional/service-level, and enterprise energy management decision makers can use ESAT to select optimal sets of energy infrastructure improvement options along with the corresponding budget and schedule that are compatible with their situation. ESAT analyses can be used to track the progress towards various installation and enterprise level goals and mandates and to uncover gaps in meeting those goals. Based on Boeing's prior experience, the multi-objective approach can lead to net present value (NPV) improvements of 7%-47% over current practice. Through integrated analysis of energy efficiency measures to reduce power and energy demand, renewable energy to enable sustainment of the mission without external energy supplies, energy storage to smooth out renewable energy production, and secure smart controls to manage energy surety and resilience, ESAT presents the decision maker with optimal portfolio of investments that together contribute to improving mission assurance.

1.2 OBJECTIVE OF THE DEMONSTRATION

The Energy Security Assessment Tool (ESAT) technology provides decision makers, at the installation, regional/service, and enterprise levels, sets of optimized energy project portfolios that meet competing multi-year goals subject to funding constraints. It uses constraint management and multi-objective optimization to perform an integrated assessment of energy efficiency improvements, renewable energy choices, energy storage options, and energy surety enhancements to simultaneously address economic, environmental, and energy surety goals. We expect ESAT to dramatically improve the effective utilization of limited resources, resulting in improved energy surety and enhanced mission effectiveness, while reducing life-cycle cost.

The objectives of the demonstration are to: 1) Demonstrate, validate, and extend this capability to a larger scale – confirming that it can be successfully implemented to provide decision makers, from the installation to enterprise level, a clear understanding of the impact of their investment strategies on meeting their energy goals; and 2) Refine the current estimates of required effort and cost of gathering data, adapting models, and performing analysis in support of energy investment decisions. The goal is to track the costs and benefits and determine the potential return on investment of the technology.

Successful demonstration is expected to have an impact in the following areas:

Validation and Acceptance: Validation of applicability, ease of use and return on investment will result in increased acceptance of this technology for energy project portfolio decision making across the DoD installations as well as regional/service and enterprise levels.

Findings and Guidelines: Demonstration results can be used to inform future DoD policy, especially at the enterprise level, regarding how budget is allocated to potential environmental sustainability investment projects.

Technology Transition: Experience in supporting energy project investment decisions at the demonstration sites has informed technology transition/delivery options as well as guided us in tailoring the decision support dashboards for different users. Delivery options under consideration include services contract, web-hosted service, and a licensed software. Boeing is currently planning to offer this technology to other DoD facilities through contracting with its services business. Installation energy teams can use this capability for their long term strategic planning, demonstrating how they will meet DoD or service energy goals through their multi-year investment plan. This plan will supplement funding requests by providing quantifiable substantiation for those requests. Regional/service-level and enterprise users of this capability will employ it as a decision aid in evaluating the many submitted energy projects that are seeking funding.

Additional Benefits: Long term, should our technology be used widely across the installations and at the enterprise level, DoD could recognize accumulating savings over subsequent years in the form of investment savings, return on investment and meeting energy related goals more quickly than current practice. Based on DoD's fixed installation annual energy costs of $4B, there is a large opportunity for savings to be realized by using ESAT integrated analysis. Environmental emissions would naturally also be reduced by following the produced recommendation plan of ESAT analysis.

1.3 REGULATORY DRIVERS

Many of the current regulations (Executive Orders, Legislative Orders, and Service Policy) are relevant to, and addressed by, our proposed technology. The fact that there are many regulations, with their associated requirements, goals, and guidance, precipitates the need to make decisions while navigating multiple competing objectives and operating within a budget-constrained framework. Our technology is specifically designed to help with this by handling the complexity of simultaneously meeting multiple objectives in an optimal fashion, and delivering a recommended, time-phased investment plan.

Following is a partial list of the many relevant regulations or policies applicable to DoD sites, with regard to meeting environmental goals. Our technology will help these sites meet the goals required by these policies and regulations in an optimal way.

Executive Order 13423:

As stated by the Office of the Federal Environmental Executive, EO 13423 requires federal agencies to lead by example in advancing the nation's energy security and environmental performance by achieving the following goals:

- Energy Efficiency: Reduce energy intensity 30% by 2015, compared to an FY 2003 baseline.
- Greenhouse Gases: Reduce greenhouse gas emissions through reduction of energy intensity 30% by 2015, compared to an FY 2003 baseline.
- Renewable Power: At least 50% of current renewable energy purchases must come from new renewable sources
- Water Conservation: Reduce water consumption intensity 16% by 2015, compared to an FY 2007 baseline.

- Alternative Fuel: Increase use of alternative fuel consumption by at least 10% annually, compared to an FY 2005 baseline.

Executive Order 13514:

The Executive Order requires agencies to meet a number of energy, water, and waste reduction targets, including:

- 30% reduction in vehicle fleet petroleum use by 2020;
- 26% improvement in water efficiency by 2020;
- 50% recycling and waste diversion by 2015;
- 95% of all applicable contracts will meet sustainability requirements;
- Implementation of the 2030 net-zero-energy building requirement;
- Reduce the use of fossil fuels.
- Established an agency-wide GHG emissions percentage reduction target (Scope 1 & Scope 2) by FY20. FY08 baseline.

Energy Policy Act of 2005:

Renewable energy purchase requirement:

- ≥ 3% for FY2007-FY2009,
- ≥ 5% for FY2010-FY2012,
- ≥ 7.5% for FY2013 and each fiscal year thereafter
- By October 1, 2012, all Federal buildings shall, for the purposes of efficient use of energy and reduction in the cost of electricity used in such buildings, be metered

Energy Reduction Goals for Federal Buildings:

Fiscal Year	% reduction
2006	2
2007	4
2008	6
2009	8
2010	10
2011	12
2012	14
2013	16
2014	18
2015	20

Energy Independence and Security Act of 2007:

High-Performance Federal Buildings

- New standards and grants for promoting efficiency in government and public institutions. New and renovated federal buildings must reduce fossil fuel use by 55% (from 2003 levels) by 2010, and 80% by 2020. All new federal buildings must be carbon-neutral by 2030.

Facility Energy usage:

- Reduce Total Usage by Fiscal Year (FY03 Baseline)
  - 2006: 2% | 2007: 4% | 2008: 9% | 2009: 12% | 2010: 15% | 2011: 18% | 2012: 21% | 2013: 24% | 2014: 27% | 2015: 30%

Renewable Sources:

- Energy consumption from fossil fuels in new/renovated buildings is reduced: 55% by 2010; 100% by 2030
- At least 30% of hot water consumed in new/renovated buildings is heated via solar energy by 2015

Other Provisions

- Smart grid - modernization of the electricity grid to improve reliability and efficiency.
- Beginning in FY10, each Federal agency shall reduce petroleum consumption and increase alternative fuel consumption.

National Defense Authorization Act 2010

- Produce or procure 25% of the total energy from renewable energy sources, beginning in 2025.
- Explore expeditionary use of solar and wind to provide electricity.

Air Force Infrastructure Energy Plan 2010:

The primary Infrastructure Energy Plan goals are listed below:

- Reduce infrastructure costs by 20% by 2020
- Reduce facility energy intensity by 3% per annum through 2015
- Reduce base water use by 2% per annum through 2015
- Increase use of renewable energy at annual targets (3%, 5%, 7.5%, 25%) through 2025
- Reduce ground vehicle fuel use by 2% per annum through 2015
- Increase alternative fuel use by 10% per annum through 2015

U.S. Air Force Energy Strategic Plan 2013:

Increase facility use of alternative and renewable energy

- Increase facility consumption of renewable or alternative energy to 25% of total electricity use by 2025
- Construct on-base renewable energy production to achieve 1% of Air Force facility consumption by 2013 and develop 1,000 megawatts of on-site capacity by 2016
- Ensure all new buildings are designed to achieve zero-net-energy by 2030, beginning in 2020

Implement required systems and tools that support risk, energy, performance, and life cycle analysis

- Develop methodologies to better incorporate energy security as a factor in budget processes by 2015
- Identify energy assessment methodology to enhance decision-making by 2013

Reduce built infrastructure energy and water consumption

- Reduce energy intensity by 30% by 2015 (2003 baseline) and 1.5% annually through 2020 (2015 baseline)
- Reduce built infrastructure energy and water consumption
- Reduce total facility energy consumption by 15% by 2020 (2010 baseline)
- Ensure energy performance remains on track to meet all applicable requirements from laws, regulations, and executive orders
- Reduce potable water consumption intensity by 26% by 2020 (2007 baseline)
- Reduce industrial, landscaping, and agricultural water consumption by 20% by 2020 (2010 baseline)
- Ensure all installed facility electricity, gas, and steam smart meters are integrated with the appropriate computer network by 2016

<u>Department of the Navy's Energy Program for Security and Independence October 2009:</u>

Increase Alternative Energy Ashore

- By 2020, at least 50% of shore-based energy requirements will come from alternative sources; 50% of DON installations will be net-zero

Increase Alternative Energy Use DON-Wide

- By 2020, 50% of total DON energy consumption will come from alternative sources

<u>Army's Installation Management Campaign Plan (IMCOM):</u>

- % Reduction in energy intensity per square foot baseline year (Minimum 15% in 2010, 18% in 2011, 21% in 2012, 24% in 2013, 27% in 2014, and 30% in 2015); verified with meter data.
- % Reduction in potable water consumption per square foot baseline year (Minimum 6% in 2010, 8% in 2011, 10% in 2012, 12% in 2013, 14% in 2014, and 16% in 2015); verified with meter data.
- % renewable and alternative energy consumption in compliance with EPAct05 and not less than: 5% in 2010 -2012; 7.5% in 2013; and in compliance with EISA 2007 and not less than 25% in 2025.
- Reduce Scope 1 and 2 Green House Gases (GHG) emissions by 34% by 2020 from the baseline year 2008.

2.0 TECHNOLOGY DESCRIPTION

2.1 TECHNOLOGY OVERVIEW

The Energy Security Assessment Tool (ESAT) evaluates in a single analytic environment alternative energy efficiency measures, renewable energy and storage choices, and energy surety options, in order to support multi-faceted investment decisions. Local, regional/service-level, and enterprise energy management decision makers can use ESAT to select optimal sets of energy infrastructure improvement options, and determine the budget and schedule required for implementing them. ESAT analyses can be used to track the progress towards various site and enterprise level goals and mandates and uncover any gap in meeting those goals. ESAT uses multiple-objective optimization to simultaneously minimize life cycle cost, initial investment, and GHG emissions, while maximizing energy savings, and accounts for available annual budget, renewable energy goals, energy resilience/surety requirements, etc. in arriving at its recommendations. Instead of providing a single recommended solution, ESAT provides decision makers the tradeoff envelopes among expenditure, schedule, energy generation and savings, and surety, from which they can select an optimal solution that is specific to, and compatible with their mission.

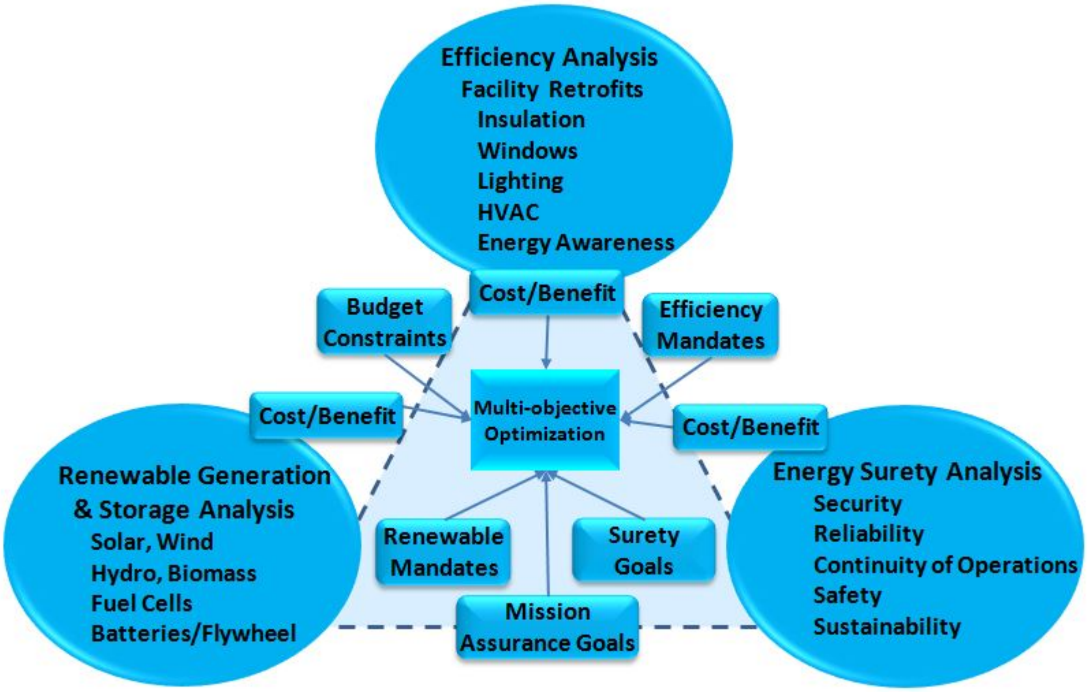

Figure 1. ESAT Integrates Energy Efficiency, Renewable Energy, and Energy Resilience/surety into a Single Analytical Framework for Energy Project Investment Decision Support.

Figure 1 is a graphical depiction of ESAT that illustrates the three facets of its energy analysis, namely energy efficiency analysis, renewable generation and energy storage analysis, and energy surety analysis. Key ESAT features include:

- Leverages government/industry accepted models for analyzing energy generation and efficiency improvements.
  - For energy generation and storage systems modeling, it relies on the HOMER model, originally developed by National Renewable Energy Laboratory (NREL).
  - For energy efficiency and retrofit analysis, it relies on Facility Energy Decision System (FEDS), developed by the Pacific Northwest National Laboratory (PNNL).
- A flexible architecture that allows additional analysis models, for example energy resilience/surety, to be easily integrated.
- Uses advanced tradeoff and multi-objective optimization framework to integrate these analyses to provide a comprehensive view of the investment and energy tradeoffs to the decision maker.
- The cost-benefit analysis is consistent with the BLCCA standard that NIST developed for Federal Energy Management Program (FEMP).

Boeing's Design Sheet™ is the system-of-systems analysis framework at the core of ESAT integrated analysis. It relies on algebraic constraint management technology to rapidly develop and integrate multi-disciplinary models for analysis and optimization of complex engineering systems. It combines symbolic algebra, advanced numerical methods, graph-theoretic techniques, state-of-the-art optimization algorithms, and a specially designed trade study interface to support an efficient formulation of the mixed-variable, multi-objective problem that is needed for rapid what-if analysis, while ensuring that the model can be quickly modified with additional objectives and constraints.

In contrast to prevailing approaches to energy analysis, ESAT is innovative on several fronts.

Integrated Analysis**:** ESAT performs integrated analysis of energy generation, efficiency retrofits, and energy resilience/surety. Second, it uses multi-objective optimization to provide to the decision makers tradeoffs with respect to their competing objectives. Whereas a prevailing technology ranks the energy retrofits under consideration according to a metric such as SIR, ESAT is able to determine which combination of retrofits and renewable generation projects *together* are ideal given the annual budgetary constraints, renewable generation, and energy savings goals. Additionally, it presents these results as multi-objective tradeoffs, which allows the decision maker to explore and choose a specific combination based on his/her priorities between the competing objectives. ESAT quickly provides many trade studies and sensitivity analyses, including the impact of variability in power prices, discount rates, and projected capital costs on factors such as internal rate of return, net present value (NPV), and primary mission effectiveness. The model also incorporates location-specific tax credits and incentives, GHG impact based on fuel mix, and time-phased investment.

Multiple-Objective Optimization: ESAT uses multiple-objective optimization to provide decision makers with the Pareto-optimal[2] set of solutions from which they can make an appropriate choice based on their specific mission. Figure 2 is from an analysis completed at a Boeing facility and shows a typical multi-objective tradeoff between total investment over a 14-year investment horizon and the resulting NPV. Each point on the curve is the optimal combination of energy efficiency measures and renewable generation projects for the indicated total investment.

[2] A point, p, is "Pareto optimal" in a universe, U, with respective to a set of multiple objectives, if there is no other point in U that is as least as good as the point p in all objectives and is superior to point p in at least one objective.

The points are optimal not only in terms of NPV, but also in terms of meeting renewable energy and energy savings goals. In this example, the energy savings goal is 10% and renewable generation goal is 25%. Two points are called out in Figure 2– one for the currently planned investment level, and the second for the optimal investment level to meet the stated goals. As shown in the highlight boxes, ESAT produces several energy and financial metrics for each combination of energy investments. ESAT further provides year-by-year costs and savings for any selected investment level. The bottom panel in Figure 2 shows the upfront investment, investment that can be funded from operational savings, and net savings, for the optimal solution that meets the energy goals.

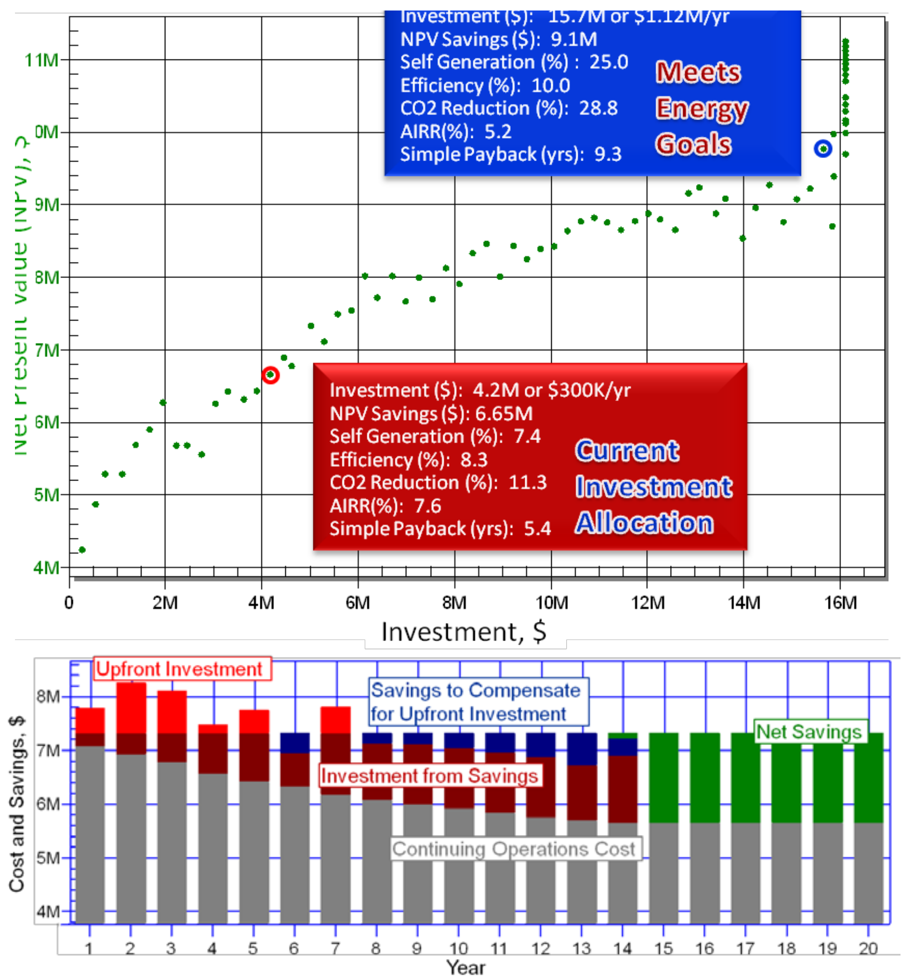

Figure 2. Multi-objective Optimization Results from ESAT Analysis

Top panel shows the tradeoff between total investment and NPV for different optimal combinations of energy projects; the bottom panel shows the distribution of costs and savings over the study period, for a specific overall investment.

Investment Plan and Gaps in Goal Realization: Each point in the Pareto-optimal set produced by ESAT is the optimal solution choice for a given investment level. A facility energy manager or an enterprise decision maker can drill down further to obtain the year-by-year optimal project investment list. Figure 3 shows, from a preliminary analysis done for Luke AFB, the annual recommended energy efficiency project implementation list, the total investment required, and the cumulative energy savings realized. In this preliminary study, only efficiency measures were considered and a four-year investment horizon was chosen. When renewable energy projects are also considered in the study, these investments are included in this chart as well.

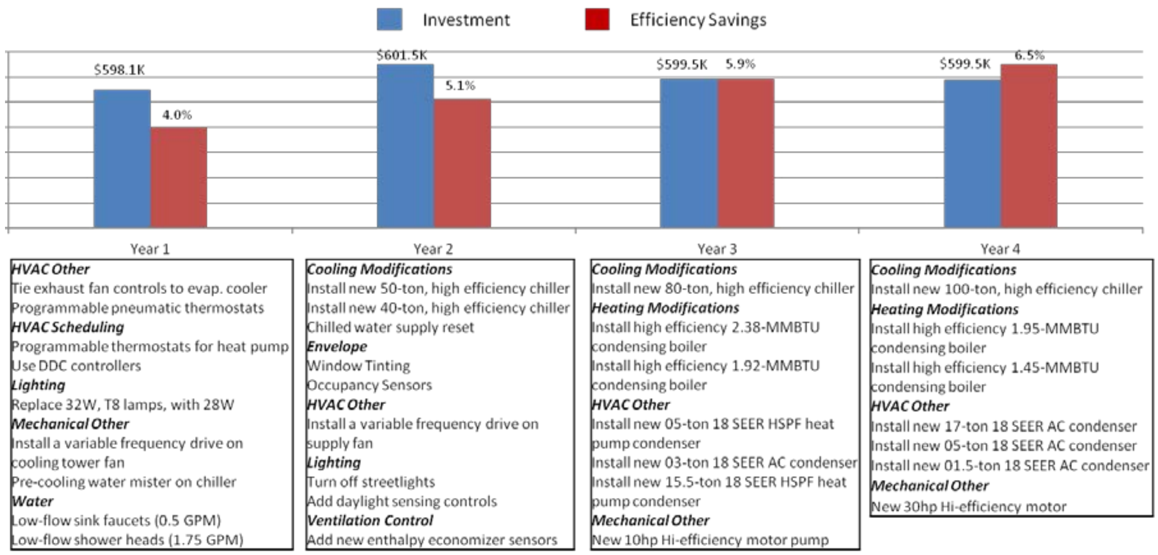

Figure 3. ESAT Produces an Optimal Year-by-year Investment Plan to Meet the Specified Energy Goals.

Figure 4 shows the progress expected to be made in meeting the energy goals, as well as the gap in meeting the goals. It also shows how two different levels of investment ($350K and $600K per year for four years) impact the realization of energy goals. The gap in meeting goals can be reduced by identifying more efficiency measures and ESAT estimates both the needed investment, the realized improvement in NPV, and the progress towards meeting the energy goals.

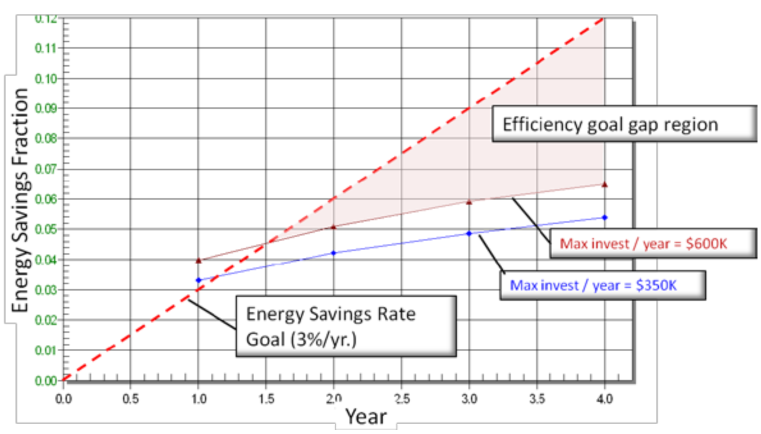

Figure 4. ESAT Helps Decision Maker Track the Progress Towards Meeting Energy Goals and Shows Any Gaps in Meeting Such Goals.

Rapid Trades: A major ESAT innovation is in efficiently performing multiple-objective optimization for rapid trade studies to provide energy project portfolio investment decision support. ESAT uses a formulation of the multi-objective optimization that relies on the use of efficient mixed integer programming (MIP) algorithms to determine the non-dominated sets of solutions on the Pareto frontier. Figure 5 shows the three-dimensional Pareto frontier with the non-dominated solutions that are optimal with respect to the three objectives of minimizing investment and maximizing energy savings, and NPV. There are many combinations of energy project investments that are dominated by the solutions on the Pareto frontier, and ESAT efficiently navigates the extremely large space of possibilities and rapidly identifies the solutions on the Pareto frontier. The specific solution from the Pareto-optimal set can be chosen by the decision maker based on the importance of the different objectives and other subjective criteria.

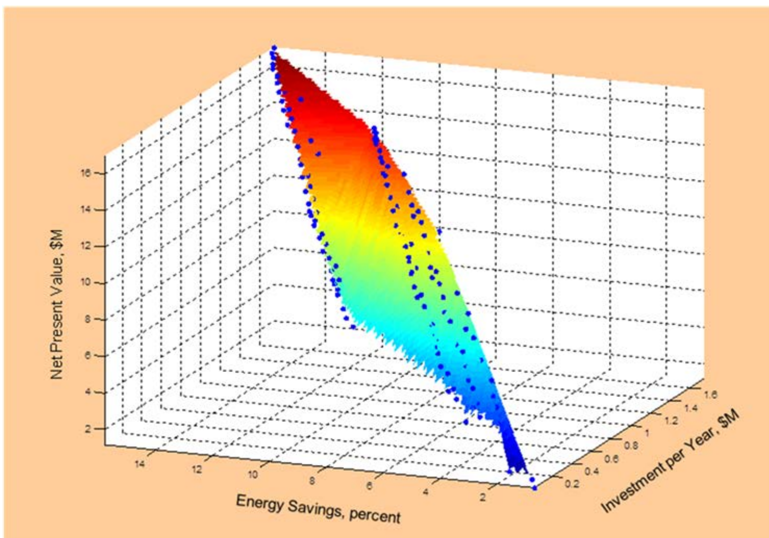

Figure 5. Three-dimensional Pareto Frontier Between Investment, Net Present Value, and Energy Savings.

ESAT creates several useful information sets in the form of graphical charts and tables, some of which are shown in Figures 2-5. Once the project evaluation data is available[3], ESAT produces the Pareto-optimal solutions within a range of a few minutes to a couple of hours depending on the size of the solution space searched. These initial results are presented to the facility managers (or other decision makers) by the analysis team. ESAT is not limited to a set of pre-programmed trades, and novel trades can be performed rapidly, if desired by the decision makers.

[3] When individual project evaluation data are available, for example from separate analyses of energy efficiency measures, renewable energy projects and energy surety projects, the results of those analyses are used by the multi-objective optimization framework to provide the decision maker with the Pareto-optimal sets of energy projects for different investment levels and specified multi-year energy goals. If individual project evaluations are not available for certain projects to feed into the optimization framework, FEDS tool is used for identifying and analyzing potential efficiency projects, HOMER tool is used to evaluate the renewable energy and energy storage projects, and Design Sheet models are used for evaluating energy surety projects. The overall framework is, therefore, able to deal with different levels of data availability. Further, ESAT is able to provide uncertainty estimates on the different metrics, arising due to the uncertainty in the input data.

Once the initial search for Pareto-optimal solutions is complete, the analyst can interactively, in a few minutes, perform sensitivity and what-if analyses based on decision maker interests. Some of these may require minor model refinement but can be completed rapidly (in a matter of a few hours) to produce the desired tradeoffs.

Easy Extensibility: Boeing's innovative constraint management system (CMS) based tool, Design Sheet, is used for easily integrating the analyses from multiple sources, and efficiently performing multiple-objective optimization. Design Sheet can integrate external analysis models[4], where they exist, as well as support the rapid development of new mathematical models when required. The mathematical model has components to calculate the total energy saved, peak demand reduced, etc., based on different combinations of the energy projects being considered for investment during each year of the planning period. The model also calculates the economic metrics (NPV, AIRR, SIR, etc.), and is consistent with BLCCA standard.

The ESAT model can be easily extended as necessary to accommodate new requirements. Currently, ESAT only has a limited analysis capability for energy resilience/surety analysis, but this can be easily enhanced should there be a need for such an analysis to guide portfolio optimization[5]. The resilience/surety model evaluates the impact of the reliability and availability of renewable and other local generation capability, energy storage capacity, and smart controls to determine metrics such as the maximum critical loads and the duration of islanding. Water conservation projects are also included in the integrated analysis, and goals on water savings and constraints on water project investments drive the generation of optimal project portfolios. The model architecture has been developed to easily accommodate the addition of water and other resources (e.g., solid waste) into the optimization analysis. The approach taken is to collect the volume savings generated by the individual water projects, and convert these savings into cost savings using the rates for different types of water resources.

Flexible Integration Architecture: ESAT relies on FEDS and HOMER for individual evaluation of potential energy efficiency measures and renewable/local energy generation options. It uses FEDS for potential retrofit recommendations to augment efficiency projects identified from site audits. ESAT can be used for peak demand analysis to identify potential local generation and energy storage options, which are evaluated using HOMER. ESAT can interact with HOMER either through an API or a file-based interface. It interacts with FEDS through a file-based interface (Boeing has had discussions with PNNL regarding a FEDS API and may pursue that as an additional option.[6]) FEDS is available free of charge for use on federally-funded projects. HOMER can be licensed for use by DoD, and a free version is also available. Boeing uses the current released versions of FEDS and HOMER. We expect that any future enhancements and version releases will benefit ESAT analysis.

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[4] Design Sheet can integrate models written in Microsoft Excel, MATLAB, C, FORTRAN, and LISP.

[5] Currently, resilience/surety projects can be included in the project planning and optimization, if surety project metrics are available from external analyses. A limited model has been prototyped to calculate islanding time given a mix of renewable energy generation capabilities.

[6] Interaction of ESAT with FEDS through an API is not a requirement for this demonstration. No such development is planned as part of this demonstration effort.

As might be expected, potential ESAT users may currently employ a variety of unique, preferred tools for generating, analyzing, and validating candidate project data. The outputs from these tools can be leveraged by ESAT in one of three ways (of varying streamlining provisions):

(1) As mentioned earlier, in reference to HOMER, ESAT can interface with other tools via API. Through this communication mechanism, the tool can be directly called by ESAT to perform the appropriate function or provide the needed data.
(2) Auto translation of the tool's output file into an ESAT standard format, via script. This conversion script would be unique to the data-submitting tool
(3) (3). Manual input of data into ESAT via copy/pasting and/or formatting of the feeding tool's output data.

Technology Development and Maturity: Prior to this demonstration, the integrated ESAT model has been used on limited laboratory-scale demonstrations, and thus is at a technology readiness level, TRL5. Two of the component tools, FEDS used for developing energy efficiency retrofit opportunities and HOMER used for analyzing energy generation and storage options are at TRL9. Both these tools have been deployed successfully on numerous studies. Design Sheet™ has been successfully employed on many multi-disciplinary analysis and optimization studies in the aerospace domain. The goal of this effort has been to mature the overall ESAT technology from TRL5 to TRL7.

Boeing has developed ESAT starting in 2009, and has over the next two years performed several proof-of-concept demonstrations. In 2011, ESAT was applied to a large Boeing manufacturing site. The FEDS and HOMER tools were used, and optimization analysis included energy efficiency measures, solar, wind and hydro-kinetic turbine installations, and state and federal incentives. This analysis addressed the complexity of multi-year investment, with associated annual budget constraints and energy goals. Also in 2011-2012, ESAT was applied at Luke AFB. This optimization analysis included energy efficiency measures, alternative solar array generation options, and battery storage, subject to complex electric rate schedules.

The federal and state incentives for inclusion in the analysis are collected from multiple sources:

(1) Federal Energy Management Program (FEMP) Energy Incentive Programs listing http://www1.eere.energy.gov/femp/financing/energyincentiveprograms.html
(2) U.S. Department of Energy Database of State Incentives for Renewables & Efficiency (DSIRE) http://www.dsireusa.org/
(3) Unique incentive arrangements between the installation and their local utility provider, which are discovered through discussions with the installation staff and by reviewing their utility contracts.

The ESAT tool does not maintain the entirety of the incentives from the above sources. Instead, only the applicable incentives for the installation are included when performing the optimization analysis. This is done because the complete incentive set is large, complex, and changing.

The early studies involved only energy efficiency measures (EEMs) at multiple Boeing locations, but have been helpful in quantifying the benefits of ESAT analysis. These studies involved multiple objectives of maximizing NPV and minimizing investment & CO2 emissions, but did not consider multi-year goals or investment. Figure 6 shows a tradeoff between investment and NPV for a case study done at a Boeing site in Arizona. Each point in these charts is the recommended combination of EEMs for a specific investment level. The chart in Figure 6 compares ESAT results to the commonly used rank-ordering approach and clearly shows that, at any investment level, the optimization method produces solutions that are superior to the rank-order method. The highlighted choices show that, with ESAT, the same savings can be achieved for less investment or increased savings can be realized for the same investment, relative to the rank order method. Overall, ESAT produced improvements in NPV savings ranging from 7%-47% relative to the rank-order method. Another benefit of multiple-objective optimization is that the knees[7] in the tradeoff envelopes can be used to choose optimal investment levels. For example, referring to the graph in Figure 6, the decision maker can see that investment can be reduced from $800K to $600K with only a marginal reduction in the NPV.

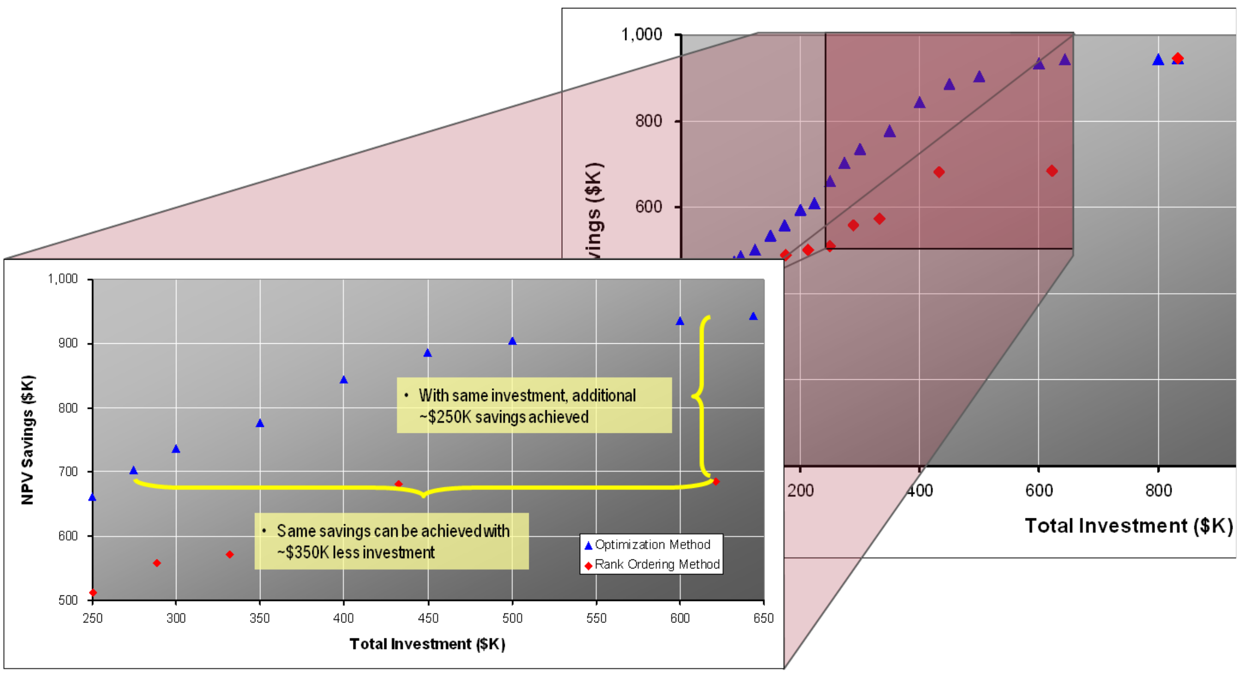

Figure 6. The Pareto-optimal Solutions Produced by Multiple-objective Optimization Approach Used by ESAT Results in Superior Decisions, by Either Reducing Investment or Increasing Savings.

Boeing conducted an analysis based on the combined list of projects from several different installations, using an enhanced multiple-objective optimization algorithm to scale the system to this larger problem. Figure 7 shows the Pareto-optimal solutions for analysis done independently at Boeing's Arizona and Pennsylvania sites, as well as a multi-site analysis done with projects from both sites considered together. It shows that, at every investment level, the combined analysis produces superior solutions in terms of NPV. The highlighted points in the figure refer to the savings (NPV) based on ESAT recommended solutions for an investment of $100K independently at these Boeing sites, and a combined investment of $200K at both sites considered together.

[7] For a two-objective Pareto-optimal tradeoff, a knee is a place on the tradeoff envelope where there is a sharp change in the value of one objective for a small change in the value of the other objective.

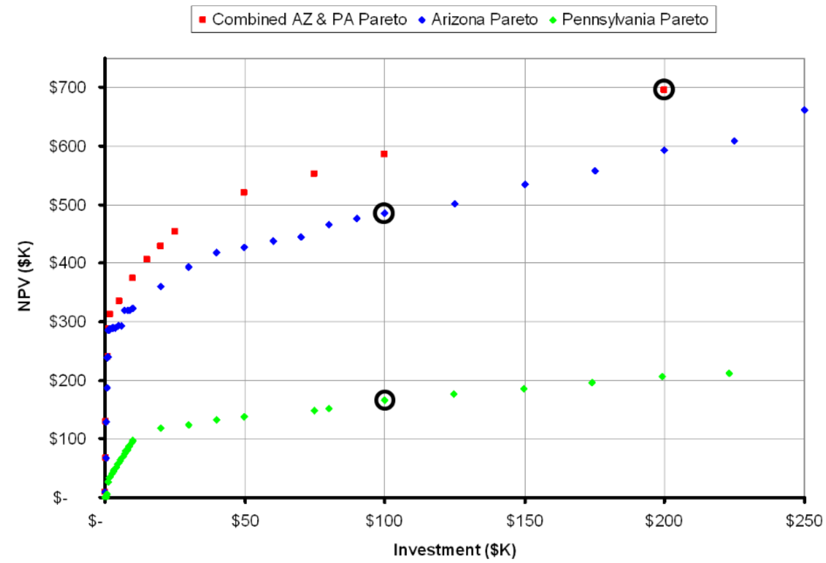

Figure 7. ESAT Enterprise Level Analysis Produces Superior Solutions Compared to Analysis Done Independently at the Sites.

2.2 TECHNOLOGY DEVELOPMENT

ESAT technology has been developed with internal Boeing funding, primarily before the commencement of the ESTCP demonstration project. Some optimization and visualization enhancements have been developed concurrent with the ESTCP demonstration project, once again under separate Boeing internal funding. The only development that was funded by the ESTCP project is the updating of the optimization model and the visualization dashboards to accommodate the demonstration site specific needs, especially at the Energy Conservation Investment Program (ECIP).

2.3 ADVANTAGES AND LIMITATIONS OF THE TECHNOLOGY

ESAT offers breakthrough benefits on multiple levels – optimizing energy investments at site and enterprise level and improving mission assurance. The technology is broadly applicable at all fixed installations for energy investment decision support and energy surety/mission assurance planning.

Energy investment optimization: Through its rapid, integrated analysis, ESAT presents multi-objective tradeoffs between NPV and investment, which allows a decision maker to explore and choose specific combinations of energy investments based on mission-specific priorities. ESAT clearly indicates solution choices that can either reduce the cost substantially for a limited sacrifice in energy goals, or substantially increase the energy goals achieved by a limited relaxation of the budget constraints. The FEDS studies cited in Section 9.0 show savings of 10%-20% on annual energy usage. Our experience has demonstrated that ESAT multi-objective analysis can lead to NPV improvements of 7%-47% over current approaches. Based on DoD's fixed installation annual energy costs of $4B, there is a large opportunity for savings to be realized by using ESAT integrated analysis.

Additionally, ESAT provides a comprehensive planning solution to meet mandates and goals. It determines whether the current investment rate will be sufficient to meet the goals, and estimates the marginal impact of additional investment. It also enables the energy manager to track progress of infrastructure investments in meeting energy savings, renewable energy, GHG emissions, and mission assurance goals. ESAT sensitivity analyses help the decision maker understand the impact of variability in cost and other parameters on the project recommendations and the energy and financial metrics.

Mission assurance: Assuring that critical mission activities can remain operational, when grid power is compromised, requires investments in energy efficiency to reduce power and energy demand, renewable energy to enable sustainment of the mission without external energy supplies, energy storage to smooth out renewable energy production, and secure smart controls for managing energy surety. Only through integrated analysis offered by ESAT can the decision maker have a clear picture of how these factors *together* contribute to improving mission assurance.

Enterprise-level decision support: Investment decisions that are optimal for individual installations are not always optimal at the enterprise level. Current approaches allocate resources at the enterprise level based on a calculated composite score, subject to pre-determined weights accorded to various metrics such as SIR, payback period, etc. As the objectives/metrics may not be directly comparable, assigning weights before examining the tradeoffs is difficult as well as highly subjective, not to mention weighted approaches can easily produce sub-optimal solutions. ESAT provides superior support for enterprise-level decision making by automatically producing the portfolios of projects that are Pareto-optimal with respect to multiple objective criteria. This facilitates the decision maker's ability to examine critical tradeoffs between the various objective metrics, and choose the optimal portfolio to satisfy given investment level, and desired energy, financial, surety, and other goals. Enterprise level ESAT analysis also ensures that the investments made across all installations meet the multi-year enterprise level goals on energy efficiency and renewable energy, while simultaneously constrained by annual budget availability.

***Potential Limitation - Energy Conservation Project Data Availability*:**

Likelihood: Low; Consequence: Moderate: If project investment and savings data are unavailable, such data will need to be created, resulting in an increase in time and cost to perform analysis. For this demonstration, however, the potential increases in time and cost have been factored into the proposed plan.

Mitigation Plan: The availability of project data is important to the success of ESAT analysis. A partial list of potential projects can be generated by ESAT via FEDS; however, this approach still relies on the installation host to provide building characteristic and equipment data. We planned to work closely with the installation energy managers to identify potential projects from previous internal and third-party assessments. Incorporating mission assurance parameters into the tradeoffs requires some installation-specific modeling, and will require coordination with installation commanders. Also, at Installation 2 – Davis-Monthan AFB, we have installed smart meters to collect usage data (see Appendix B: Advanced Metering System Installation for Davis-Monthan AFB).

***Potential Limitation – Energy Surety Project Data Availability*:**

Likelihood: Moderate; Consequence: Moderate: If surety project investment and savings data are unavailable or classified, they may need to be either derived or invented (assuming the site wants to consider this analysis dimension). This will result in an increase in time and cost to perform analysis. The analysis results will be accurate for the proposed scenario, but would not necessarily be directly applicable to the site until real data were substituted for the provisional data.

Mitigation Plan: If desired by a demonstration site that has no surety plans under consideration, analysis can be performed using estimated investment levels, surety impact (e.g. islanding time), and potential energy savings for estimated representative surety projects.

***Potential Limitation – Optimization Algorithm Performance*:**

Likelihood: Moderate; Consequence: Moderate: When the number of potential investment projects to evaluate is very large (greater than 200, which may be the case for enterprise level analysis), we may encounter a performance degradation of the optimization algorithms. When the number of projects is less than 100, each optimal portfolio can be obtained in about a second on a Windows workstation, requiring less than 5 minutes for a set of optimal portfolios used in decision space exploration. For multi-year portfolio analysis with about 200 projects spread over 4 years, a small set of optimal portfolios may be obtained within an hour, depending on the number of constraints involved. However, beyond 200 projects, the current algorithm scales exponentially with the number of projects.

Mitigation Plan: Grouping like projects into a single category, but offer partial implementation of the category will have the effect of processing fewer projects, thus restoring optimization performance. We also have experience in developing specialized optimization algorithms to address such issues.

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3.0 PERFORMANCE OBJECTIVES

Many innovative technologies are being developed to address energy and water security, cost avoidance, and greenhouse gas reduction. The "Optimized Decision Support for Portfolio Energy Investment" methodology provides decision makers, from installation to enterprise level, a clear understanding of the impact of their investment strategies on meeting energy, water, greenhouse gas, and surety goals. In addition, the decision aid will help energy management teams in determining the optimal portfolio of projects in which to invest over a multi-year investment horizon subject to yearly budget constraints. As the projects are diverse with varying impacts on energy, GHG, and surety goals, a single financial metric such as NPV does not provide sufficient guidance to select projects for investment. Therefore, the performance objectives for the portfolio energy investment technology demonstration are two-fold – first, to measure the improvement in multiple-objectives (energy savings, renewable energy, GHG, energy surety) that can be obtained relative to current practice (rank-ordering with respect to a single metric); and second, to estimate the additional effort and cost of gathering data, formulating models, and performing analysis in support of energy investment decisions.

Table 1 lists both quantitative and qualitative performance objectives that were tracked during the technology demonstration. The quantitative performance objectives help installation and enterprise decision makers to determine how effective the proposed approach is relative to current practice, and to estimate the return on investment provided by the multi-objective decision support methodology. In addition, qualitative performance criteria are also important in order to support energy investment decisions based on subjective decision maker tradeoffs between multiple competing objectives.

The purpose of this demonstration is to evaluate the benefits provided by the proposed analysis and decision support approach over current practice. It is important to compare the results between the approaches at more than a single baseline investment level or baseline list of projects under consideration. Therefore, the results over a range of investment levels (decided in consultation with installation energy managers) were analyzed and compared. Also, when dealing with simultaneously addressing multiple, competing objectives, providing an understanding of the nature of the tradeoffs between the objectives (which can only be known after the analysis is performed) is as important to the decision maker as determining an optimal solution.

Table 1. Summary of Performance Objectives

Objective	Metric	Data Requirements	Success Criteria	Success?
Quantitative Performance Objectives				
Analysis effort	Labor effort (hrs)	Labor hours for data collection, model building/refinement, analysis for model runs, and results creation and presentation; labor rates for calculating costs.	Excess savings due to optimized analysis over current practice exceed additional cost of analysis by 50%	Yes
Net Present Value	Pareto Optimal NPV ($) as a function of Investment level per year ($/yr)	Capital & maintenance costs; electrical & gas energy dollars saved per year; candidate energy efficiency, renewable, storage, and local generation projects; feasible investment levels per year.	5% improvement in NPV when compared to current practice for different investment levels	Yes
Energy savings	Projected energy savings per year (kWh for electricity and MBTU for mixed energy sources)	Baseline energy usage given existing plans. Energy savings using rank order of energy projects. Selected points from Pareto optimal NPV versus investment set.	Meet energy savings goals with either improved NPV or reduced investment level of 5%.	Yes
Cost savings	Projected annual savings ($/yr) as a function of investment	Rate structure for electricity and gas; Above energy savings data.	5% improvement in annual energy cost savings when compared to current practice for baseline and different hypothetical investment levels.	Yes
Renewable Fraction	Fraction of energy produced by renewables (kWh renewables per kWh yearly load)	Yearly demand. Existing & planned renewable projects with estimated energy production. Site solar, wind, geothermal, and hydro generation area/restrictions (e.g. noise restrictions, height restrictions)	Improvement in renewable fraction over current practice	Yes
GHG (CO_2) savings	Reduction (kg)	Fraction of energy produced by gas versus electricity. GHG (CO_2) emissions for grid obtained electrical energy.	Reduction in GHG over current plans/practice of 5%.	Yes
Energy surety	Islanding time (hrs); Capital and operation costs ($) to meet alternative critical power level profiles for given islanding times and assurance levels.	Critical & essential loads – levels/durations required; Local generation resources availability; Cost of local generation (operational & maintenance), energy storage, and control systems.	Quantification of the tradeoff between islanding times and costs associated with an optimal selection of energy surety alternatives.	Partial
Qualitative Performance Objectives				
Analysis schedule	Calendar time (days or hours)	Calendar days to completion of data collection, model building/refinement, analysis model runs, and results creation and presentation.	Characterization of elapsed time to initial results & final results as a function of alternative scenarios	Yes
Insight gained	Degree of under-standing of tradeoffs between competing objectives	Sensitivity studies, parameter variation studies, Pareto optimal subsets.	Site management and energy team endorsements of the impact of this approach on their decision making	Yes
Budget justification	Pareto optimal budgets ($/yr) versus installation objectives	Multi-year project plans specifying project portfolio NPV together with investment required per year, energy savings per year, GHG savings, increase renewable fractions achieved, impact on energy surety, etc.	Results incorporated into installation project proposals.	Yes

3.1 PERFORMANCE OBJECTIVES DESCRIPTIONS

Analysis effort: This objective measures the labor hours spent to provide optimized energy portfolio decision support. The purpose is to evaluate the return on investment of this technology for improving the energy investment decision making. The metric that is used is the labor effort (in hours). The data that are needed for this include the labor hours expended for project evaluation that is beyond that required for rank ordering approaches[8]. This includes labor hours for data collection, model building/refinement, analysis for model runs, and results creation and presentation. The methodology used is standard economic analysis, such as specified by the NIST BLCCA standard. We can convert the additional labor effort to cost using labor rates. We expect this technology to be of value (successful), if the increased savings due to optimized analysis over current practice, such as a rank-ordering approach, exceed cost of additional effort due to the optimization analysis by 50%. The overall NPV savings are expected to be far in excess of the analysis cost, but this objective measures the excess savings resulting from additional analysis.

Net Present Value: This objective measures the net present value (NPV) improvement of the project mix recommendations from this approach relative to current practice. The purpose is to evaluate the return on investment of this technology for improving the energy investment decision making. The metric that is used is improvement in NPV (in $). The data that are needed for this include candidate energy efficiency, renewable, storage, and local generation projects, capital and maintenance costs, electrical and gas energy cost savings per year, and feasible investment levels per year. The burden of collecting these data is not new to the proposed approach. The methodology used is standard economic analysis, such as specified by the NIST BLCCA standard. We expect this technology to be of value (successful), if there is 5% improvement in NPV when compared to current practice for different investment levels.

Energy savings: This objective measures the energy savings over a specified time frame, as well as the recurring annual energy savings. The purpose of these objective measures is to address the various energy savings mandates (see Section 1.2 Drivers for some of the executive orders and other mandates). The metric used is the projected energy savings per year (kWh). If the reduction in energy varies over time, the average annual energy savings over the specified analysis timeframe (usually 25 years in NIST BLCCA) is used as the metric. When forms of energy other than electricity are involved, the energy savings are expressed in MBTU. The required data include baseline energy usage given existing plans, and projected energy savings for different energy projects. In order to determine the excess energy savings from using the proposed approach, the Pareto-optimal points are first computed for different levels of investment, and then savings for the projects that constitute the optimal portfolio for a specific level of investment are calculated. The success criteria with respect to this measure is the ability of the proposed approach to meet mandated energy savings goals with either improved NPV or reduced investment level by 5% over current practice. The same energy savings goal, for example, a 3% per year energy reduction, is used for baseline (current practice) approach and the optimization approach.

Cost savings: This objective measures projected cost savings due to reduced energy usage. Though this is incorporated into NPV calculation, this measure may be important to assess independently, as budgetary constraints may be different for investments and operational and maintenance costs.

[8] When existing analyses are not available at an installation to serve as a baseline for comparison with the optimization approach, we performed a rank-ordering based project selection analysis to serve as a baseline.

The metric that will be used is projected annual savings (in $/yr) as a function of investment. In order to calculate this measure, the required data include the rate structure for electricity and gas, in addition to the energy cost savings data, and maintenance cost savings data. The success criteria will be for the proposed approach to realize a 5% improvement in annual savings when compared to current practice. As this improvement will depend on the investment available, this approach can provide the savings information for baseline as well as different hypothetical investment levels.

Renewable fraction: This objective measures the fraction of energy produced from renewable energy sources. The purpose of this objective is to address the various renewable energy mandates. The metric will be the fraction of energy produced by renewables (kWh renewables per kWh of baseline yearly load). In order to calculate this metric, data on yearly energy consumption, and site solar, wind, geothermal, and hydro generation area/restrictions (e.g. noise restrictions, height restrictions) need to be collected for existing and planned renewable projects under consideration. Improvement in renewable fraction with this approach, relative to current practice, will be one of the success criteria. This may be appropriate at the enterprise level, where there are many renewable energy projects under consideration. However, at installation level, it is more important to provide the decision maker with a full understanding of the impact on NPV and other objectives of meeting renewables goals.

GHG savings: This objective measures the reduction in greenhouse gas emissions. The metric that will be used will be the reduction of CO_2 (in kg or tons). Depending on the needs, the reduction in other GHGs can either be calculated independently or converted into kg of CO_2 equivalent. Calculating this requires fraction of energy produced by gas versus electricity and other sources for the grid electricity procured by an installation. Many utilities also provide the GHG data for grid-supplied electricity, which will be used. The success criterion for this objective is to improve the GHG emissions reduction by 5% relative to current practice. Success will also be measured by the successful demonstration of joint optimization of GHG's, NPV, and investment over multiple years, which is not feasible in current practice.

Energy surety: This objective measures energy surety, which is the ability to ensure that the critical capabilities at any installation can be sustained when grid power is lost. The metrics that will be used are islanding time (hrs), as well as capital and operational costs to meet alternative critical power level profiles for given islanding times and assurance levels. The data that are required are critical and essential loads, their levels and durations for which these levels need to be maintained, local generation resources availability, cost of local generation (both operational and maintenance), and costs of energy storage and control systems. The success criterion for this measure is the quantification of the tradeoff between islanding times and costs associated with an optimal selection of energy surety alternatives.

Analysis schedule: This objective measures the calendar time needed to provide optimized energy portfolio decision support. The purpose is to ensure that the burden of additional data and analysis requirements is sufficiently limited so that this approach remains viable for practical decision making. The metric that will be used is the calendar time between the start and end of the analysis (in days or hours). The data that are needed for this include calendar days to completion of data collection, model building/refinement, analysis model runs, and results creation and presentation.

This performance objective is aimed at accurately measuring the calendar time required by the comprehensive optimization approach over and above current practice, so that installation decision makers can make informed decisions regarding when the advantages of using this technology outweigh any additional time expended in performing the comprehensive analysis. For example, if the projects under consideration all have their energy savings, renewable energy production, and cost data available, then we expect initial analysis to be done within a day or two. However, if the renewable energy analysis has to be performed, it would take as long as a week depending on how readily the input data is available. Surety analysis may take longer, because installation-specific surety models have to be crafted before analysis could be completed. The purpose of this objective is to collect data for different scenarios to provide guidance for future usage of this approach. The goal is not to have absolute targets, but to have good estimates about the additional calendar time required for performing the comprehensive analysis.

Insight gained: This objective measures the degree of understanding provided to the decision maker about the tradeoffs between multiple, competing objectives. As the energy investment decisions are based on subjective decision maker tradeoffs between competing objectives, the purpose of this objective is to determine how well this approach accommodates the decision maker's preferences that cannot *a priori* be built into a single prioritization criterion. The qualitative metric is the degree of understanding of the tradeoffs that is gained by the decision maker through sensitivity studies, parameter variation studies, and Pareto optimal subsets that are produced by this approach. This is necessarily a subjective measure, and will be determined based on the installation decision maker interviews. The success of this technology, from this perspective, will be based on site management and energy team endorsements of the impact this approach has on their decision-making process.

Budget justification: This objective measures the utility of this approach in providing justification to funding authorities for projects selected by the installation management. In the enterprise decision making scenario, this objective measures the ability to provide rationale for the budgetary decisions. The metric is Pareto-optimal budgets ($/yr) versus installation objectives that can be used in justifying project funding. Supporting data include multi-year project plans specifying project portfolio NPV together with investment required per year, energy savings per year, GHG savings, increase in renewable fractions achieved, impact on energy surety, etc. The proposed approach will be successful when analysis results are incorporated into project proposals by the installations.

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4.0 FACILITY/SITE DESCRIPTION

We have originally chosen three sites (two installations, one enterprise level program) to demonstrate our analysis technology. The two physical sites are Luke AFB (near Phoenix, AZ) and AMARG at Davis-Monthan AFB (in Tucson, AZ). The enterprise-level site is the Energy Conservation Investment Program (ECIP) program at Office of the Secretary of Defense (OSD). We have later added Air Force Civil Engineering Center (AFCEC) as an additional demonstration site, so the technology can be demonstrated at both installation, regional/service, and enterprise levels.

4.1 FACILITY/SITE SELECTION CRITERIA

Collectively, there are several reasons why we have chosen these sites for our demonstration:

- There is reasonable potential of alternative/renewable energy generation to be installed at the sites. In the case of Luke AFB, solar generation is a potential project under consideration, where as in the case of Davis-Monthan AFB, micro-turbines are an alternative under consideration. It is helpful to demonstrate our technology if there is complexity arising from meeting both energy efficiency improvement goals as well as the goal of increased alternative/renewable energy generation.
- We have worked with both Luke and Davis-Monthan AFBs already, so we have established working relationships, familiarity with their site facilities, and have some site data collected.
- The facilities are representative of the size of sites expected to be encountered, should our technology transition in the future, and where optimization can be of value, since complexity is introduced when operations and facilities size increases. Each site has a site energy manager, or has had past energy audits performed on site, which is helpful for generating energy efficiency improvement ideas, which provides data for analysis.
- The Luke and Davis-Monthan AFB sites volunteered to partner in this ESTCP demonstration effort based on previous similar work performed earlier. Each has written endorsement letters expressing interest in continuing a working relationship, and expecting to derive additional value from this project.
- The ECIP office recognized potential significant cost savings advantages given the large number of projects which it needs to evaluate each year, their total investment value, and the number of simultaneous objectives attempting to be achieved through the program.

4.2 FACILITY/SITE LOCATION AND OPERATIONS

<u>Site 1</u>: **Luke AFB** (see Figure 8) is located about 30 miles northwest of Phoenix, Arizona. It is the home of the Air Education and Training Command’s 56th Fighter Wing, whose mission is to train the world's greatest F-16 fighter pilots while deploying mission-ready warfighters. Luke Air Force Base is the largest fighter wing in the U.S. Air Force with 138 F-16s assigned. The base population includes about 4,830 military and DoD civilian members. With about 70,000 retired military members living in greater Phoenix, the base services a total population of nearly 80,000 people. An integral part of Luke's F-16 fighter pilot training mission is the Barry M. Goldwater Range.

The range consists of 1.8 million acres. There are also many (13) satellite operation sites, called geographically separated units (GSU), associated with Luke main base. The main base has approximately 150-200 buildings on site. Annual base energy consumption is approximately 370K MBTU. Main base experienced peak electric load of nearly 15 Mega Watts (MW) and a total electrical energy usage of approximately 74 Giga Watt hours (GWh), during Fiscal Year 2011. Annual electric bills are greater than $4M.

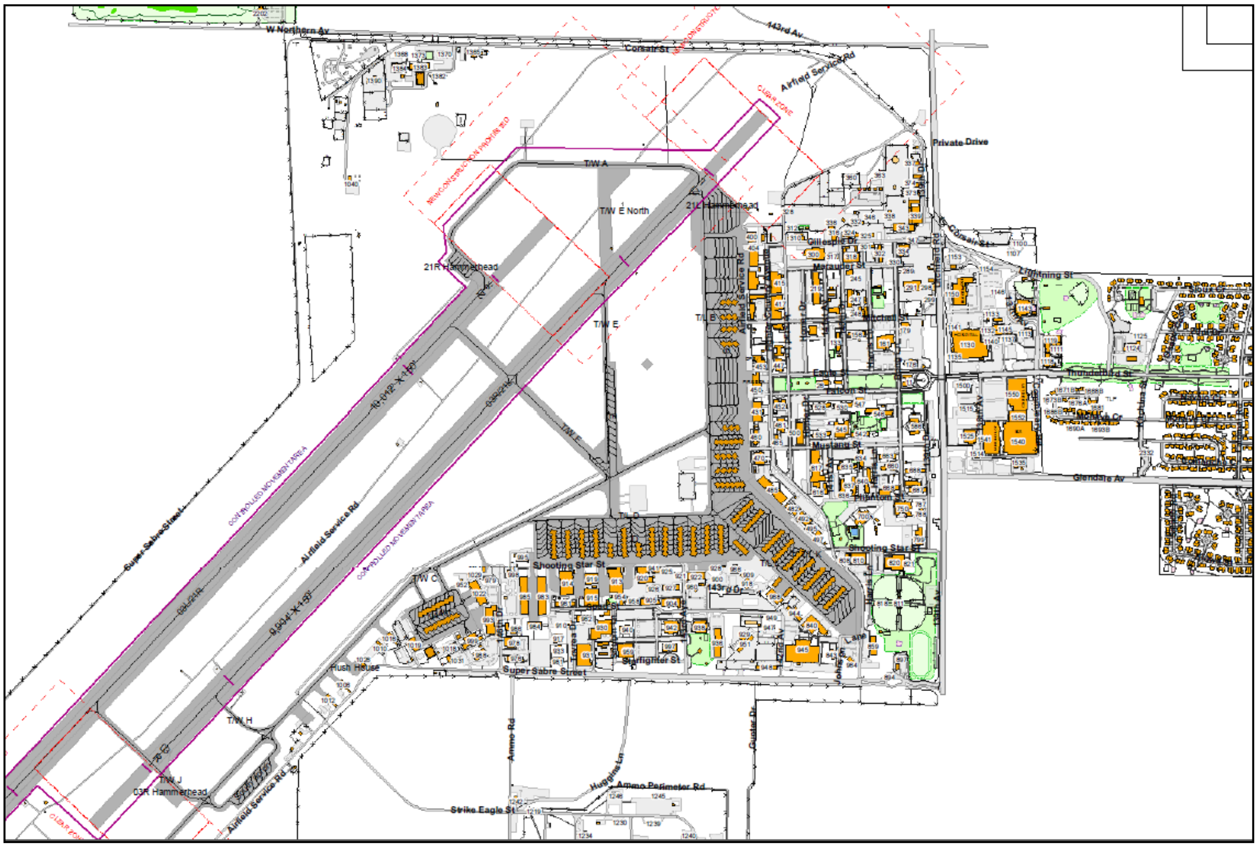

Figure 8. Site Map of Luke AFB

<u>Site 2</u>: Davis-Monthan AFB (see Figure 9) is located on the south end of Tucson, AZ city limits. There resides the 309th Aerospace Maintenance and Regeneration Group (309 AMARG), which is within the Air Force Materiel Command structure. 309 AMARG provides critical aerospace maintenance and regeneration capabilities for Joint and Allied/Coalition warfighters in support of global operations and agile combat support for a wide range of military operations. This includes more than 4,400 aircraft and 13 aerospace vehicles from the Air Force, Navy-Marine Corps, Army, Coast Guard, and several federal agencies including NASA. AMARG employs 550 people, almost all civilians. The 2,600 acre facility is adjacent to the base. The 2,600 acre facility is adjacent to the base. Base utilities and related work order cost for FY12 was more than $1.5M. Electric consumption was more than 5 GWh.

Figure 9. Davis-Monthan AFB site

Enterprise Site: OSD ECIP - virtual site, no physical site demonstration necessary. The Energy Conservation Investment Program (ECIP) is managed under the Office of the Deputy Under-Secretary of Defense – Installations and Environment. OSD centrally controls ECIP funding allocation on a by-project basis.

4.3 SITE-RELATED PERMITS AND REGULATIONS

At installation 1, Luke AFB, there are no site-related permit requirements, and no regulation issues or agreements to address. No hardware or software was installed at this site. At installation 2, Davis-Monthan AFB, a metering system was installed. The details describing the installation are defined in the Venergy company proposal "Wireless Communication and Installation of Advanced Meters", dated Feb. 25, 2013. Davis-Monthan has gained the necessary permit approvals for the installation of the metering system. See "Appendix B: Advanced Metering System Installation for Davis-Monthan AFB" for additional detail.

For the enterprise phase of the project, there is no related physical site – we worked with OSD ECIP. Therefore, no hardware or software was installed, and again permits, regulations, and agreements do not apply.

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5.0 TEST DESIGN

The fundamental problem addressed by the technology that is being demonstrated is how to properly incorporate multiple objectives into an energy portfolio selection process. The demonstration applies Boeing's ESAT and supporting methodology to two DoD installations to optimize investment portfolios for these installations as well conduct the same type of analysis at a regional/service and/or enterprise level. By collecting data at two installations, we expect to show how decision making that considers multiple goals in a rigorous manner can result in additional savings, as well as show how mission priorities at the different installations can be used to guide such decision making. The enterprise decision problem is different from the installation-level decision problem in that the metrics are more numerous and varied, but the level of analysis detail may involve less fidelity. The enterprise-level demonstration is aimed at proving the ESAT technology on a solution space that is not only orders of magnitude larger, but is qualitatively different.

The hypothesis being tested in this demonstration is that the ESAT methodology will provide installation energy managers and decision makers with an optimized set of energy projects, for investment over multiple years compared to a simple rank-ordered analysis, resulting in an improvement of Net Present Value (NPV) of at least 5% for a range of investment levels. The independent variable under consideration is the type of decision support tool/approach used, with the two possible states for this variable being either the ESAT approach or the rank-order approach. The dependent variables include the set of performance objective metrics listed in Table 1, namely, analysis labor effort, NPV, projected energy savings per year, fraction of energy produced by renewable energy, projected greenhouse gas reduction, and islanding time for energy surety projects. Multiple experiments were performed to compare ESAT and the rank-ordered approach. At each installation, the controlled variables include the projects considered for portfolio selection/optimization, as well as the projected energy savings from these projects, predicted by existing studies or FEDS and HOMER analyses. Another controlled variable are the energy surety requirements (critical loads and minimum islanding time) and energy surety solutions that are being considered.

The two installation tests and the enterprise test address the need to prove the utility of the proposed approach in helping the decision makers optimally allocate limited budgetary resources across different energy projects, at the same time meeting the various energy savings, renewable energy and energy surety mandates. In order to assess this properly, we collect the project data, installation objectives, and various mandates to perform ESAT analysis. ESAT analyses are conducted in three phases:

A. Joint planning with site management and energy teams
B. Energy efficiency and renewable energy multi-objective optimization
C. Special studies phase incorporating energy surety.

In Table 2, we outline the high-level steps in a typical ESAT analysis of a fixed installation. The steps are based on Boeing's experience on internal Boeing-specific site studies, as well as initial ESAT analyses performed at multiple US Air Force bases. During each ESAT analysis, it is important to gather the data on the cost and benefits of ESAT itself in order to compute the metrics in Table 1. We plan to obtain the data in Table 3 to support this need.

It is to be noted that the special studies phase is conditioned by the site's requirements for energy surety. The analysis requires a specification of the site's critical power level needs and islanding duration needs in the event of grid power loss. It is understood that this information may not be readily available, so the level of analysis is, of necessity, tuned to the level of detail the site is capable of providing. For example, if an installation can identify the critical loads by time-of-day and month-of-year, as well as the likely PV and generator choices, then the surety analysis will include the performance and cost of these specific solution choices to satisfy the identified critical loads. On the other hand, if much of this data is not available, then the critical load is assumed a percentage of the overall load, and PV and generation capacity is appropriately scaled and parametrically varied in a trade study. The need for this information is established at the first meeting with the site energy personnel in order to give them time to develop energy surety information to the depth they require.

Table 2. ESAT Analysis Steps

A. Joint planning Phase (Initial site interactions) *a.* Gather data to determine baseline energy usage and plans, and projects in pipeline. *b.* Interview site management to gather energy mandates/goals, and yearly investment levels.
B. Energy-Efficiency/Renewable Energy Phase (Multi-objective optimization) a. Gather cost/benefit model data including energy efficiency data, via energy audits already performed at the site or obtaining input data for FEDS analysis to produce candidate energy efficiency projects. Other data required are existing or planned renewable energy projects w/estimated energy generation, constraints on renewable projects, regulatory incentives, utility billing rates, demand and consumption profiles, local environmental data. b. Refine cost/benefit model to produce optimal investment profile. c. Determine Pareto optimal sets of energy efficiency measures and renewable energy projects to optimize NPV, energy saved, total capital investment, and GHG emissions, while meeting other constraints/goals on metrics such as fraction of energy due to renewable energy. d. Perform trade studies varying selected parameters to determine sensitivity of results to assumed input values.
C. Special Studies Phase (Energy resilience/surety, etc.) a. Identify site vulnerabilities, critical infrastructure, and critical energy requirements (load shed list, power needs vs. duration.) b. Determine feasible alternative energy management/control strategies for energy surety applications, and refine models for estimating the associated cost/benefit properties. c. Run model to determine cost/benefit of a range of energy surety capabilities versus investment level. d. Integrate surety models into ESAT energy efficiency model developed in Step B above. Exercise this model to determine Pareto optimal investment portfolio. e. Perform analysis varying selected parameters to determine sensitivity of results to input values.

Table 3. Required ESAT Metric Data

1) Labor hours for *a.* Data gathering by type and phase. *b.* Analysis and presentation creations. *c.* Baseline energy plan creation. Comparison of recommended investment decisions to the baseline. *d.* Energy improvements for a given investment level. *e.* Operating budget improvements due to energy savings, demand peak reduction, load shifting. *f.* Vulnerability reductions; energy surety metric improvements versus investment level. *2)* Interviews with site energy team to determine their ease of understanding of multi-objective optimizations, trade study results, etc. *3)* Site management feedback as to benefits of gap analysis in achieving energy goals and tracking. *4)* Determination if ESAT analyses had an impact on the site's future investment strategy or provided sufficient justification for hard-to-obtain budgets.

There are several parts to the overall methodology used in providing optimized decision support for portfolio energy investment. When individual project evaluation data are available, for example from separate analyses of energy efficiency measures, renewable energy projects and energy surety projects, the results of those analyses are used by the multi-objective optimization framework to provide the decision maker with the Pareto-optimal sets of energy projects for different investment levels and specified multi-year energy goals. If individual project evaluations are not available for certain projects to feed into the optimization framework, the FEDS tool is used for identifying and analyzing potential efficiency projects, the HOMER tool is used to evaluate the renewable energy and energy storage projects, and Design Sheet models are used for evaluating energy surety projects. Other sources of efficiency project candidates include: (1) analysis performed by the site's Resource Efficiency Manager (REM); (2) ideas generated from the site's energy team staff; (3) energy audits performed by one of the national labs, an engineering consulting company, or Air Force Civil Engineer Support Agency (AFCESA); (4) analysis of building sensor meter data. The overall framework is, therefore, able to accommodate variable levels of data availability.

FEDS generates efficiency project recommendations based on building characterization input data. FEDS analysis can be run using "minimum set inputs", where remaining inputs are inferred based on these inputs. If more detailed building characteristic data is known, "maximum detail inputs" can be invoked to override the previously inferred data. The minimum set inputs include: building type, construction year, size, operating occupancy, lighting technology, heating fuel type, cooling technology, and service hot water fuel type. This set of inputs is expected to be easily collected from site facilities staff. In our internal pilot project, we were able to collect the maximum detail inputs for three buildings in one and a half days from a knowledgeable facilities engineer. We may encounter more buildings at the chosen sites; however, each building is not required to be individually modeled. Groups of similar buildings are represented by increasing the building quantity when modeled. FEDS produces several output reports of varying detail. ESAT extracts the set of potential energy efficiency projects and their associated annual energy savings, peak power reduction, maintenance costs, and replacement costs from the FEDS report.

The HOMER tool is used to analyze candidate renewable energy projects identified by the installation energy team. There are four sets of inputs to HOMER, namely, the electrical loads over a typical year, the renewable resource data such as the solar flux and wind speed, the performance data for different solar arrays, wind turbines, and batteries, and the cost data for different technologies. The load data is collected from the installation energy team. The renewable resource data is readily available from publicly-available sources (e.g., NREL), based on the latitude and longitude of the location. HOMER provides the performance data for commonly used types of solar arrays, wind turbines, generators, and batteries. The cost data needs to be researched and provided by the installation energy teams. For preliminary analysis, parametric cost estimates are used based on available survey data. For each renewable technology option under consideration, ESAT extracts the annual energy output, as well as power output at specified time intervals from the output of HOMER for further analysis.

5.1 ESAT ANALYSIS AT INSTALLATION 1 AND INSTALLATION 2

Studies at Luke AFB and at Davis-Monthan AFB were done with a time phase lag so that lessons learned from the first study could be used to help guide the effort in the second. We started with the demonstration at Luke AFB.

<u>Data Gathering</u>: The effort begins with a set of site visits with AFB management and members of their energy team to establish project goals and requirements. The agenda for these visits have been established beforehand due to our working relationships with the personnel at Luke AFB and Davis-Monthan AFB. Typically, these visits take two to three days, during which time the analysis plan is outlined and the required data are initially defined. The data include:

a) Previous energy efficiency audits in which each proposed project has, as a minimum, an estimated capital cost, an estimated yearly energy savings in electricity and gas, and an estimated maintenance and operational cost savings. Importantly, we need to quantify any interactions, synergistic or otherwise, between the several projects. The intent is to isolate mutually dependent projects into independently selectable exclusive sets. For example, if projects A and B interact so that A and B together have an energy savings different from their sum, we would consider the choice of A and B together as a separate project. The ESAT tool will consider selecting 1) neither A nor B, 2) A only, 3) B only, or 4) A and B together. Each choice will have a well-defined capital cost, yearly energy savings, and maintenance and operational cost.
b) A listing of buildings, their characteristic data needed to perform FEDS analyses in the event previous energy audits are insufficient, which may be the case at Davis-Monthan AFB. This effort would either be an immediate follow-on visit or an extension of the initial visit, depending upon the preparedness of the base. Again, we need to quantify interactions between the multiple projects suggested by the FEDS analyses in the same manner as above.
c) Existing renewable installations and records of their energy generation, preferably in 15 minute intervals over a one-year period.
d) Existing local generation capabilities (gas turbines, diesel generators, etc.), fuel and energy storage capabilities, together with their reliabilities, operational and maintenance costs, lifetimes, and replacement costs, if available.

e) Potential renewable energy projects along with possible power output ranges. Information on sizing constraints (e.g. acreage for solar), as well as local restrictions (e.g. height constraints for wind turbines, noise constraints, etc.) If available, local measurements of (preferably in 15-minute intervals for one complete year) solar incidence, wind velocity, geo-thermal potential, and hydro potential will be identified.
f) Other potential non-renewable, local generation options, including gas turbine and/or diesel generators.
g) Information that will allow the quantification of base demand and energy costs, preferably by time of day and day of the year. This typically includes identification of any historical metered data at the building or other subnet level, along with local utility bills for the previous years, including usage and demand charges, credits, etc.

Spiral Multi-objective Analysis: Based on prior experience, gathering data can span from days to weeks and consume a large fraction of the man-hours needed for an ESAT analysis. However, the flexible analysis architecture of ESAT allows us to evolve the model development appropriate to the growing availability of data and accuracy needs. The models and data are iteratively refined to provide increasingly accurate assessment of the cost/benefits of alternative portfolio choices in areas of the trade space that are of interest.

We present interim results to site personnel on a regular basis, as appropriate. Depending upon the availability of data, initial results on the cost benefits of alternative energy efficiency projects are typically available within a few weeks of the initial site meeting. This leads to a series of refined analyses incorporating alternative local (renewables) generation capabilities, which results in Pareto optimal sets of alternative investment strategies (see Figure 2.) Each investment strategy selects an optimal subset of energy efficiency projects and renewables generation investments over an investment period, for example, ranging from one to ten years. As part of the demonstration, we compare the results of this analysis with any investment plans that are developed based on existing processes at the demonstration sites, if available. If no such plans are available, project allocations based on a rank-ordering approach are developed and compared with the results from the optimization approach.

Surety Analysis: Concurrent with the data gathering and spiral multi-objective analysis with energy efficiency projects and renewable energy generation possibilities, we include the information provided to incorporate energy surety into the multi-objective models. These models rely on two main input categories:

1. An understanding of the various levels of power needs for critical missions and the duration of those needs.
2. A set of local generation and/or energy storage options from which to choose power to meet the critical needs. Included in this category is the degree of control required to manage the supplemental power.

We obtain estimates of the capital cost, operational and maintenance costs of the possible local generation options. Additionally, if renewable energy generation is being considered, one needs estimates of the probability that such energy is available through each needed period (e.g., reduced solar energy due to cloud cover, etc.) High-availability systems will require backup generation capabilities or energy storage. Each of these alternatives may require a different level of energy management control system.

Each of these options are incorporated into our multi-objective optimization models so that the Pareto optimal subsets of these options can be produced that will trade off multi-year investment portfolios with respect to investment level, NPV, GHG, renewable generation goals, energy savings goals, and energy surety levels (power levels and durations.)

5.2 ESAT ANALYSIS AT REGIONAL/SERVICE AND/OR ENTERPRISE LEVEL

In this task, we have performed ESAT analysis at the enterprise and/or regional levels. The ECIP program serves as the main demonstration for the enterprise analysis. For the regional/service-level analysis, the Air Force Civil Engineering Center (AFCEC) serves as the demonstration facility.

The multi-objective optimization for the regional/enterprise level analysis includes additional metrics over those used at the installation level. These could include regional/enterprise level energy savings goals, net-zero installation goals, service priorities, priorities for inter-agency partnerships, etc. that can be translated into objectives and constraints for the optimization formulation. The ECIP FY13 selection requirements for ECIP projects form a useful set of metrics, which provided a starting point for this analysis. The actual metrics used during an analysis cycle are based on a discussion with the ECIP program manager[9]. The ECIP FY13 selection metrics are shown in Table 4 along with the weights given to different metrics. The ECIP selection approach is based on the eROI methodology for project ranking used by the US Navy. These approaches rank-order the projects based on a calculated composite score subject to pre-determined weights, and use a cut-off threshold based on available investment. ESAT, on the other hand, automatically determines the portfolios of projects that are Pareto-optimal with respect to selected objectives, subject to soft and hard constraints on additional metrics.

Table 4. ECIP FY13 Selection Criteria[9]

Energy Efficiency, Renewable Energy and Water Conservation Projects	
Metric	**Weight**
SIR	10%
Simple Payback	10%
Benefit to Investment ratio	15%
Impact of project on installation’s energy goals	10%
Synergistic effects of multiple technologies or multi-year program	5%
Partnership with Doe or others	10%
Test Bed Application	20%
Service Priority	20%
Energy Security Projects	
Metric	**Weight**
Impact of critical load support or reliability	25%
Synergistic effects of multiple technologies or multi-year program	15%
Partnership with DoE or others	15%
Test Bed Application	20%
Service Priority	25%

[9] Any chosen metric should be able to be combined into an aggregate portfolio metric across multiple projects (e.g. additive metrics.)

The objective for this part of the demonstration is similar to the installation demonstration – to compare the ESAT approach to current practice in terms of the improvement in the cost and performance objectives listed in Table 1. For this comparison, the current, or baseline, approach is a rank-ordering of the candidate projects by their full ECIP metric. In order to do this comparison, for each candidate project, we will need similar cost and performance information. This will include, as a minimum, project description, project cost (by year), estimated annual energy savings, energy production, and water savings, if applicable, along with electrical consumption and renewable energy production for previous years.

The analysis pools all projects together in one framework and produce the Pareto optimal portfolios across the region being analyzed. Additional regional/enterprise level objectives and/or constraints outlined above are added as appropriate. Our experience has been that of combining multiple sites in this manner can produce significantly improved NPV for the same regional investment level, or alternatively significantly reduced investment level may be required for the same NPV and/or energy savings.

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6.0 PERFORMANCE ASSESSMENT

6.1 DEMONSTRATION PLAN

Analysis Effort: Data related to the analysis effort will be collected over the demonstration period in order to determine the return on investment for this effort. Care will be taken to differentiate between effort required to perform the baseline analysis (e.g. using rank order approach) versus the additional effort required to implement the ESAT approach, ensuring an accurate result. The labor hours expended for project evaluation will be the main data that will be tracked for this purpose. This includes labor hours for data collection of energy conservation, renewable or surety projects, model building or refinement, model runs and analysis, and results creation and presentation. It is expected that the ESAT analysis approach will require some additional effort. This effort will have the baseline approach effort subtracted, leaving the marginal effort to implement the new approach as the remainder. An agreed upon standard labor rate will then be applied to convert the effort to dollars. The return on this effort investment can subsequently be calculated. ROI = 100*(Savings from effort)/(marginal additional effort required for new approach).

Net Present Value: This performance metric is a core comparison metric, serving as a primary metric when evaluating the current analysis and project selection approach versus the ESAT optimization analysis approach, and subsequently determining whether an improvement in investment and savings has been made based on each approach's recommendations. The comparison will be made by examining the NPV associated with the project investment portfolio recommended by the baseline and the optimization analysis approaches, with all other input parameters held constant, e.g. investment threshold, energy cost, etc. It will be determined quantitatively as the percentage improvement of the ESAT approach over the baseline approach. Figure 10 shows a sample NPV chart.

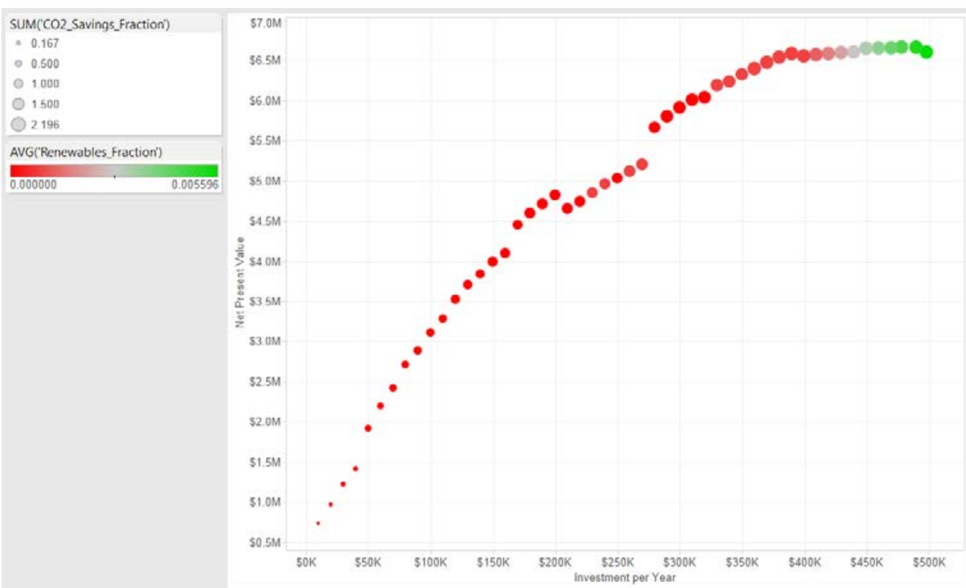


Figure 10. Sample Net Present Value Analysis Graph - NPV vs. Investment per Year

Energy Savings: For a given optimal portfolio project set (identified by the chosen investment threshold), the total annual energy savings is calculated by summing the annual energy savings of the underlying individual products. Each individual project's annual energy savings will have already been pre-calculated, before being run through the optimization model, either by the local Resource Efficiency Manager (REM), energy team, previous audit, FEDS or HOMER simulation, or other means. These individual projects may have also already accounted for any existing inter-project interactions which would increase or reduce their energy savings had it been implemented independently[10]. The default savings unit is kWh, as electrical type energy savings typically predominates. However, when encountering a mix of combined projects, electrical and non-electrical (such as gas heating), energy savings will be converted to the common unit of MBTU. Having established the ESAT approach optimized annual energy savings, it is now possible to compare it to the current standard approach annual energy savings results. The difference between these two values represents the marginal annual energy savings which can be realized by implementing the recommended ESAT plan. Figure 11 shows a sample Energy Savings chart and progress towards meeting annual goals set by regulation. Similar charts for the baseline approach and the ESAT approach will be developed to find the additional savings resulting from the ESAT approach.

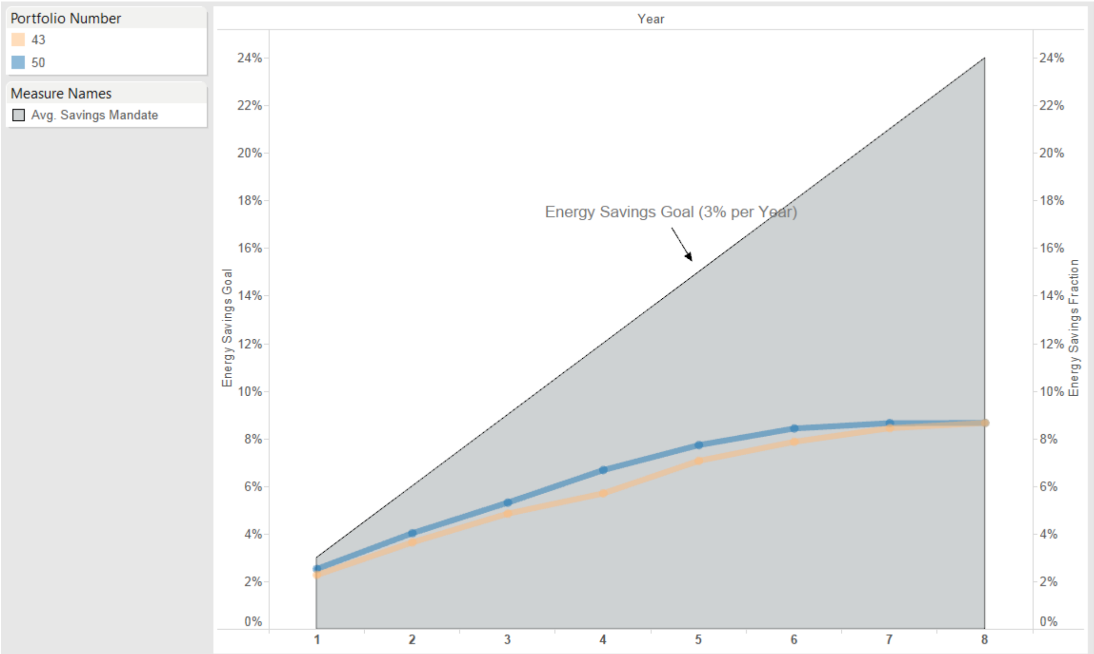


Figure 11. Sample Energy Savings Graph Indicating Progress Towards Meeting Policy Goals

Cost Savings: Annual cost savings are accumulated and integrated into the final NPV calculation. However, the annual cost savings contribution will also be calculated and presented for the study period of interest, as shown in Figure 2. This annual cost savings presentation is useful for showing how investment is translating to savings over time and the payback period is visually indicated.

[10] The methodology to account for interacting effects between projects is discussed in Paragraph *a* of the *Data Gathering* subsection in Section 5.1.

For a given optimal portfolio project set (identified by the chosen investment threshold), the annual cost savings is calculated by summing the investment, operations and maintenance savings resulting of implementing the individual projects. This cost savings is directly related to the energy savings described immediately above. Having established the ESAT approach optimized annual cost savings, it is now possible to compare it to the current standard approach annual cost savings results. The difference between these two values represents the marginal annual cost savings increase which can be realized by implementing the recommended ESAT plan. Figure 12 shows a sample annual cost savings chart. Once again, similar charts will be developed for both the baseline approach and the ESAT approach.

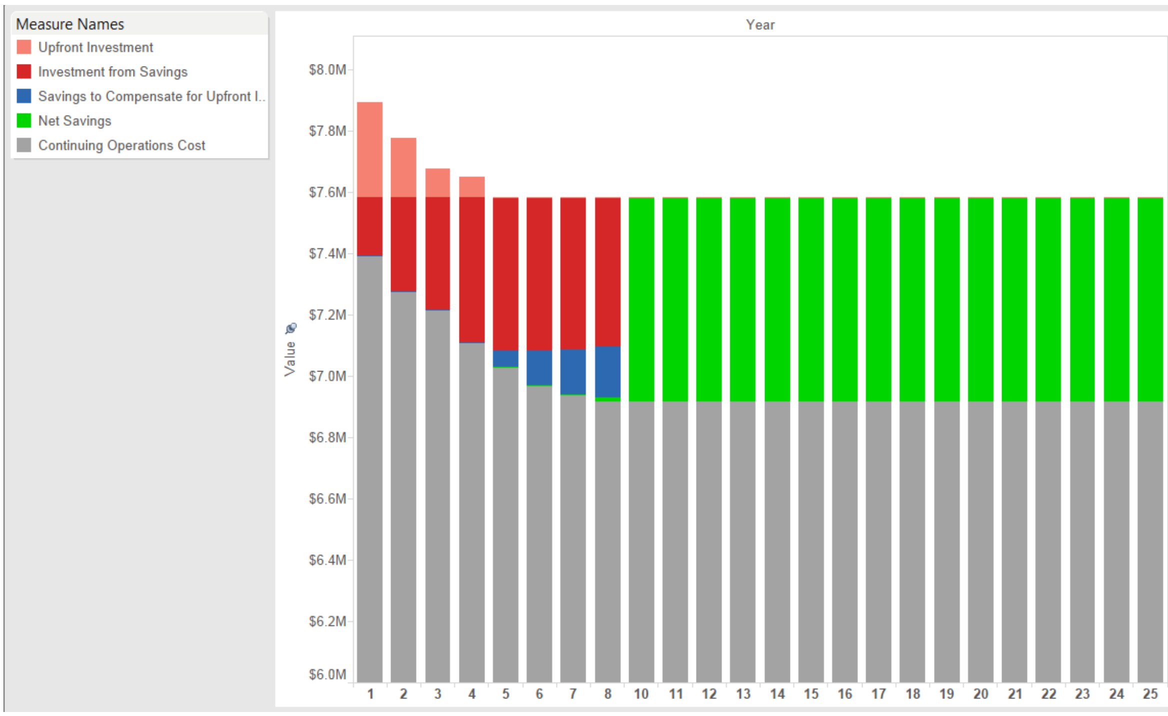


Figure 12. Sample Graph Indicating Annual Cost Savings

Renewable Fraction: This metric represents the percentage of annual energy demand supplied by renewable energy generation sources located on site. It is calculated by summing the individual renewable energy generation sources (e.g. solar, wind), for a given year, then dividing by that same year's (baseline) annual demand load. This calculated fraction is subject to meeting the published policy guideline schedule table, such as the Air Force Infrastructure Energy Plan 2010, which requires an increase of the renewable fraction by specific amounts by certain times. See Section 1.2 Drivers for details. The ESAT approach uses this metric and helps the DoD site meet this goal in multiple ways. First, ESAT predicts progress towards meeting the required scheduled thresholds, showing how a range of investment plans will perform compared to the requirement, measured by how closely it meets the time phased goals. Second, ESAT is selecting the optimal set of proposed projects to implement to meet those goals in the most cost efficient way, simultaneously with the other objectives. A comparison will be made between the standard and ESAT approaches to determine if, for the same renewable fraction goal and investment level choice, whether it can be met sooner, or at a lower cost. Figure 13 shows a sample chart showing annual progress towards meeting the renewable energy fraction goal.

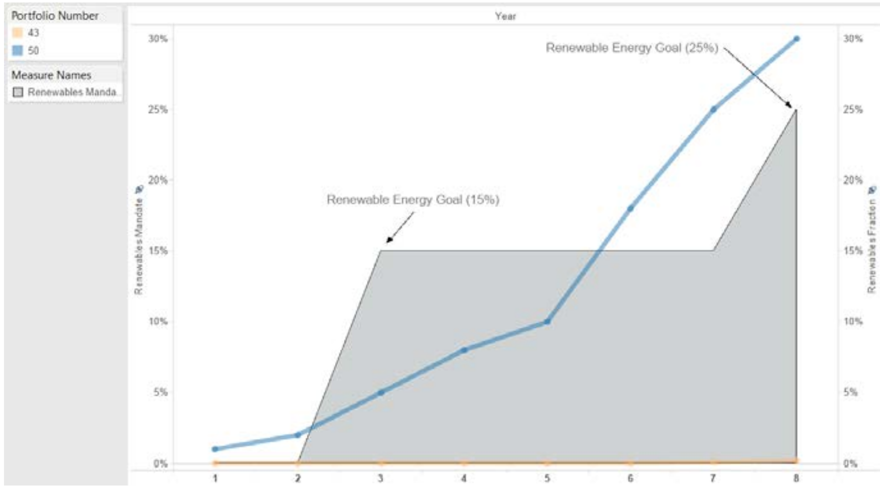


Figure 13. Sample Graph Indicating Renewable Fraction Progress Towards Policy Goals

GHG Savings: As with renewable fraction just described, there are also published GHG emission reduction policy requirements, which is why this metric is an important one to calculate and track. In addition, the same purposes as described in *Renewable Fraction* above, apply here. First, ESAT tracks the predicted progress towards meeting the required scheduled thresholds, showing how a range of investment plans will perform compared to the requirement, measured by how closely it meets the time phased goals. Second, ESAT is selecting the optimal set of proposed projects to implement to meet those goals in the most cost efficient way, simultaneously with the other objectives. A comparison will be made between the standard and ESAT approaches to determine if, for the same GHG emissions reduction goal and investment level choice, whether it can be met sooner, or at a lower cost. GHG emissions reduction is calculated by summing the energy savings from the proposed projects to implement, as recommended in the investment plan. This is derived by noting their energy source (e.g. electric, gas), then using local utility generation mix to determine the GHG emission reduction amount for the given consumption (kWh) savings. Figure 14 shows a sample chart for potential GHG emissions reduction for various portfolio plans and investment level.

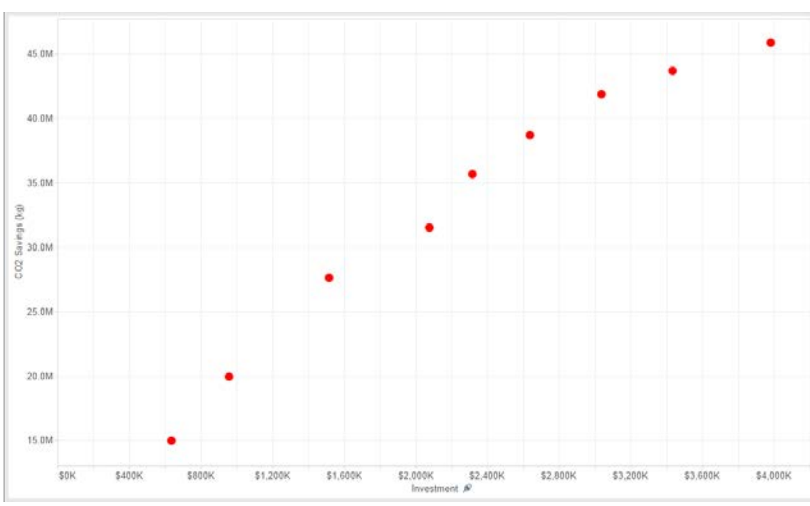


Figure 14. Sample Graph Indicating CO2 Savings for a Given Annual Investment Level

Energy Surety: Though explicit quantitative energy surety goals are not subject to a current established policy, it is of high strategic interest to the DoD and its sites. The decision to invest in energy surety may restrict investment in the other site energy goals (e.g. energy savings, increased renewable energy fraction, reduced GHG emissions, etc.). For this reason, it is important to ensure that budgets extend as far as possible to meet, or come as close as possible to meeting, the multiple goals required of the site, so having an efficient optimal investment plan is important. ESAT provides this. The underlying technology of ESAT also provides modeling capabilities to explore energy surety trade studies. These trade studies represent trade-offs and sensitivities between capital investment, site islanding time, ability to meet critical base loads, usage of alternative energy generation and storage systems, and more. These trade studies will produce important energy surety insights and provide a broad set of optimal energy surety configuration decision options to choose from. The methodology used will be customized according to site needs and incorporate the latest research in the energy surety domain. A sample hypothetical analysis is shown in Figure 15.

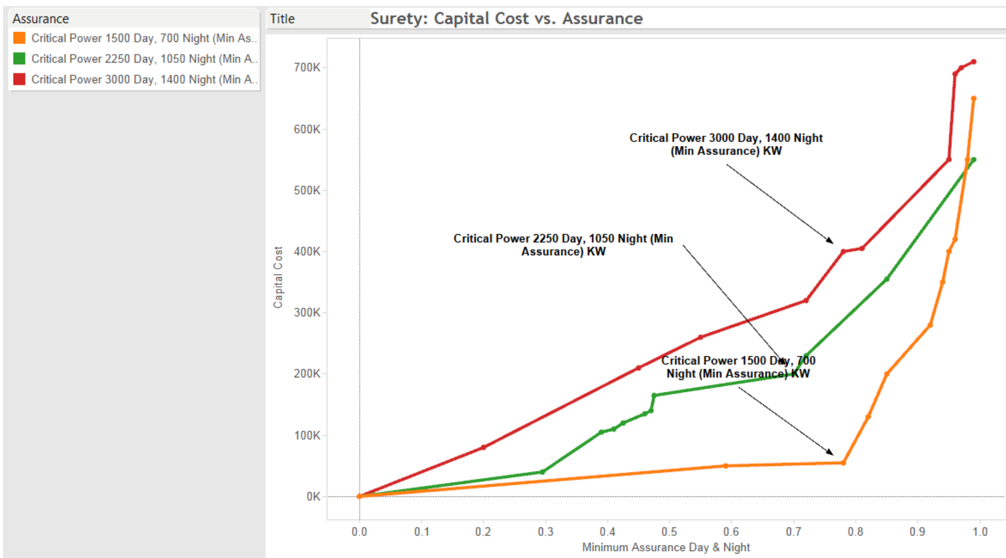


Figure 15. Sample Energy Surety Analysis Graph Indicating Energy Assurance Given a Level of Capital Investment

Analysis schedule: In addition to total analysis effort in hours spent, it is important to determine whether the calendar duration to complete the analysis is of a timely nature and can synchronize well with the decision-making tempo of the organization's operations. For this reason, we plan to record the beginning and end dates of the analysis cycles. The analysis cycle contains the same activities as described above in *Analysis Effort*, but this performance metric measures start to end duration vs. hours expended to complete. Different runs of the analysis for different scenarios (e.g., all the projects under consideration have their energy savings, renewable energy production, and cost data available, all the energy savings analysis are available but the renewable energy analysis has to be performed, and surety analysis need to be performed, but all the other projects have already been individually analyzed) will be tracked separately to collect this metric. The resulting value will be compared to the baseline analysis (without ESAT optimization analysis) approach and to the typical decision cycle requirements of the base decision makers (energy team and leadership).

Insight Gained: The ESAT analysis approach is intended to supplement and improve the information available to the site decision makers (leadership, energy team, REM, etc.). Through a wider exploration of the decision space, beyond what conventional (rank order) approaches offer, the possibility of discovering non-intuitive analysis results is expected to increase. Through frequent coordination with the site staff, we will be recording indications where improved results and processes are indicated over the business as usual approach. We will also note to what extent the recommendation plan is accepted as credible, and whether interest is strong enough that the investment plan development process is updated (or planned to be) to incorporate the ESAT analysis approach.

Budget Justification: In the individual installation scenario, this metric will be measured by observing whether (1) one of the optimal recommended investment plans is accepted as valid, (2) it is subsequently adopted as their site's short term and long term energy investment plan, and (3) it is presented as supporting evidence to budget approval / project funding allocation authorities as an indicator that a sound investment plan is in place to meet the goals imposed on them, as best they can, and in the most cost efficient manner available to them. For the enterprise level analysis phase of the project, the first two events similarly apply, while the third event is replaced with whether the ESAT methodology will be used in the approval process of submitted candidate projects over their current filtering and decision methodology. Figure 16 shows a sample comprehensive dashboard, highlighting select important analysis results, which supports a budget request for the selected portfolio.

Figure 16. ESAT Analysis Dashboard Showing Comprehensive Assessment Supporting Budget Requests.

6.2 LUKE AFB DEMONSTRATION SITE

The demonstration with Luke AFB was initiated in February, 2014. The ESAT team visited Luke AFB and met with their energy team February 18-19, 2014. During the visit, we were given a briefing about the general health of their energy program and received a tour of some of the key facilities. We also learned about the current tools and initiatives in place, and we performed preliminary data collection.

We observed substantial change in the Base energy program since having previously worked with the Luke team and chosen them as a demonstration site. There had been significant turnover in the energy team membership. The new team in place had limited experience. No Resource Efficiency Manager (REM) was assigned to the base, and none was expected to fill the role in the near future. So there was limited analysis expertise available to generate candidate energy efficiency projects. NRG funding ended in FY14, which now serves as a disincentive to generate and submit energy related projects for funding consideration. As a result, there were no candidate energy projects for which our optimization planning technology could be applied. As mentioned in our demonstration plan, this was addressed by collecting the necessary facilities data to conduct a FEDS analysis to generate candidate projects.

Some energy meter data was collected during our initial site visit, and preliminary energy intensity analysis was performed in preparation for identifying buildings for FEDS analysis. Based on the energy meter data that was collected, using energy intensity analysis and energy manager interviews, we identified and recommended the top ten buildings targeted for FEDS analysis. We further modeled and performed preliminary FEDS analysis for three of these buildings, based on minimum required inputs. After a preliminary review of these results, the Luke AFB energy team requested a follow-on site visit for the purpose of collecting additional facility characteristic data, and complete the FEDS analysis for the designated top ten buildings. The potential ECMs derived from FEDS analysis were used as inputs to the ESAT portfolio optimization analysis.

A second site visit was conducted August 5-6, 2014, to collect additional building characteristic data to supplement, confirm or correct earlier provided building data. All ten buildings were visited (note these buildings were selected based on analysis which identified them as high energy intensity usage). Facility managers were interviewed during these visits, resulting in building and system notes and photos (see Appendix D: FEDS Bldg. Characteristic Data & Notes, Luke AFB, Aug. 2014). Further research was conducted to identify additional system/equipment technical specifications. The resulting collected data was then used to develop a detailed FEDS model of the building set. The FEDS model simulation was run, which produced an output of recommended retrofit technology projects which will result in energy and cost savings. The project recommendation set subsequently served as an input to ESAT analysis, which produced an optimal project portfolio for a range of investments. A chosen optimal project portfolio produced by ESAT can then be potentially packaged and submitted by the Luke AFB Energy Team for service or enterprise agency funding consideration.

A project progress status review was held Oct. 1, 2014 to update the base energy team on these accomplishments. The Luke AFB Energy Team was given a chance to review the analysis assumptions and results to provide any model or input edits, prompting a re-running of the analysis to produce updated results.

A draft report, which summarizes the FEDS modeling & analysis and ESAT optimization analysis effort completed at Luke AFB was written. Shortly after, it was learned that an opportunity existed for improved analysis. FEDS software had a major new release (FEDS 7.0) with new capabilities and bug fixes. We ordered and received it in January 2015. We re-ran the Luke facilities models using the new FEDS 7.0 to regenerate a revised set of retrofit efficiency projects. The ESAT portfolio optimization was also re-run with these new project inputs, and the results incorporated into an updated summary report. These results were reviewed with the Luke AFB Energy team.

6.2.1 FEDS Modeling Purpose

FEDS modeling and analysis was conducted for the Luke AFB demonstration site. The purpose for conducting the analysis is to:

1. **Supplement energy efficiency improvement candidate project generation –** Luke AFB had no Resource Efficiency Manager (REM) during the demonstration time-frame, and was not expected to retain one in the near future. The lack of a REM, compounded by the regular rotation/turnover of the military energy staff, results in limited process continuity and ability to generate energy project ideas, along with required associated analyses. FEDS project recommendations can supplement any projects that the base staff might independently generate.
2. ***Automate* candidate project analysis** – FEDS not only generates potential project recommendations, it does so automatically via its simulation engine. It provides extensive analysis results related to cost, energy, and emissions savings. After the model is created, the simulation is run, and in this instance, analysis results are produced in less than ten minutes. One of the output report formats is consistent with Energy Conservation Investment Program (ECIP) guideline requirements.
3. **Provide support for potential ECIP project submission –** The USAF energy specific funding (NRG) has, at the time of this demonstration, recently been discontinued -- after FY14, this funding vehicle is unavailable. Therefore, energy projects must now directly compete with Sustainment, Restoration and Modernization (SRM) candidate projects for funding. However, ECIP funding is still available at an annual budget level of approximately $150M. Packaging some of the FEDS recommended projects together, along with any staff generated project ideas, could then be submitted for ECIP funding consideration.
4. **Provide project inputs to demonstrate ESAT technology performance** – Having candidate projects to potentially invest in, is a required input to exercise ESAT portfolio analysis optimization. This is necessary to test and prove ESAT optimization technology.

6.2.2 Building Selection for Modeling

The buildings chosen for FEDS modeling and analysis were selected based on their historically measured energy intensity. Three months (November 18, 2013 – February 19, 2014) of electrical energy meter data was provided by the Luke AFB staff and analyzed by the Boeing team. The top ten ranked (based on energy intensity) facilities were selected for FEDS modeling. This list was also filtered for buildings expected to be demolished in the near future, refurbished, or those designated as “customer reimbursable” buildings (buildings leased to paying tenants, who manage the facilities themselves).

6.2.3 Building Characteristic Data Collection

Partial input data, required by the FEDS model to produce results, was collected by Luke AFB personnel. Data was collected from facilities managers as well as from a facilities database being used by the base, called "BUILDER". In addition, the Boeing ESAT team visited Luke AFB during February 18-19, 2014. During this period, building electrical energy meter data was downloaded from their database repository. Analysis was subsequently performed on this data to determine the energy intensity for each building. These were then ranked from highest to lowest.

A second site visit was conducted during August 5-6, 2014 to collect additional building characteristic data to supplement, confirm or correct earlier provided building data. All ten buildings were visited. Facility representatives were interviewed during these visits to collect the needed building and system data, in addition to taking notes and photos. Further independent research was conducted to identify additional needed system/equipment technical specifications related to the audit (e.g. capacity/age of HVAC equipment). The resulting collected data was then used to develop a detailed FEDS model of the building set. See Figure 17 for a sample data input screen for FEDS. The FEDS model simulation was run, thereby producing an output of recommended retrofit technology projects, which will result in energy and cost savings, if implemented. The project recommendation set, with their associated energy, cost, and emissions savings data, subsequently served as inputs to the ESAT model and analysis, which produces an optimal project portfolio for a range of possible investment. A chosen optimal project portfolio produced by ESAT can be potentially packaged and submitted by the Luke AFB Energy Team for service level or enterprise level agency funding consideration.

FEDS related data collected during the visit included:

1. Building type
2. Size
3. Construction year
4. Occupancy
5. Operations schedule
6. Lighting technology
7. HVAC systems (type, fuel)
8. Service hot water

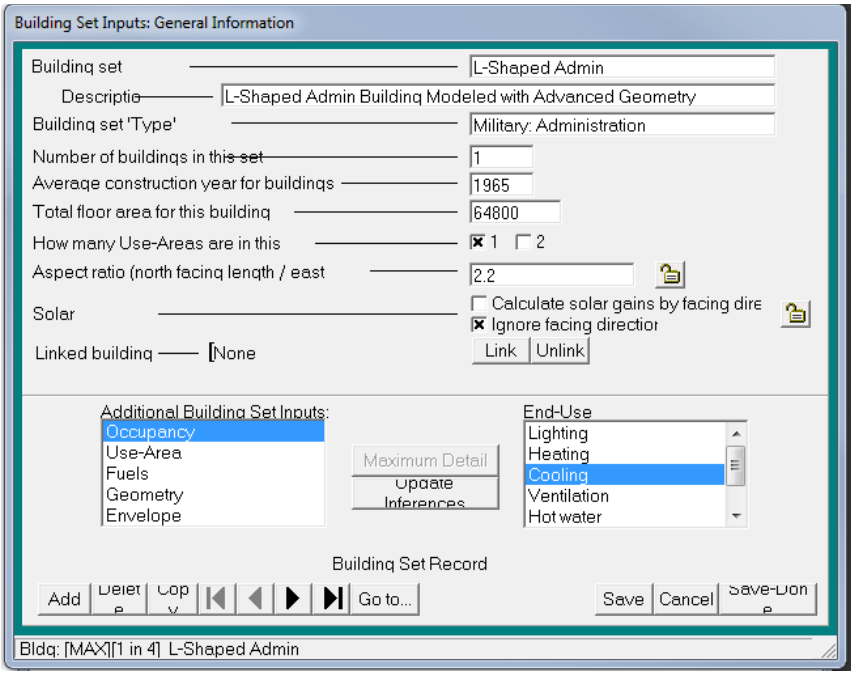


Figure 17. FEDS Sample Input Window.

6.2.4 Data/Results Visualization

No development effort was required for the data visualization supporting the FEDS analysis results, as the needed capability has already been developed during previous customer engagements. Subsequent figures illustrate this visualization.

6.2.5 FEDS Simulation Analysis Results

The FEDS simulation run resulted in 53 recommendations (22 different types), requiring a total investment of $520k, if all were to be implemented. Total predicted life cycle cost savings is $435k. Total annual energy savings is 1153 MBTU/year. See Appendix D: FEDS Bldg. Characteristic Data & Notes, Luke AFB, Aug. 2014 for more detailed summary results.

6.2.6 ESAT Optimization Analysis

The data interface and format for passing the required data between the FEDS output results and the inputs to the ESAT optimization model had already been established from performing previous similar analyses for other customers. This step of the process is routine.

The following section shows the results of the ESAT optimization run based on the FEDS output results. Two primary cases were run: (1) Comparison of Savings to Investment Ratio (SIR) rank order approach vs. ESAT, using no (0%) energy savings constraint (the energy savings constraint emulates the requirement to save a designated annual energy savings amount against a baseline consumption level); and (2) Comparison of SIR rank order approach vs. ESAT, using a 3% energy savings constraint.

There are eight related figures shown. The first is the NPV vs. investment Pareto, which shows the behavior of how the rate of NPV increases as investment increases in $10k increments (see Figure 18). Each point on the chart represents a portfolio of projects. The size of the point and the color intensity increases with an increase of energy savings. The green circles represent ESAT methodology selected portfolios and the red squares represents the rank order approach.

Key data points to note are (1) the portfolio data points which are at investment increments where disproportionate increases in NPV occur; and (2) the investment level where increased investment has minimal impact on increasing NPV. This is observed at the $400k investment level. Additional investment does not increase NPV much. This is primarily due to the fact that the remaining projects to select from are only marginally beneficial (e.g. SIR of 1.0 or barely above).

The second figure (see Figure 19) shows a portfolio comparison, indicating project differences for the selected portfolios. Important metrics, such as Investment, Annual Savings, and Simple Payback are also shown. This chart format enables seeing the detail portfolio construction, and how it evolves with increased investment. This chart is helpful when reviewing other charts and discovering something counter-intuitive. Cross referencing with this view can help solve some of these related questions that arise. All the portfolio project details are available to support this.

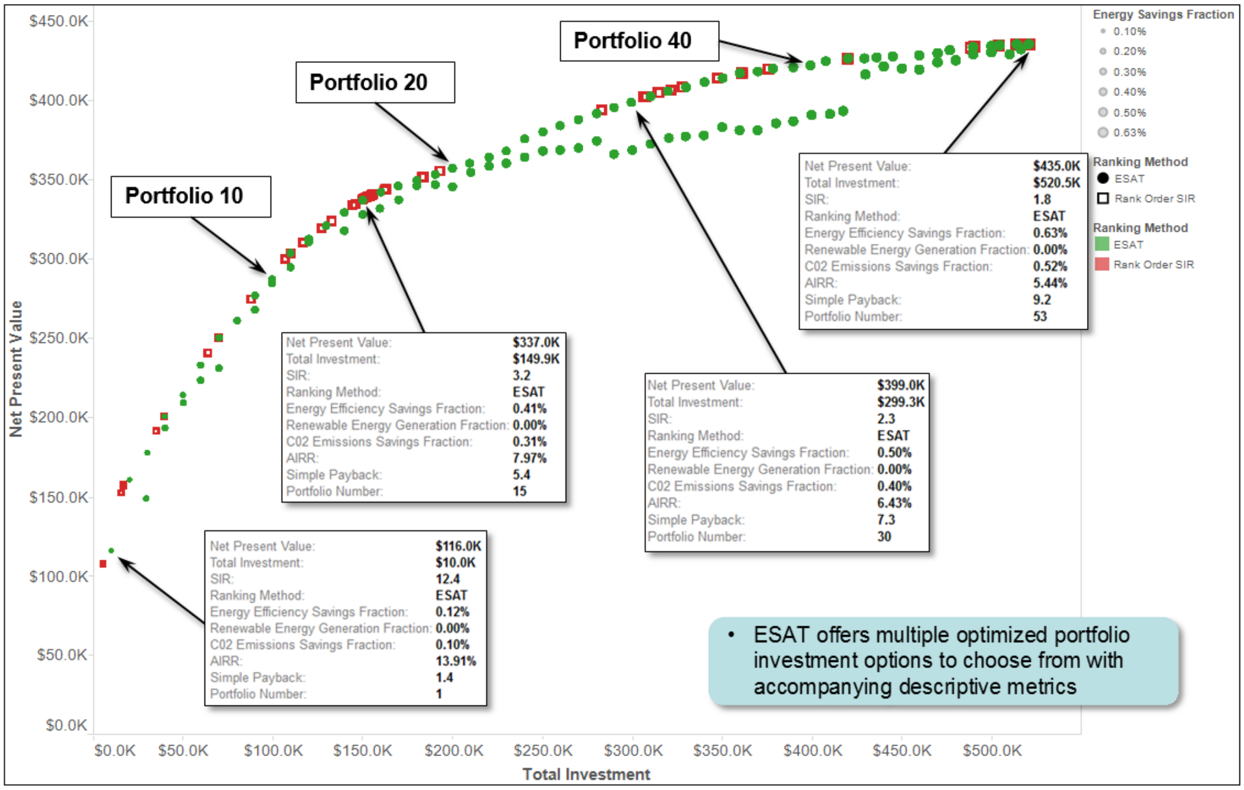


Figure 18. Portfolio Optimization Analysis: NPV vs. Investment Pareto.

Project economic life is normalized for the 25-year NPV calculation.

Project	Project Ty..	Investment	SIR	Net Present Value (Project)	Portfolio Number 1	10	15	20	30	40	53
B176[Floor Project]	Floor	$7.08K	1.3	$2.27K				■		■	■
B176[Heating Project]	Heating	$4.28K	1.8	$3.21K			■	■	■	■	■
B176[Lights Project]	Lights	$0.35K	1.4	$0.14K				■	■	■	■
B176[Window Project]	Window	$10.13K	1.9	$9.05K			■	■	■	■	■
B245[Floor Project]	Floor	$5.74K	1.8	$4.56K			■	■	■	■	■
B245[Lights Project 1]	Lights	$0.35K	1.4	$0.13K					■	■	■
B245[Lights Project]	Lights	$18.77K	2.3	$24.90K		■	■	■	■	■	■
B245[Roof Project]	Roof	$2.30K	1.1	$0.25K							■
B245[Window Project]	Window	$17.93K	2.3	$24.14K			■	■	■	■	■
B289[Floor Project]	Floor	$6.33K	1.3	$1.91K						■	■
B289[Heating Project]	Heating	$0.08K	1.0	$0.00K	■		■	■	■	■	■
B289[Lights Project]	Lights	$0.64K	1.5	$0.35K				■	■	■	■
B289[Roof Project]	Roof	$6.75K	1.0	$0.01K							■
B289[Window Project]	Window	$20.37K	1.4	$7.90K				■	■	■	■
B328[Floor Project]	Floor	$3.18K	2.0	$3.25K	■	■	■	■	■	■	■
B328[Heating Project]	Heating	$1.24K	4.8	$4.71K	■	■	■	■	■	■	■
B328[Lights Project]	Lights	$0.35K	1.4	$0.13K					■	■	■
B328[Roof Project]	Roof	$10.09K	5.4	$44.88K		■	■	■	■	■	■
B328[Wall Project]	Wall	$5.38K	21.0	$107.37K	■	■	■	■	■	■	■
B328[Window Project]	Window	$4.88K	2.8	$8.67K		■	■	■	■	■	■
B450 Bay[Lights Project]	Lights	$0.35K	1.3	$0.11K					■	■	■
B450 Office[Heating Project]	Heating	$0.22K	2.1	$0.25K		■	■	■	■	■	■
B450 Office[HotWater Project]	HotWater	$0.10K	3.7	$0.57K	■	■	■	■	■	■	■
B450 Office[Lights Project]	Lights	$0.64K	1.5	$0.30K				■	■	■	■
B547 Bay[Lights Project]	Lights	$0.35K	1.3	$0.11K					■	■	■
B547 Office[Floor Project]	Floor	$1.38K	1.8	$1.05K				■	■	■	■
B547 Office[Lights Project]	Lights	$0.35K	1.3	$0.12K					■	■	■
B547 Office[Roof Project]	Roof	$0.49K	1.0	$0.01K					■	■	■
B547 Office[Window Project]	Window	$0.97K	1.5	$0.53K		■	■	■	■	■	■
B913 Hangar[Lights Project]	Lights	$0.64K	1.5	$0.30K				■	■	■	■
B913 Office[Cooling Project 1]	Cooling	$9.24K	1.0	$0.48K							■
B913 Office[Cooling Project]	Cooling	$13.47K	1.0	$0.79K							■
B913 Office[Floor Project]	Floor	$6.31K	1.3	$1.90K							■
B913 Office[HotWater Project]	HotWater	$0.01K	7.3	$0.14K	■	■	■	■	■	■	■
B913 Office[Lights Project]	Lights	$0.64K	1.5	$0.34K				■	■	■	■
B913 Office[Wall Project]	Wall	$6.97K	2.0	$6.99K		■	■	■	■	■	■
B913 Office[Window Project]	Window	$23.26K	1.4	$8.31K					■	■	■
B959[Cooling Project]	Cooling	$89.85K	1.4	$38.41K					■	■	■
B959[Floor Project]	Floor	$13.93K	1.2	$3.46K						■	■
B959[Heating Project]	Heating	$11.82K	1.8	$9.40K			■	■	■	■	■
B959[Lights Project]	Lights	$0.64K	1.5	$0.34K				■	■	■	■
B959[Roof Project]	Roof	$44.00K	1.1	$6.27K						■	■
B959[Window Project]	Window	$68.74K	1.1	$7.46K							■
B961[Floor Project]	Floor	$9.35K	1.4	$3.43K				■		■	■
B961[Heating Project]	Heating	$6.05K	2.6	$9.67K		■	■	■	■	■	■
B961[Lights Project]	Lights	$0.64K	1.5	$0.34K				■	■	■	■
B961[Window Project]	Window	$7.10K	1.4	$3.12K				■	■	■	■
B968 Bay[Heating Project]	Heating	$24.36K	2.7	$40.66K		■	■	■	■	■	■
B968 Bay[Lights Project 1]	Lights	$0.35K	1.3	$0.11K					■	■	■
B968 Bay[Lights Project]	Lights	$17.72K	2.9	$34.11K		■	■	■	■	■	■
B968 Office[Lights Project]	Lights	$0.64K	1.5	$0.33K				■	■	■	■
B968 Office[Roof Project]	Roof	$14.44K	1.1	$2.16K							■

Figure 19. Portfolio Optimization Analysis: Portfolio Comparison.

A square in the portfolio column indicates whether the project is included in that portfolio.

The third figure (see Figure 20) is a portfolio comparison Sparkline chart (a simple, highly condensed chart representing many different output result variable values), which highlights multiple key metrics, in a graphical way, for each of the optimal portfolio solutions. The changes in these metrics can be observed as investment is increased. Key metrics shown are Total Investment, Net Present Value, SIR, Energy Savings Fraction, and Simple Payback. This chart is useful for portfolio comparisons near investment levels of interest or inflection points in the Pareto curve.

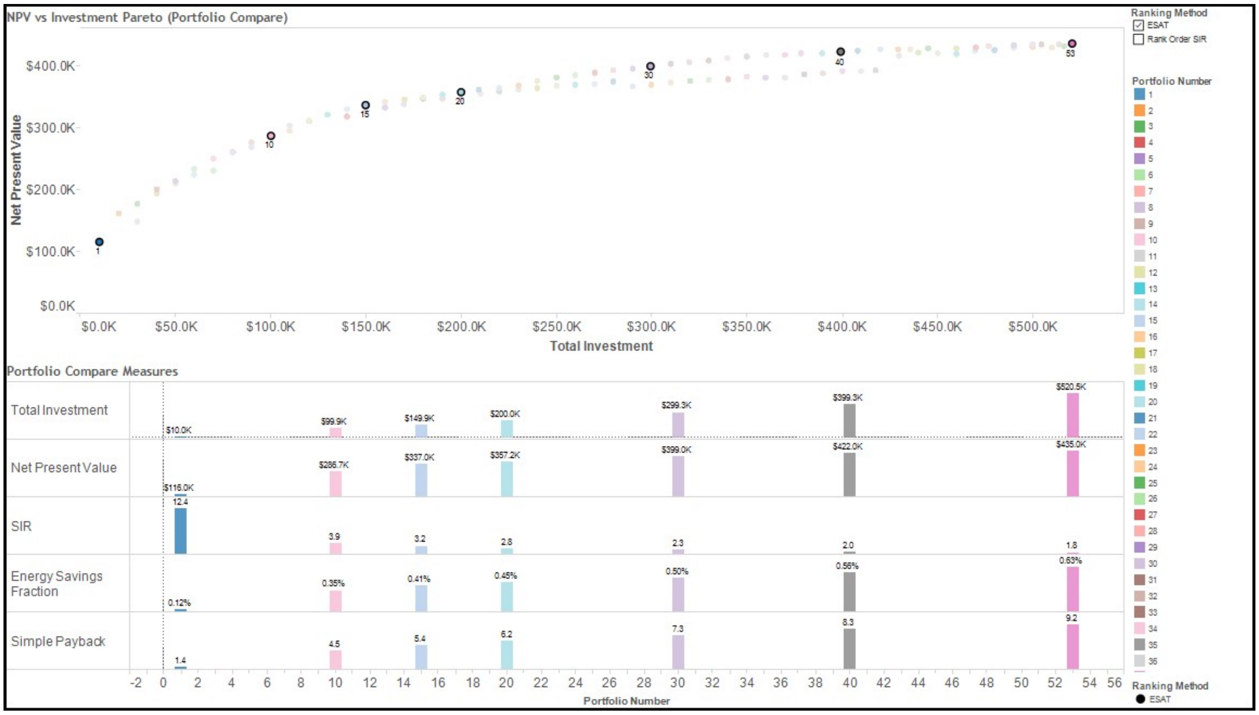


Figure 20. Portfolio Optimization Analysis: Portfolio Comparison Sparkline.

Different portfolios are compared with respect to selected metrics.

The fourth figure (see Figure 21) shows, for the selected portfolio, how investment is distributed over the various project type options, e.g. cooling, lighting, windows, etc. Within ESAT, once the portfolio is chosen, all the other dashboard visuals and metrics automatically update based on the selection. The pie chart indicates the percentage of that project type which contributes to the resulting net present value of the investment. The image on the bottom right of the dashboard shows how those projects are distributed across the base's facilities, by project type.

The fifth figure (see Figure 22) assists with indicating how the retrofit projects are distributed physically across the base. The previous figure did so conceptually, but this figure does so explicitly, using a map of the base and coordinates of the base facilities. The map image and tree map diagram are portfolio selection sensitive, dynamically changing to accurately reflect the underlying portfolio metrics of the selected portfolio. Further selecting a facility on the map (upper right) will filter further to indicate in the tree map only those projects which are planned for that building.

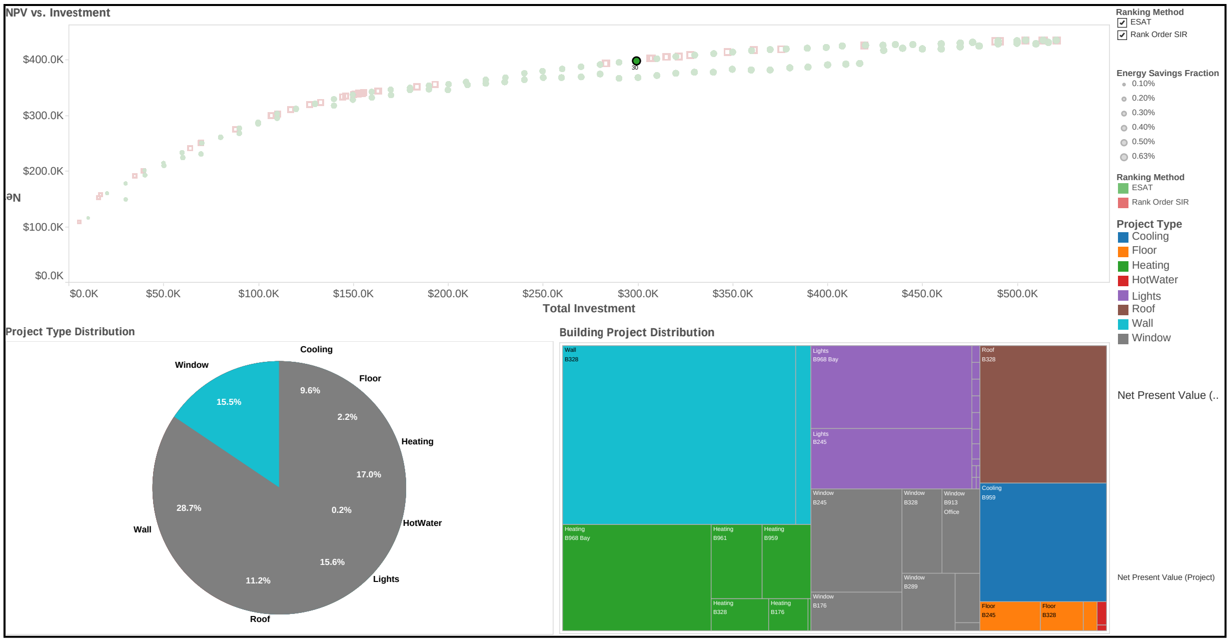


Figure 21. Project Type and Building Distribution for Selected Portfolio.

Figure 22. Project Physical Installation Location on Site for Selected Portfolio.

The sixth figure (see Figure 23), is similar to Figure 23 above, but the lower tree map is substituted with key metrics, in a tabular format, available for review. The portfolio selection in the NPV vs. Total Investment image (upper left) serves as a filter, such that selection of a portfolio automatically updates the map and table image with the associated underlying data. Further selecting a facility on the map (upper right) will filter further to indicate, in the table below, only those projects which are planned for that building.

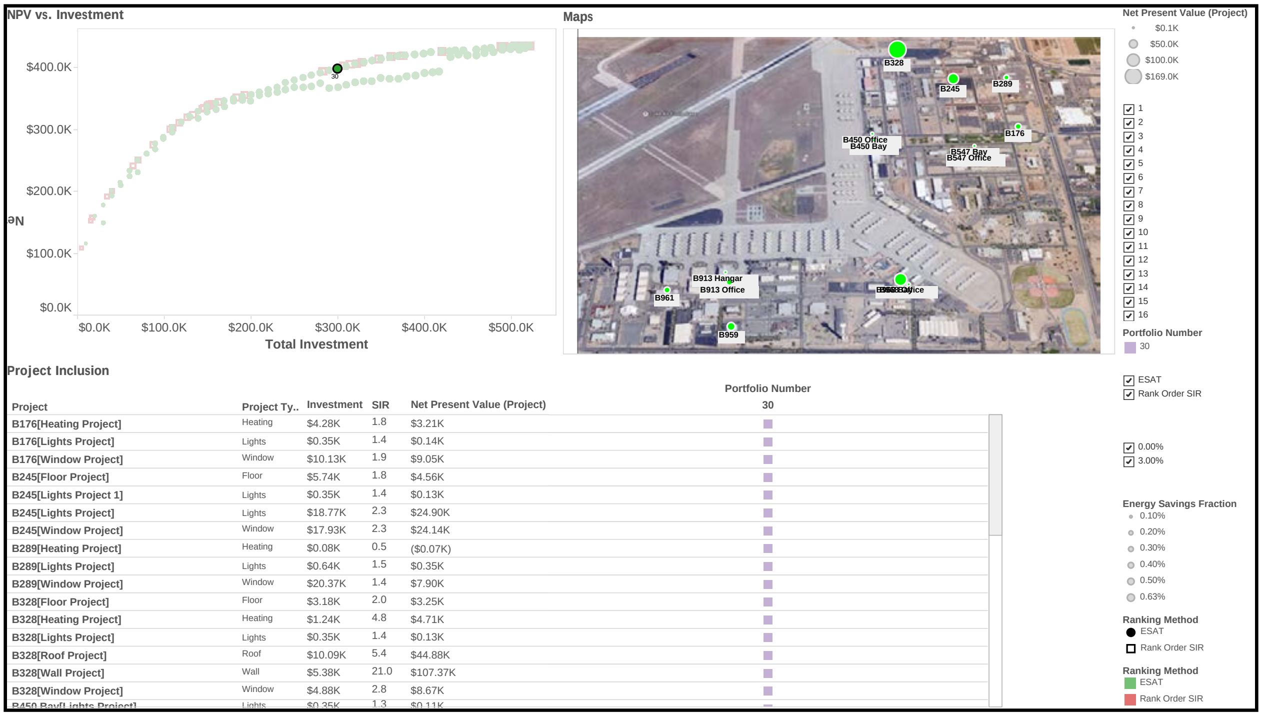


Figure 23. Detail Project Attributes/metrics for Selected Portfolio and Building

The seventh figure (see Figure 24) shows a side-by-side comparison for the Project Type's Simple Payback and SIR values. The portfolio selection in the NPV vs. Total Investment image (top) serves as a filter, such that selection of a portfolio automatically updates the metrics below. Simple Payback and SIR are two of the most important project metrics that are used for evaluation. Therefore, this chart is useful for a quick evaluation of which project types are making the most impact to the chosen portfolio. For example, in the instance of the chosen Portfolio 30, the underlying Wall project types (typically insulation projects) offer a high SIR and low Simple Payback, higher than the other Project Types.

The eighth figure (see Figure 25), shows for each Project Type, the total net present value of savings, present value of investment, and resulting net present value of each Project Type for the selected portfolio. This shows how investment is allocated across Project Types, and the return received for the investment. A simple way to interpret the bar charts is "Blue minus red equals green" (or Savings-Investment = Value). In this example, the Wall project type again stands out as providing a lot of value for the investment. The portfolio selection serves as a filter for the lower half of the dashboard, dynamically updating the bar chart and associated metrics when a different portfolio is selected.

Figure 24. Project Type Simple Payback and SIR for Selected Portfolio.

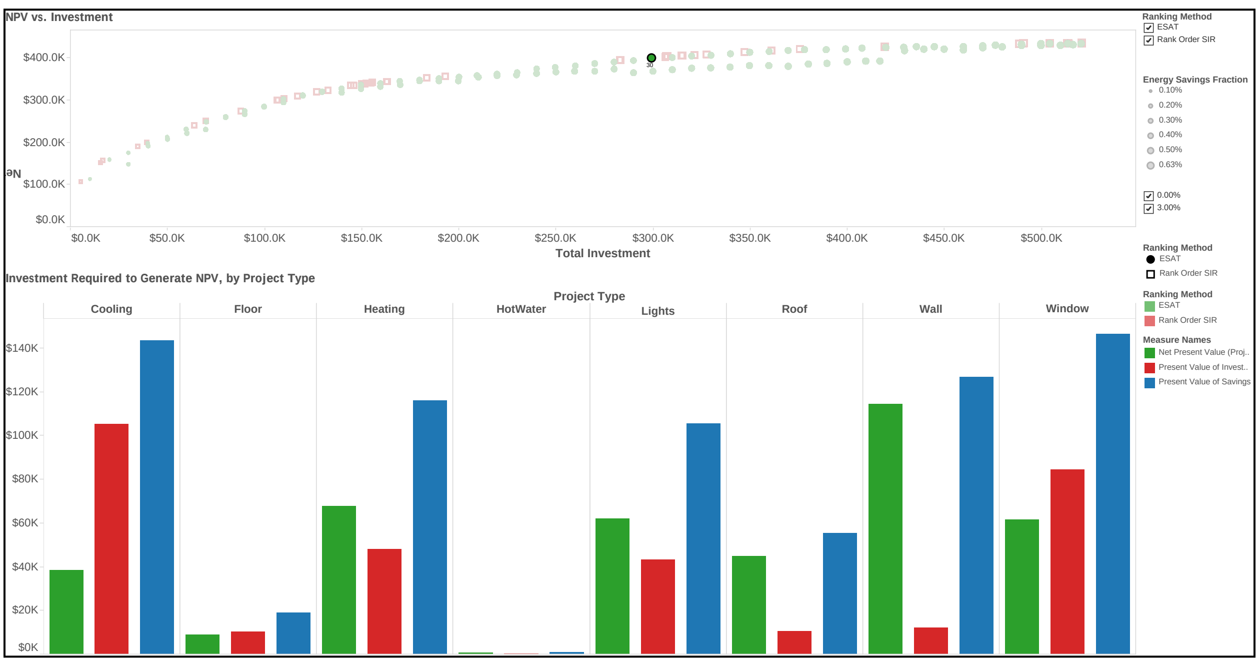


Figure 25. Project Type Present Value of Savings, Investment, and Net Present Value for the Selected Portfolio.

6.2.7 FEDS Software Use Evaluation

The FEDS tool version used for this analysis is 7.0.

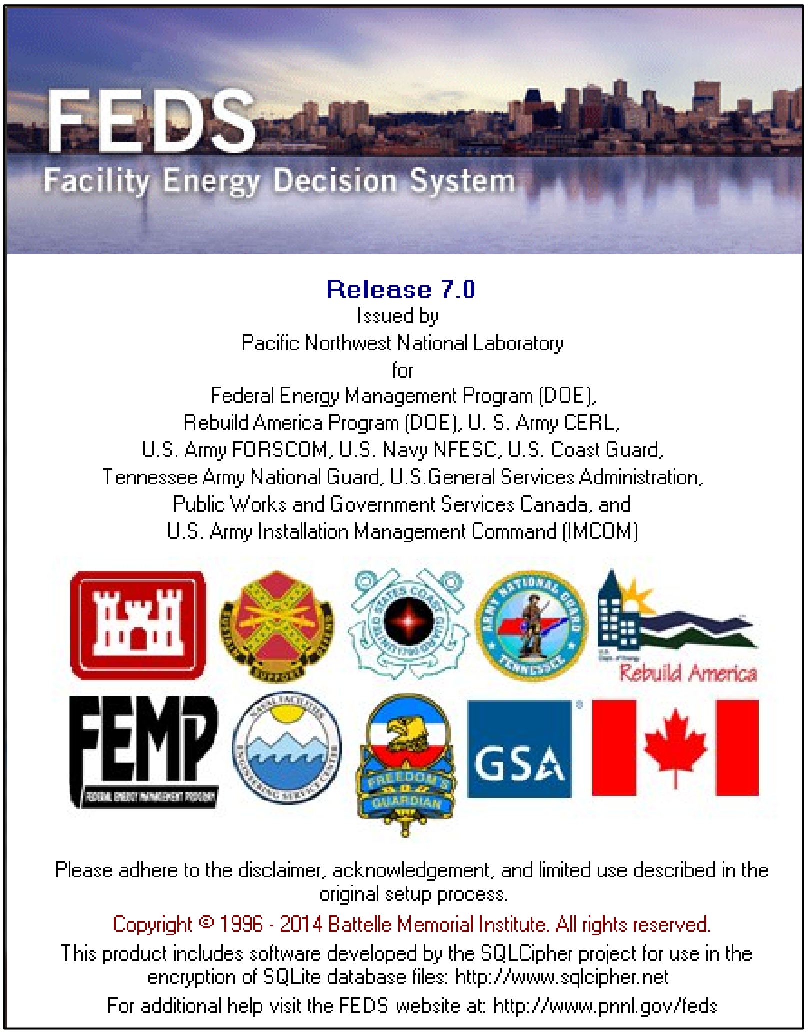
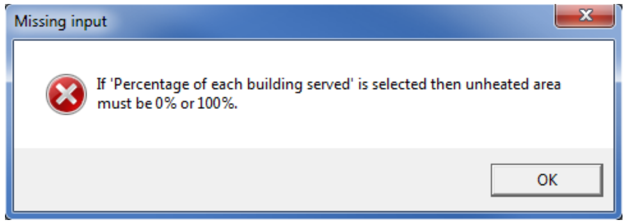


Figure 26. FEDS Version 7.0 Was Used for Facilities Model Building.

<u>Usability</u>

This section summarizes some of the usability issues encountered while modeling and running the FEDS simulations.

1. FEDS lacks the capability to pre-populate related dependent fields as required, resulting in the need to manually re-enter required input values in separate windows or tabs. This provides the opportunity for incorrect or incompatible inputs. In the instance of incompatibility, FEDS generates an error message that can sometimes be difficult to interpret. For example, the following alert is generated when an incompatibility exists between the two tabs on the Heating Inputs:



2. FEDS sometimes crashes without warning. In one instance, the cause was traced to the character length of the model name path. Our models are preferably stored on a server, and the models are stored in a project folder structure several folder layers deep. These layers add to the path name length, which caused FEDS to crash. Through experimentation, it was discovered that this was the cause of the problem and the model names were shortened and moved to the local PC hard drive which shortens the model location path name.

Modeling Constructs - The ability to model several areas of a single building is cumbersome. Some of the technologies can be split into use areas, whereas other technologies, such as heating, cannot. This leads to modeling areas as two separate linked buildings, which has its own set of limitations. This alternate modeling construct propagates through to the reports, which may lead to interpretation confusion by the end customer, as he/she is not familiar with the modeling process details, nor should he be.

6.3 DAVIS-MONTHAN AFB AMARG DEMONSTRATION SITE

The Davis-Monthan AFB demonstration was initiated with Lt. Col. Andrew Middione, IMA to the Commander, in April 2014. It began with the coordination of sub-contractor Venergy (data meter/sensor supplier and installer) with D-M AFB staff to have wireless energy sensor meters installed in select buildings on the base for which it was believed there was an opportunity for an energy savings improvement. The sensors would provide the means to measurably substantiate this belief.

Challenges to gain all necessary approvals for the meter installation resulted in an approximate six month delay in efforts to begin collecting the energy meter data for the buildings. As a parallel initiative, to potentially supplement the delayed but forthcoming sensor data, we were able to obtain smart meter building data from a previously performed ESTCP project conducted by the 3M Company. However, it ultimately turned out that the data was unusable for our purposes, as it focused on a single building (Building 65) which was not of interest to our efforts (not one of the designated candidate AMARG buildings).

Approvals were eventually gained in late September 2014, and energy meter data was beginning to be collected. These meters produced readings from end of September 2014 through beginning of February 2015. The data collected from each meter was forwarded to the ESAT team, which then performed energy intensity analysis. Eleven buildings were selected as a result of this analysis, and then further analyzed using FEDS modeling analysis.

The ESAT team visited Davis-Monthan AFB and met with Lt. Col. Middione October 15-16, 2014. We reviewed the advanced wireless energy meter installation to understand its operation, collect initial stored data, and begin the basic analysis to discover any obvious energy/power usage anomalies and develop related energy projects to address them.

The ESAT team also collected additional facility characteristic data while there, to ensure the most accurate inputs to the FEDS model for the selected buildings.

Lt. Col. Middione also provided the ESAT team with a current set of planned projects which were being considered for implementation in the near future, and wanted some business case analysis applied to determine cost and energy savings benefits. These projects included LED lighting retrofits, SuperTherm (an insulating, weatherizing roof treatment planned to be applied to several AMARG buildings), and Microturbine and solar assisted A/C installations. These projects were analyzed in depth with multiple trade studies. Additional projects were created by the ESAT team using FEDS modeling analysis. ESAT technology was then applied to this portfolio of projects to optimize an investment plan to maximize cost and energy savings.

6.3.1 FEDS Modeling Purpose

FEDS modeling and analysis was conducted for the Davis-Monthan AFB demonstration site. The purpose for conducting the analysis is the same as was for the Luke AFB demonstration, namely:

1. Supplement energy efficiency improvement candidate project generation
2. Automate candidate project analysis
3. Provide support for potential ECIP project submission
4. Provides project inputs to demonstrate ESAT technology performance

6.3.2 Building Selection for Modeling

The buildings chosen for FEDS modeling and analysis were selected based on the recommendations of Lt. Col. Andrew Middione. Eleven facilities were selected for FEDS modeling. This list was also filtered for one building which was currently under construction at the time the decision was made, so was eliminated.

6.3.3 Building Characteristic Data Collection

Partial input data, required by the FEDS model to produce results, was collected by Davis-Monthan AFB personnel. Data was collected from their local facilities managers at each building. In addition, the Boeing ESAT team visited Davis-Monthan AFB Oct. 14-15th, 2014 to verify and collect additional facility characteristic data.

All eleven buildings were visited. Facility personnel were interviewed during these visits, resulting in collecting the needed building and system data, notes and photos. Further independent research was conducted to identify additional needed system/equipment technical specifications related to the audit (e.g. capacity/age of HVAC equipment). The resulting collected data was then used to develop a detailed FEDS model of the building set. The FEDS model simulation was run, thereby producing an output of recommended retrofit technology projects, which will result in energy and cost savings, if implemented. The project recommendation set, with their associated energy, cost, and emissions savings data, subsequently serve as inputs to the ESAT model and analysis, which produces an optimal project portfolio for a range of possible investment. A chosen optimal project portfolio produced by ESAT can be potentially packaged and submitted by the Davis-Monthan AFB Energy Team for service level or enterprise level agency funding consideration.

FEDS related data collected during the visit included:

1. Building type
2. Size
3. Construction year
4. Occupancy
5. Operations schedule
6. Lighting technology
7. HVAC systems (type, fuel)
8. Service hot water

6.3.4 Davis-Monthan FEDS Analysis Results

The total optimization analysis run resulted in 52 projects (6 different project types), requiring a total investment of $474k, if all were to be implemented. Total predicted life cycle cost savings is $327k. Total electrical energy savings/year is 1208 MBTU. See Appendix E: FEDS Bldg. Characteristic Data & Notes, Davis-Monthan AFB, Oct. 2014 for more detailed summary results.

6.3.5 Meter Data Analysis

Meter data analysis was performed to provide insight into the base's current facility electrical energy consumption, instantaneous load, and consumption and load intensities for the eleven metered buildings. This analysis helps identify potential anomalies for further investigation, and point the direction towards potential candidate energy efficiency improvement projects to undertake.

The meter data compiled and sent to the ESAT team ranged from September 26, 2014 through February 2, 2015. This range provided 120 days of full data to analyze. The analysis was split into two primary categories: energy consumption (kWh) and instantaneous power (kW).

Figure 27 and Figure 28 show the daily energy consumption and energy intensity for all eleven buildings of interest. The overall pattern of decreasing consumption during the winter months is observed and expected, as this trend is attributed to the fact that in the cooler months, air conditioning is not as frequently operated.

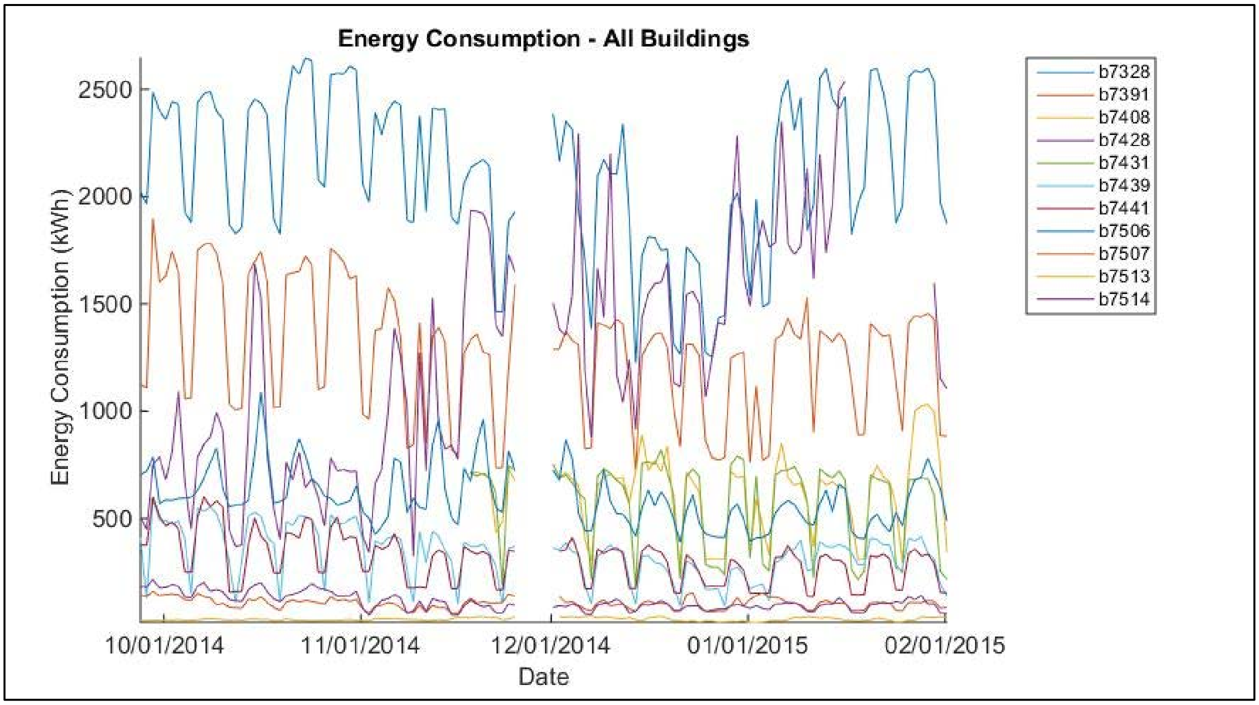


Figure 27. Daily Energy Consumption

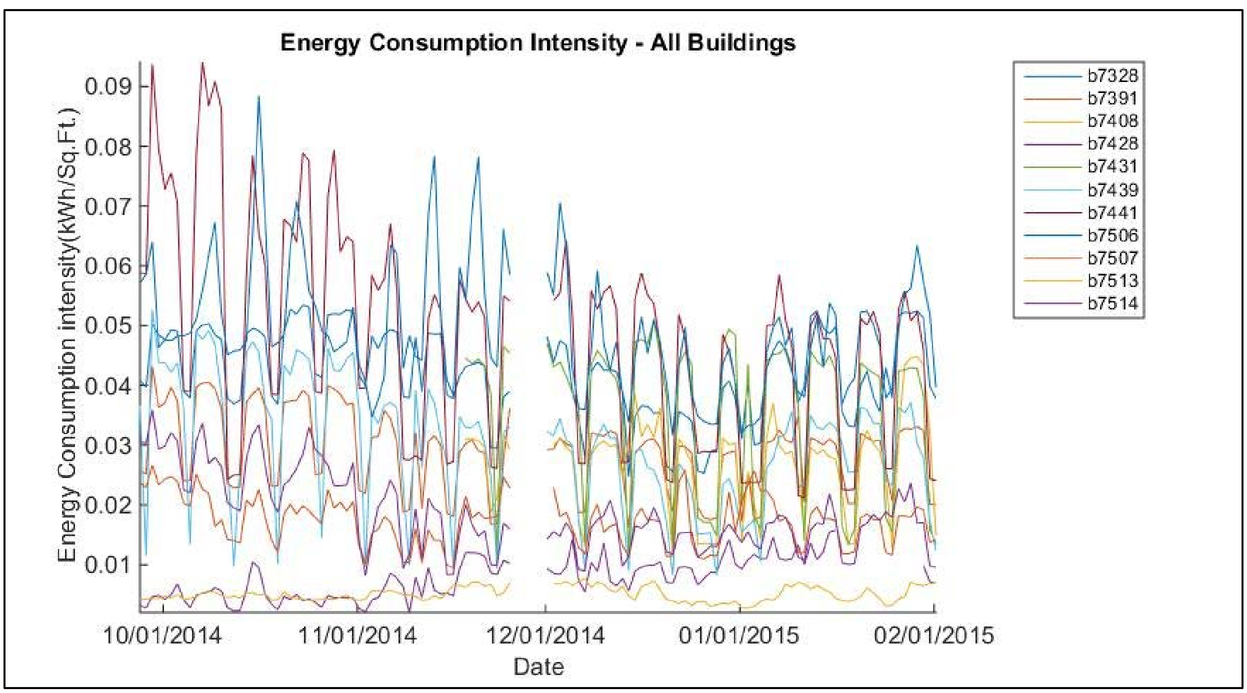


Figure 28. Daily Energy Consumption Intensity

Figure 29 and Figure 30 show the instantaneous power load and load intensities over the course of the workday. This analysis provides insight as to when significant energy loads occur.

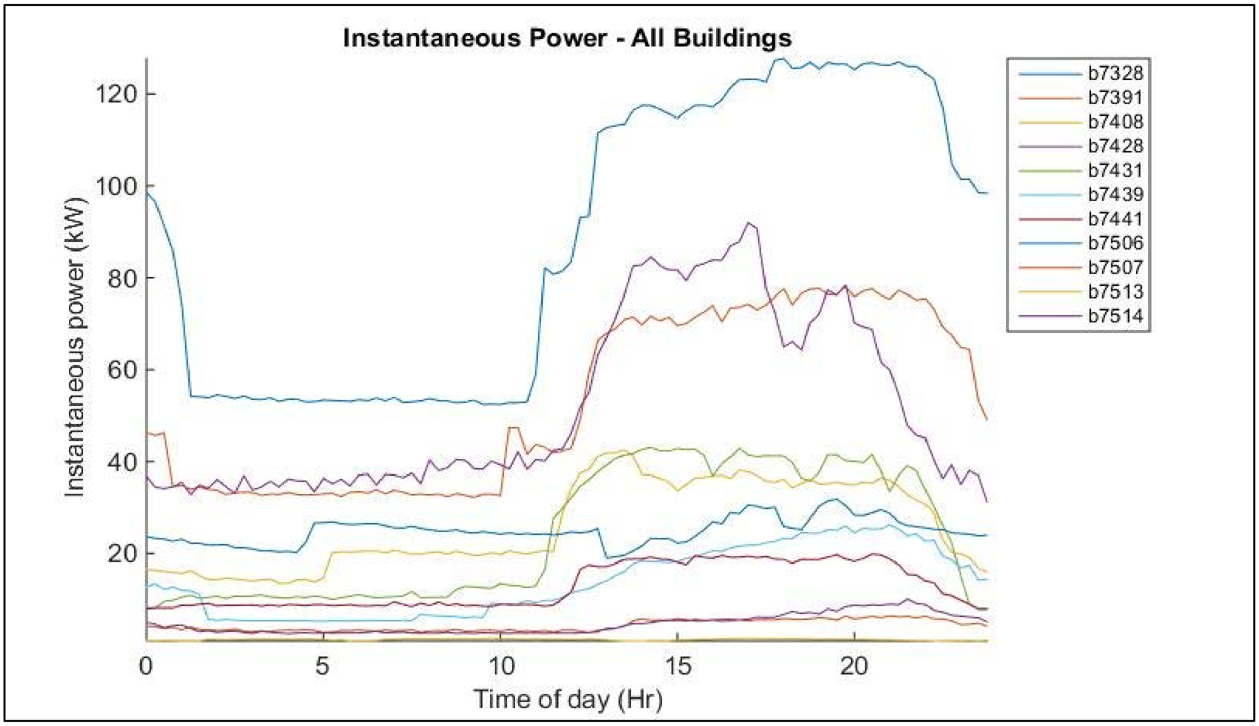


Figure 29. Hourly Instantaneous Power

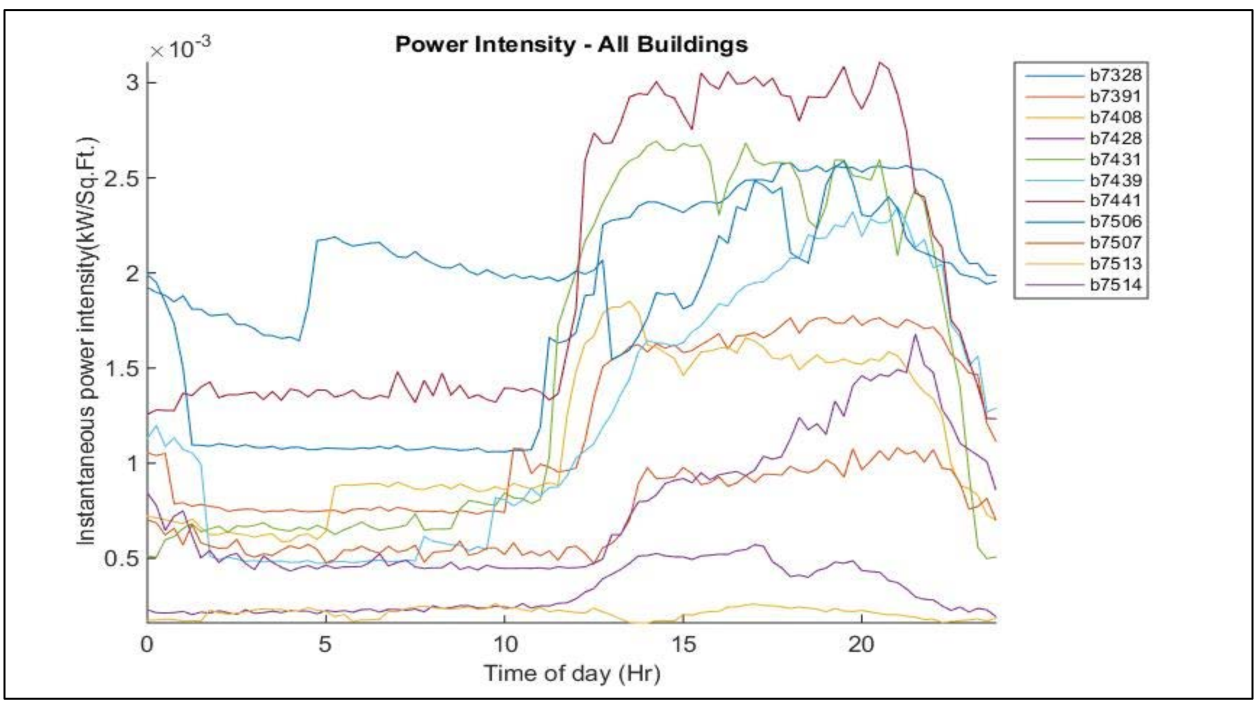


Figure 30. Hourly Instantaneous Power Intensity

The analysis of these figures provides the knowledge of which building is drawing the biggest load overall and which building is drawing the most intense load. The meter data analysis did not result in the ESAT team generating any new project for Davis-Monthan, as this is beyond the scope of the contract effort. However, these details are helpful in identifying the buildings to focus on for developing future energy savings improvement projects or energy intensity savings projects.

6.3.6 AMARG Candidate Project Analysis

The Davis-Monthan energy team provided a list of proposed energy savings projects for future implementation. This list (see Table 5) included multiple instances of SuperTherm roof coating, LED lighting replacement, micro turbine installation, and solar/thermal panel assisted air conditioning. There was interest in evaluating the economic and energy saving merits of these projects, analyzing them for cost and energy savings, payback evaluation, and comparison with other substitute technologies. They were also included in a second iteration of investment portfolio optimization (note that the first optimization run consisted of only FEDS analysis generated projects). Investment optimization of this project set was based on project investment, electric energy savings, and maintenance savings. Independent analysis (trade studies) on these projects are also presented in this section.

Table 5. AMARG Candidate Projects Table

Project Title	Building	Investment	Simple Payback (yrs.)	SIR
LED Light replacement	7428	$453,150	6.81	2.73
LED Light Replacement	7506	$75,275	9.26	2.00
LED Light Replacement	7441	$53,100	13.04	1.42
Microturbine Installation	7328	$337,500	4.02	4.33
Solar AC Assist Installation	7506	$8,192	9.60	1.81
SuperTherm Paint Application	7507	$15,660	6.87	2.17
SuperTherm Paint Application	7328	$122,670	5.23	2.85
SuperTherm Paint Application	7391	$178,770	7.91	1.88
SuperTherm Paint Application	7439	$29,080	6.56	2.27
SuperTherm Paint Application	7408	$67,455	7.10	2.10

LED Lighting Replacement - The LED lighting replacement projects are designated for the Maintenance Sun Shelter (7428), F-16 Hangar (7506), and the Welding and Machine Shop (7441) buildings. These projects represented initial investments of $453K, $75K, $53K, and resulting simple payback of 6.8, 9.3, and 13.0 years, respectively, as shown above.

SuperTherm – SuperTherm is an elastomeric roof paint. White in color, and high in infrared and radiation reflectivity, it is marketed as an energy savings paint application for commercial buildings. The energy team provided a list of SuperTherm coating projects to be completed at the base. There was no previous analysis done on the savings of SuperTherm by the energy team, but there were third party analysis reports provided which contained some energy savings data at other installation sites. The ESAT team then identified which buildings could be evaluated in accordance with the given reports. The buildings were broken into two categories: those with meter data and those without meter data.

1. Buildings with meter data could be analyzed independent of the reports. The buildings with meter data were divided again by whether or not there was significant HVAC energy consumption at this building. Those buildings with significant HVAC loads were buildings 7507, 7328, 7391, 7439, and 7408 requiring a total investment of $414K and an average simple payback of 6.9 years. Those results compared favorably to the documented results of SuperTherm. These projects were included in the analysis and were selected in the optimization run for some portfolio investment levels.
2. Buildings without meter data lacked significant data to apply towards energy savings analysis. This lead to relying solely on the report data provided. The result of doing this, however, led to unrealistic (very low) payback periods which could not be trusted to be accurate, so were excluded from the subsequent optimization analysis. With each analysis iteration – and there were several, all assumptions, decisions, and calculations were reviewed with the customer.

Figure 31 shows the business case performance assessment of SuperTherm technology versus other competing elastomeric paint technologies. SuperTherm shows the best benefit – lowest simple payback period – for the high HVAC energy consumption buildings analyzed.

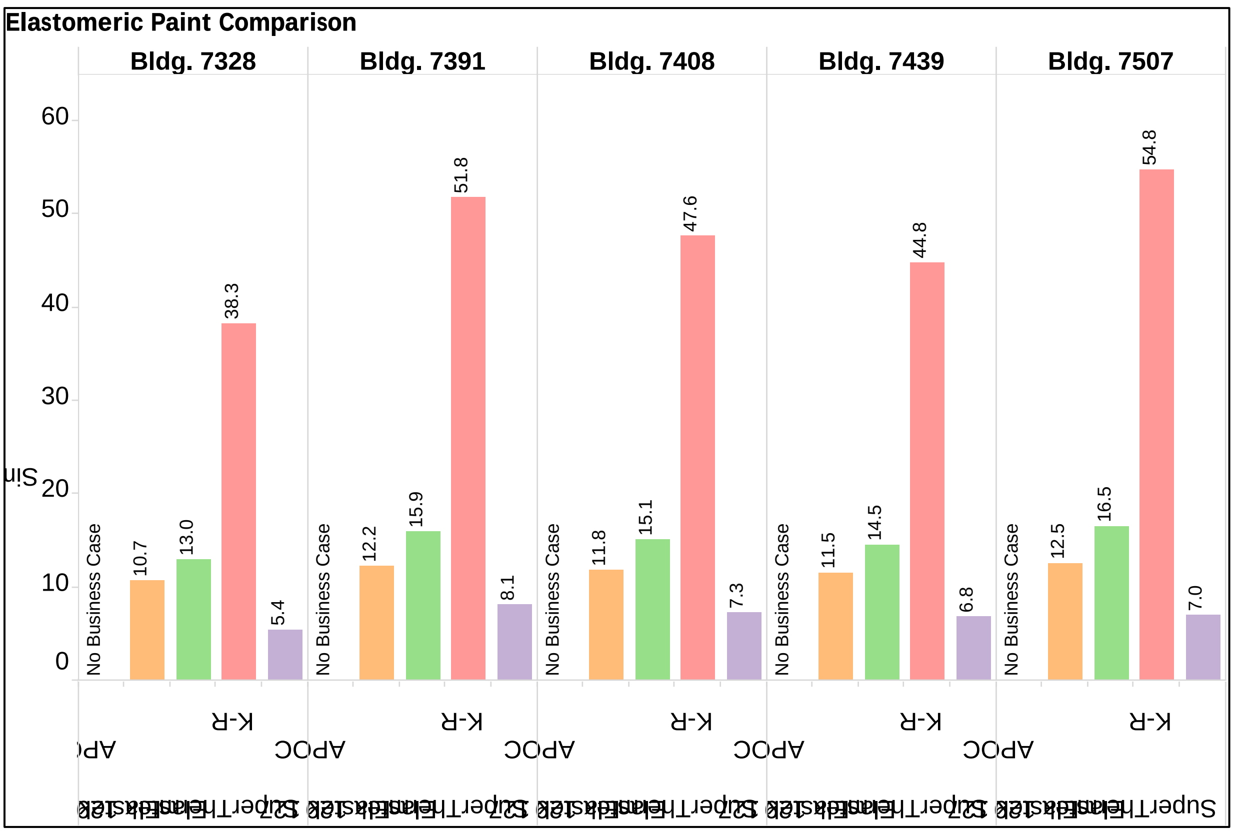


Figure 31. Elastomeric Paint Comparison between Potential Candidate Paints and SuperTherm.

Micro Turbine - The micro turbine is an electricity generating system which would enable Davis-Monthan to substitute utility grid power with micro turbine generated power, thereby creating energy independence when desired. After determining the operating scenario for the micro turbine, analysis was performed resulting in an estimated simple payback, and multiple related sensitivity analyses created by varying underlying input parameter values. After all assumptions were finalized, the project returned a simple payback of 4.0 years and was included in the portfolio optimization.

Figure 32 shows the impact to the micro turbine installation project simple payback due to changes in electrical and natural gas costs, base operations production loss, and efficiency (recovered heat). Some key parameter points are highlighted with call out statistics. Note that this trade study capability is another valuable offering of the ESAT tool.

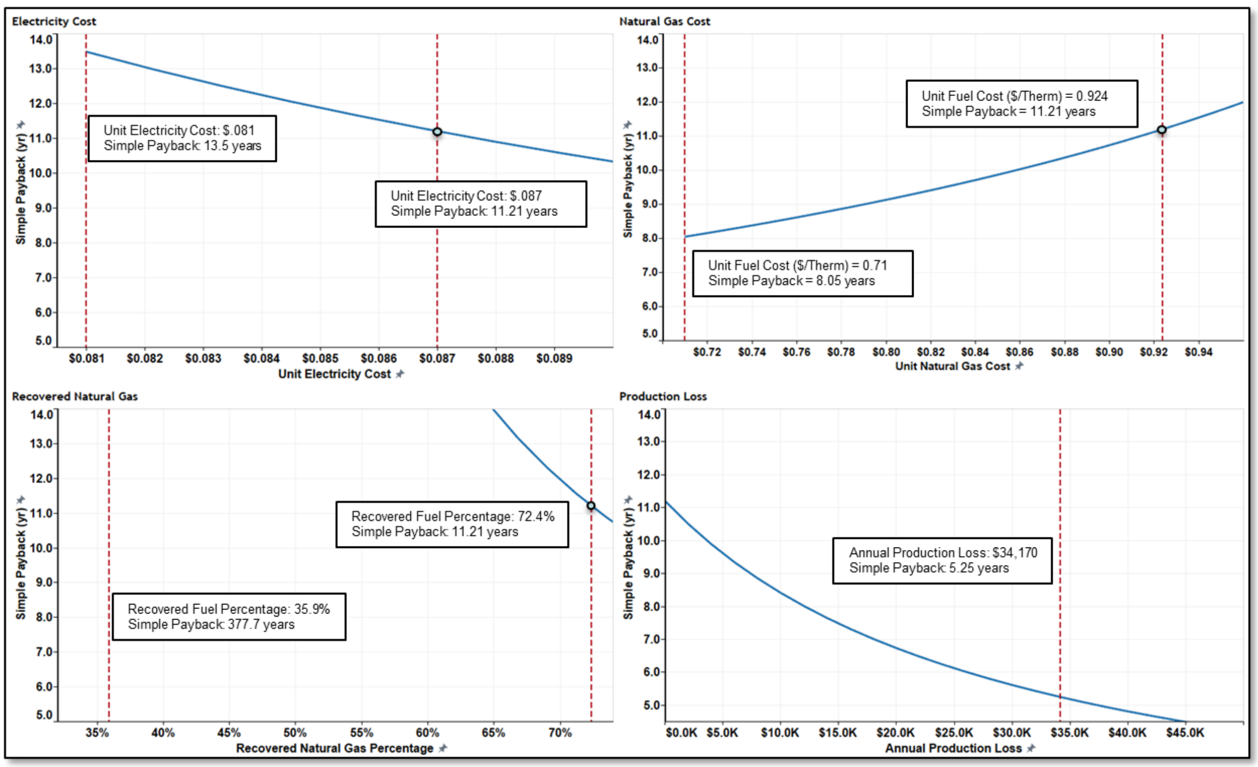


Figure 32. Microturbine Project Trade Study.

<u>Solar/Thermal Panel Air Conditioning Assist</u> - The solar/thermal panel is a system which generates electricity from sunlight and uses that electricity to supplement power to an air conditioner compressor. The solar/thermal panel is intended to be installed at Building 7506 (Small F-16 Hangar & Admin. Offices). Analysis resulted in a simple payback of 9.6 years and this project was included in the portfolio optimization run.

6.3.7 ESAT Optimization Analysis

The following section shows the results of the ESAT optimization run based on the FEDS output results combined with Davis-Monthan energy team planned projects (See 6.3.6 AMARG Candidate Project Analysis). The first graph is the NPV vs. Investment Pareto, which shows the behavior of how the rate of NPV increases as investment increases (see Figure 33). Each point on the chart represents a portfolio of projects. The size of the point and the color intensity increases with an increase of energy savings

Key data points to note are:

(1) Portfolio data points at investment increments where disproportionate increases in NPV occurs, such as is observed when increasing investment from \$0.3M to \$0.4M, between portfolios #41 and #42, and again near the \$0.8M investment level between portfolios #50 and #51.

(2) Investment levels where increased investment has minimal impact on increasing NPV. This is observed at approximately the \$1.4M investment level. Additional investment does not proportionately increase NPV that much. This is primarily due to the fact that the remaining projects to select from are only marginally beneficial (e.g. SIR of 1.0 or barely above).

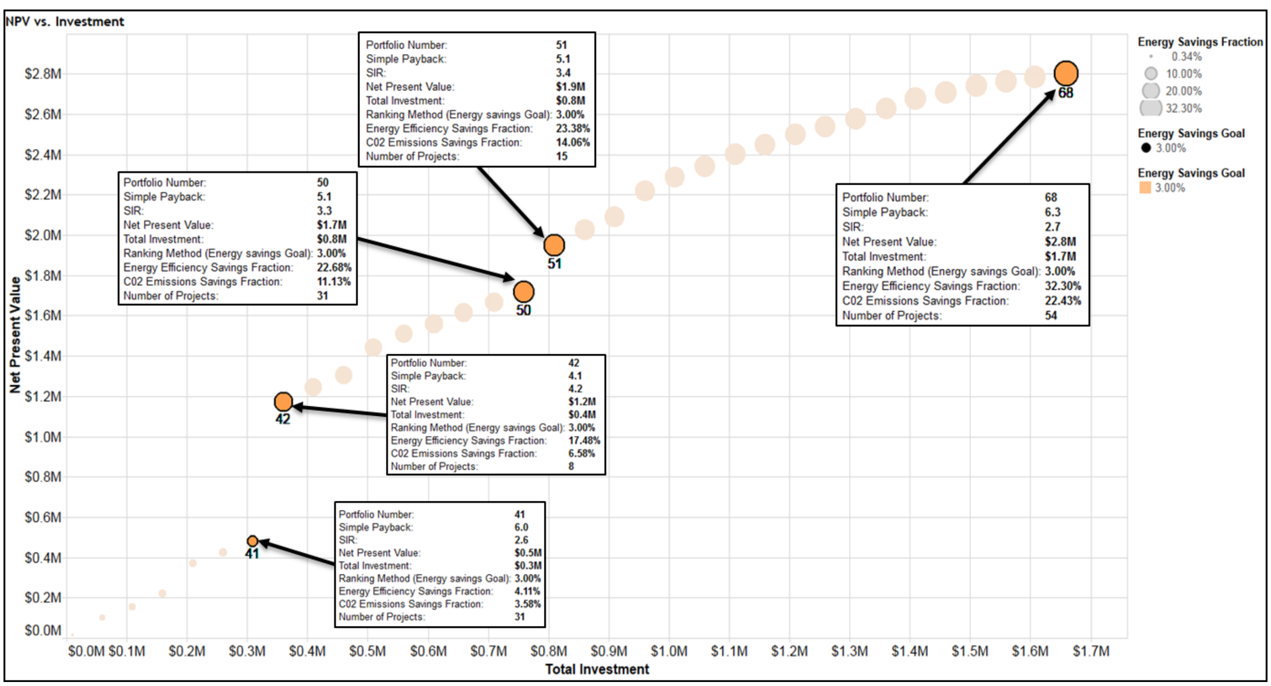


Figure 33. Portfolio Optimization Analysis: NPV vs. Investment, Non-normalized, 20-year Project Life

Figure 34 shows a portfolio comparison, indicating project differences for the selected portfolios. Important metrics, such as Investment, SIR, and NPV are shown. This chart format enables seeing the detail portfolio construction, and how it evolves with increased investment.

Project Inclusion

Project	Project Type	Investment	SIR	Net Present Value ..	Portfolio Number 41	42	50	51	68
B7428 Sun Shelter[Lights Proje..	Lights	$0.6K	1.6	$0.4K	■	■	■	■	■
B7431 Office[Heating Project]	Heating	$3.7K	3.7	$10.1K	■	■	■	■	■
B7513[Heating Project]	Heating	$0.2K	4.2	$0.6K	■	■	■	■	■
B7513[Wall Project]	Wall	$7.2K	2.9	$14.0K	■	■	■	■	■
B7328 Office[Micro Turbine Proj..	Micro Turbine	$337.5K	4.3	$1,123.0K		■	■	■	■
B7391 Inspection[Lights Project..	Lights	$0.6K	1.6	$0.4K	■		■	■	■
B7391 Office[Lights Project]	Lights	$0.4K	1.4	$0.2K	■		■	■	■
B7408 Hangar[Lights Project Ex..	Lights	$0.4K	1.4	$0.1K	■		■	■	■
B7439[Lights Project Exit Light]	Lights	$0.4K	1.4	$0.2K	■		■	■	■
B7507[Wall Project]	Wall	$5.8K	2.5	$8.7K	■	■	■		■
B7514[Heating Project]	Heating	$0.2K	2.6	$0.3K	■		■	■	■
B7328 Office[SuperTherm Proje..	SuperTherm	$122.7K	2.8	$226.5K	■		■		■
B7328 Warehouse[Lights Projec..	Lights	$0.4K	1.4	$0.1K	■		■		■
B7408 Hangar[Heating Project]	Heating	$24.3K	2.6	$39.0K	■		■		■
B7408 Office[SuperTherm Proje..	SuperTherm	$67.5K	2.1	$73.9K	■		■		■
B7428 Portable Building[Lights ..	Lights	$0.9K	1.7	$0.7K	■		■		■
B7431 Office[Lights Project Exit..	Lights	$0.4K	1.4	$0.1K	■		■		■
B7431 Shop[Lights Project Exit ..	Lights	$0.6K	1.6	$0.4K	■		■		■
B7439[Heating Project]	Heating	$7.5K	2.6	$11.7K	■		■		■
B7439[SuperTherm Project]	SuperTherm	$29.1K	2.3	$36.9K	■		■		■
B7441 Office[Lights Project Exit..	Lights	$0.4K	1.4	$0.1K	■		■		■
B7506 Hangar[Lights Project Ex..	Lights	$0.6K	1.6	$0.4K	■		■		■
B7507[SuperTherm Project]	SuperTherm	$15.7K	2.2	$18.3K	■		■		■
B7514[Wall Project]	Wall	$7.2K	2.6	$11.7K	■		■		■
B7328 Office[Lights Project Exit..	Lights	$1.7K	1.8	$1.4K	■				■
B7408 Hangar[Wall Project]	Wall	$33.2K	2.0	$33.6K			■		■
B7408 Office[Lights Project Exit..	Lights	$0.9K	1.7	$0.6K	■				■
B7408 Office[Wall Project]	Wall	$3.9K	2.0	$3.9K	■				■
B7428 Sun Shelter[Lights Proje..	Lights	$453.2K	2.7	$784.5K				■	■
B7431 Shop[Lights Project]	Lights	$11.7K	2.0	$11.4K			■		■
B7506 Hangar[Lights Project LE..	Lights	$75.3K	2.0	$75.1K			■		■
B7328 Warehouse[Lights Projec..	Lights	$12.0K	1.5	$5.7K					■
B7391 Inspection[Lights Project]	Lights	$28.8K	1.6	$17.9K					■
B7391 Office[SuperTherm Proje..	SuperTherm	$178.8K	1.9	$157.3K					■
B7391 Office[Window Project]	Window	$7.5K	1.2	$1.5K					■
B7408 Office[Window Project]	Window	$13.6K	1.3	$3.9K					■
B7439[Wall Project]	Wall	$8.8K	1.3	$2.3K					■
B7439[Window Project]	Window	$36.9K	1.6	$22.4K					■
B7441 Office[Wall Project]	Wall	$1.1K	1.1	$0.1K					■
B7441 Office[Window Project]	Window	$3.6K	1.3	$1.0K					■
B7507[Roof Project]	Roof	$17.4K	1.4	$6.6K					■
B7507[Window Project]	Window	$11.6K	1.7	$7.6K					■
B7513[Floor Project]	Floor	$5.0K	1.3	$1.3K					■
B7513[Lights Project Exit Light]	Lights	$0.9K	1.7	$0.6K					■
B7513[Window Project]	Window	$25.6K	1.7	$17.3K					■
B7514[Lights Project Exit Light]	Lights	$0.9K	1.7	$0.6K					■
B7514[Window Project]	Window	$25.6K	1.5	$12.8K					■

Portfolio Number: 41, 42, 50, 51, 68

Figure 34. Portfolio Optimization Analysis: Portfolio Comparison

Figure 35 is a portfolio comparison Sparkline chart, which highlights multiple key metrics, in a graphical way, for each of the optimal portfolios. The marginal differences among these metrics can be observed as investment is increased.

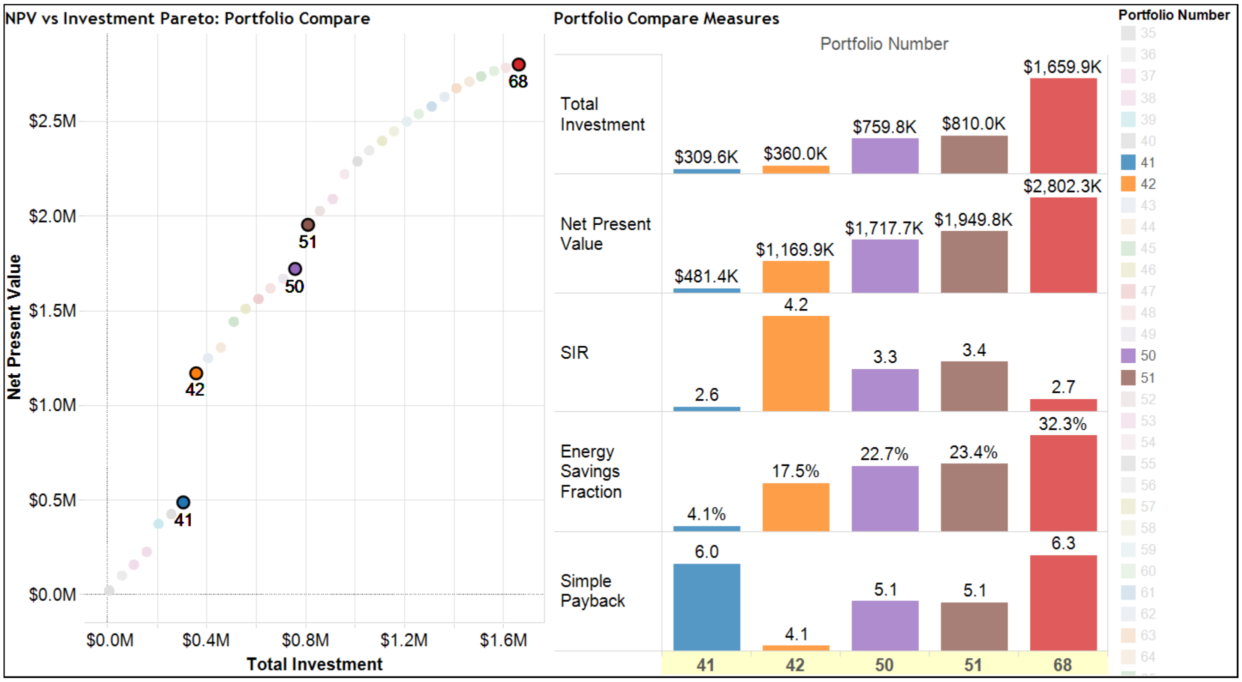
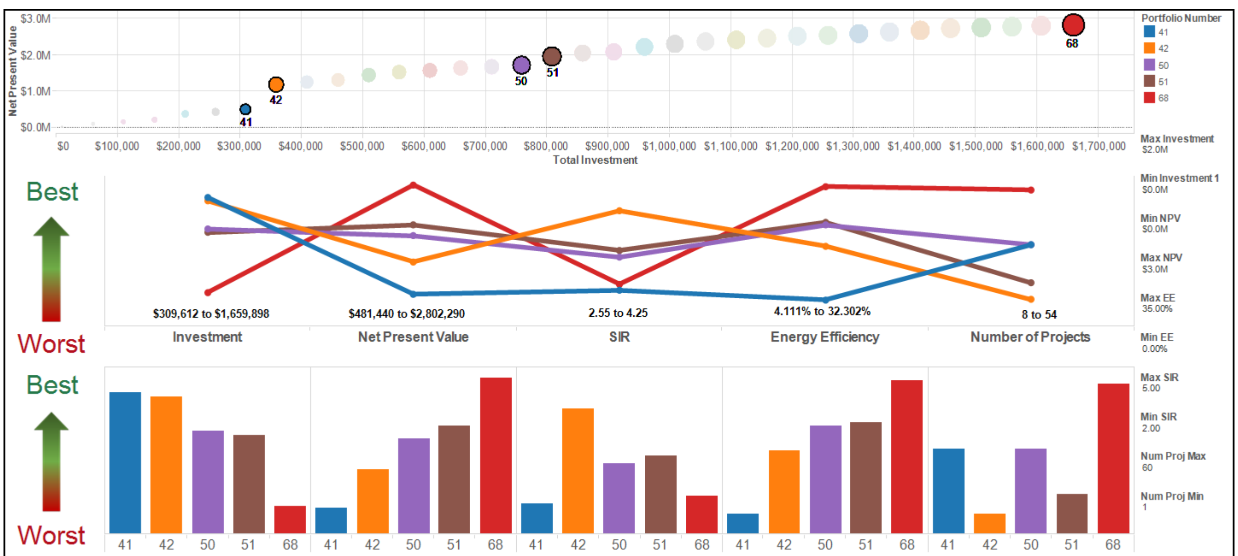


Figure 35. Portfolio Optimization Analysis: Portfolio Comparison Sparkline

Figure 36 was a popular reference dashboard for decision makers during the ECIP FY17 decision cycle. It has some similarities to the Sparkline dashboard above, but offers portfolio comparisons in several visual formats. Line and bar charts, and tabular results are all simultaneously offered in one dashboard for easy comparison.



	Investment	NPV	SIR	EE	Number of Projects
41	$309,612	$481,440	2.55	4.11%	31
42	$360,003	$1,169,939	4.25	17.48%	8
50	$759,799	$1,717,665	3.26	22.68%	31
51	$809,975	$1,949,767	3.41	23.38%	15
68	$1,659,898	$2,802,290	2.69	32.30%	54

Figure 36. Portfolio Optimization Analysis: Portfolio Comparison Spider

Figure 37 is a portfolio project location dashboard, which highlights the building locations for each of the projects included in the chosen portfolio. The project type (e.g. heating, lights, etc.) is also indicated with color, and the project's NPV contribution is indicated by size in the treemap (lower portion of the dashboard).

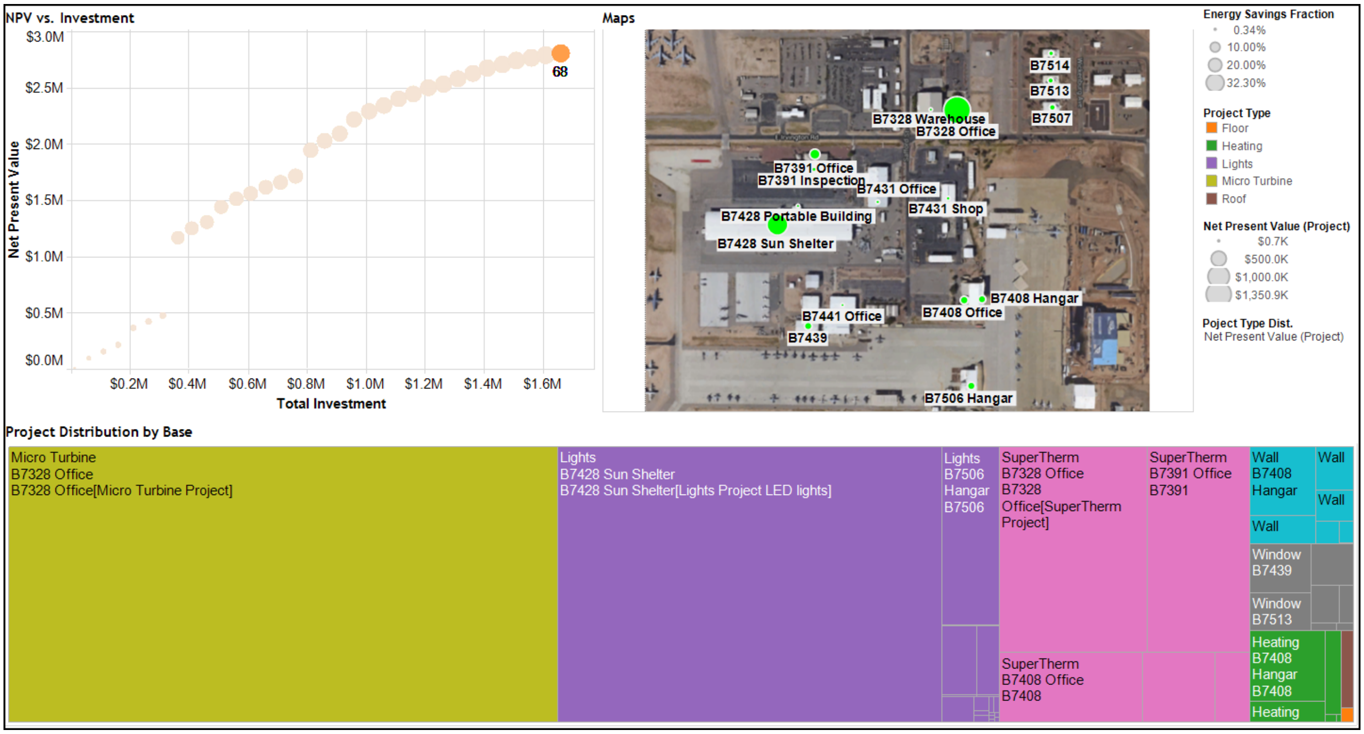


Figure 37. Portfolio Optimization Analysis: Portfolio Selected Project Location

6.4 AIR FORCE CIVIL ENGINEERING CENTER (AFCEC) – ENERGY DIRECTORATE DEMONSTRATION SITE

Through our Luke AFB contacts, the ESAT team pursued adding the AFCEC site to our analysis to validate scalability and the potential for maximum benefit at all organizational levels (site level – Luke/Davis-Monthan, service level – USAF/AFCEC, and DoD level - OSD/ECIP). The demonstration with AFCEC was initiated in March, 2014 after an initial discussion with Steve McLellan regarding both the technology and the ESTCP project. AFCEC provided FY14 data for an initial comparison of ESAT technology with their current portfolio optimization process to determine any potential benefits. Preliminary analysis demonstrated a 9-25% NPV improvement (variable based on investment level) relative to the rank order approach currently used by AFCEC.

Following the initial demonstration in March, we received FY15 data in September 2014 to further demonstrate and refine the AFCEC model in preparation for the July 2016 budget cycle. Another comparison of the ESAT technology with the Rank order Savings to Investment Ratio (SIR) method for project prioritization was ran to verify again the benefit and to help mature the process by modifying the optimization model, visualization suite, and making suggested input data improvements. The result of this second round of analysis was presented to Steve McClellan in December of 2014.

Eight analysis iterations were conducted, demonstrating an NPV improvement of up to 31% on a $19.2M budget using the ESAT technology in lieu of SIR rank order-based portfolio construction methods. We planned to apply ESAT analysis to provide decision support for FY16 project portfolio selection. However, due to constraints at AFCEC, we ended up performing portfolio analysis on FY16 data after the portfolio decisions have already been made. The following sections detail the FY15 and FY16 analyses.

6.4.1 FY15 Decision Cycle Analysis

6.4.1.1 Analysis Purpose

The analysis of FY15 project data was meant to demonstrate and further refine the ESAT AFCEC model following the initial demonstration with FY14 data in March 2015, with a goal to prepare for the 2016 budgeting cycle.

6.4.1.2 Data Collection & Analysis Assumptions

Energy project data was obtained by Steve McLellan for the FY15 decision cycle analysis. Initially, a review of data was performed to identify any issues that needed to be addressed, following which the ground rules that will be used in the analysis were established. Figure 38 shows these ground rules and assumptions for the decision analysis.

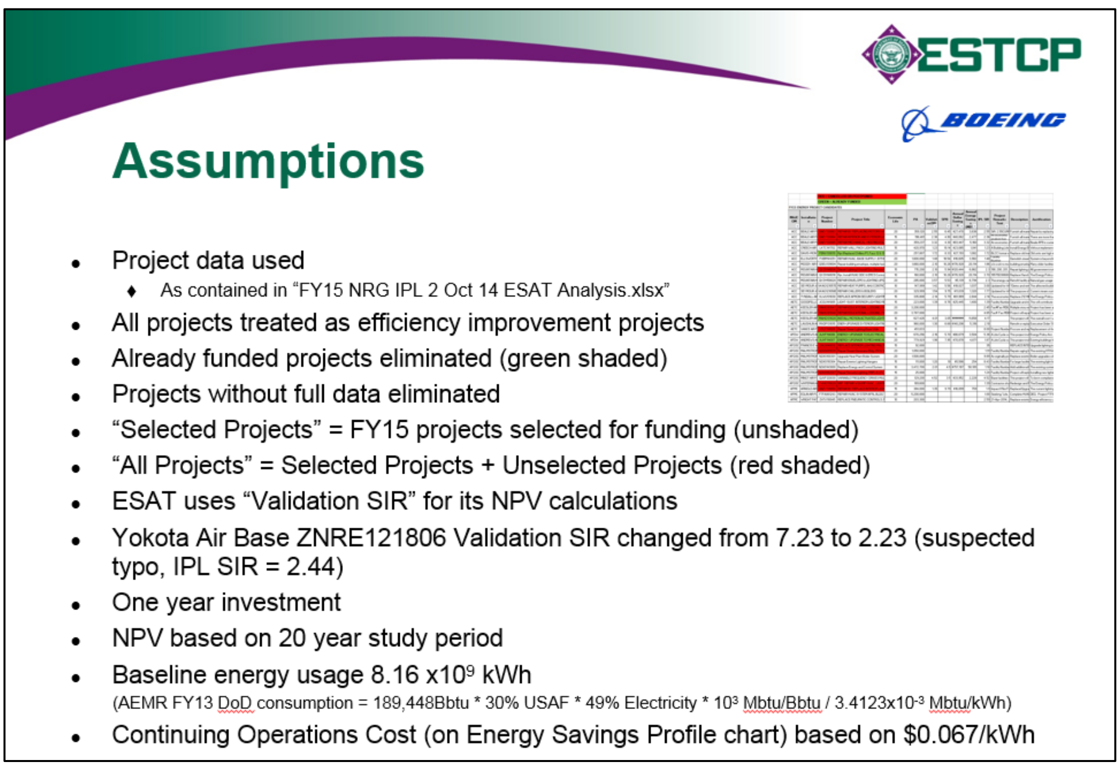


Figure 38. Ground Rules and Assumptions for FY15 AFCEC Analysis.

Additionally, only projects that had energy savings data available were considered. Energy rate information was not available to be used in the analysis; therefore, average costs were used.

The NPV used in the analysis is based on 20 year study period. As some of the projects had economic lives that were different from 20 years, there are two approaches as to how they are treated. One approach is to assume reinvestment and residual values to normalize the NPV calculations to the 20 year study period, and the other approach is to not use reinvestment and residual life in NPV calculations. FY15 analysis was performed using both approaches. The choice as to which is appropriate depends on project types and decision maker preference. Further, there were two values for SIR for each project that were provided in the data – one that was submitted (IPL SIR) and used in the initial project selections done at AFCEC, but another that was a based on AFCEC validation calculations. In comparing ESAT analysis to rank order analysis, we used two different rank order metrics, namely the IPL SIR and the validated SIR. Analysis was also performed separately for two different situations – one considering all the submitted projects with available data, and one considering only the projects that were already selected. Figure 39 lists the complete set of cases which were analyzed using ESAT.

ESTCP

BOEING

Analysis Cases Run

Primary:

Projects	Economic Life	Rank Order Metric
All	Normalized	IPL SIR

Secondary:

Projects	Economic Life	Rank Order Metric
All	Normalized	Validated SIR
All	Specified	IPL SIR
All	Specified	Validated SIR
Selected	Normalized	IPL SIR
Selected	Normalized	Validated SIR
Selected	Specified	IPL SIR
Selected	Specified	Validated SIR

8

Figure 39. Trade-off Study Summary Table Indicating Different Analysis Cases Explored.

6.4.1.3 Analysis Results

Summary results for FY15 highlighting improvement (in terms of NPV) of the ESAT approach over the rank order approach are shown in Figure 40.

In this analysis, no special consideration was given to energy savings or renewable energy goals. As expected, there was minimal improvement relative to the rank order approach when the rank order metric was the validated SIR. The improvement relative to the IPL SIR is due to the fact that IPL SIR is an imperfect metric. This comparison is made to illustrate this disadvantage.

If energy savings, renewable energy, and emission requirements are important, for example, using a validated SIR also would result in sub-optimal portfolios relative to ESAT approach, as even a validated SIR would be an imperfect metric because it only captures economic impact and not the other goals.

Unless otherwise noted, the charts that follow are based on the primary analysis run identified in Figure 39. The major assumptions underlying the analysis results presented are identified on the chart. Figure 41 shows the primary analysis results from ESAT analysis along with the comparison to rank order approach. This figure shows the tradeoff between investment and NPV. The green dots are ESAT generated portfolios, whereas the orange triangles are rank order portfolios. Note that an ESAT generated portfolio, at any given investment level, is the optimal portfolio with respect to the objectives under consideration.

Analysis Summary Results

- ESAT NPV compared to rank order method

Projects	Economic Life	Rank Order Metric	NPV Improvement near $19.2M	NPV Improvement (%)
All	Normalized	IPL SIR	$4.9M	22.3%
All	Normalized	Validated SIR	$0.4M	1.5%
All	Specified	IPL SIR	$2.3M	11.9%
All	Specified	Validated SIR	$0.0M	0.0%

Projects	Economic Life	Rank Order Metric	NPV Improvement Max Difference	NPV Improvement (%)
Selected	Normalized	IPL SIR	$4.8M	30.8%
Selected	Normalized	Validated SIR	$1.7M	13.8%
Selected	Specified	IPL SIR	$2.3M	15.8%
Selected	Specified	Validated SIR	$0.0M	0.0%

- Significant NPV improvement possible compared to Rank Order use of IPL SIR
- Minor to no NPV improvement compared to Rank Order use of Validation SIR (due to singular objective), but additional portfolio mix options available

Figure 40. Summary Results of Trade-off Studies Indicating Benefits (in terms of NPV improvement) of ESAT Technology Over Rank-order Methods.

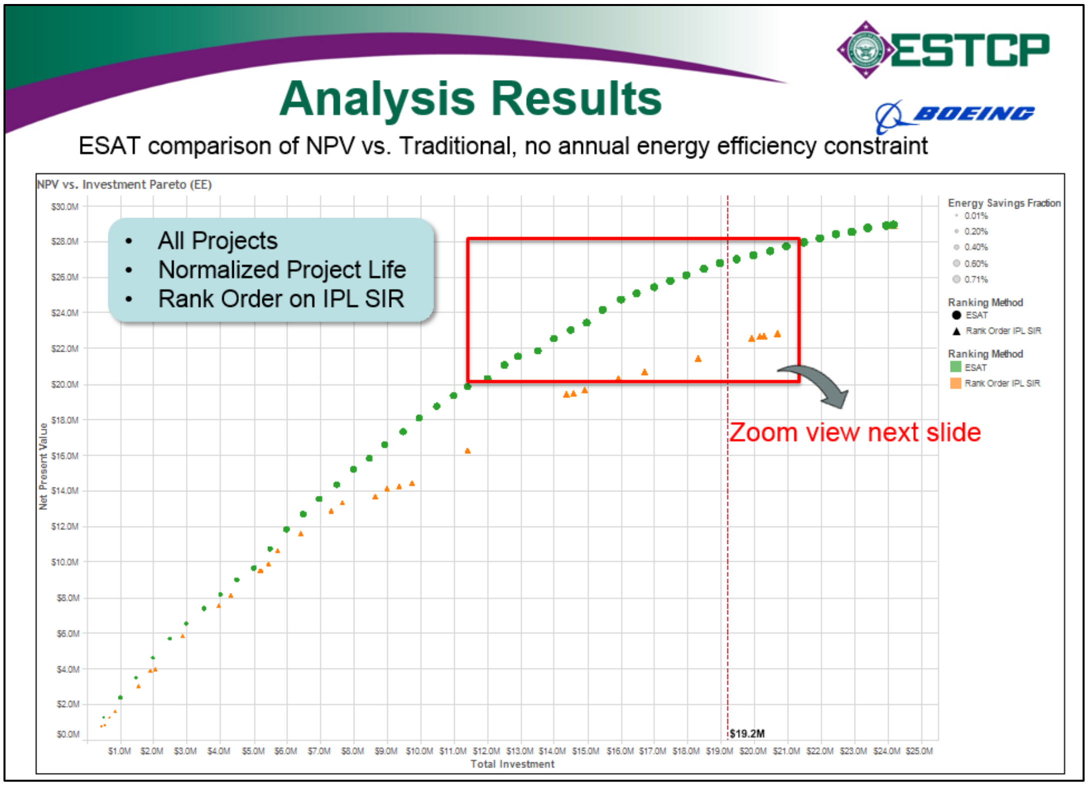


Figure 41. Portfolio Comparison Between ESAT Technology and SIR Rank Order Approach Shows the Tradeoff Between NPV and Investment.

There are two major advantages to the ESAT method over Rank Order IPL SIR. The first advantage is the improvement in NPV that can be seen in Figure 41. Figure 42 highlights this more clearly. The inset in this chart is from Figure 41, whereas the main chart here is the magnified version of the portion highlighted by the red rectangle in the inset. The red dotted line shows the investment that was considered for allocation to the projects during this decision analysis. For the selected investment, it is clear that the ESAT produces a portfolio that is superior by an NPV improvement of $4.9M. Alternatively, one can achieve with ESAT the same NPV as the rank order approach by investing $5.7M less than the rank order approach. ESAT achieves this improvement by judiciously searching all possible combinations of projects to select the optimal portfolio of projects.

As can be seen from Figure 41, the second advantage is that ESAT can generate optimal portfolios for selected interim investment levels, whereas the rank order approach cannot guarantee a portfolio that uses substantially all of any specified investment (notice the investment gaps between the portfolios using the rank order approach). This same advantage is highlighted in Figure 43, which shows the NPV vs. investment tradeoff for ESAT and rank order approach, when no reinvestment and residual value are considered in NPV calculations.

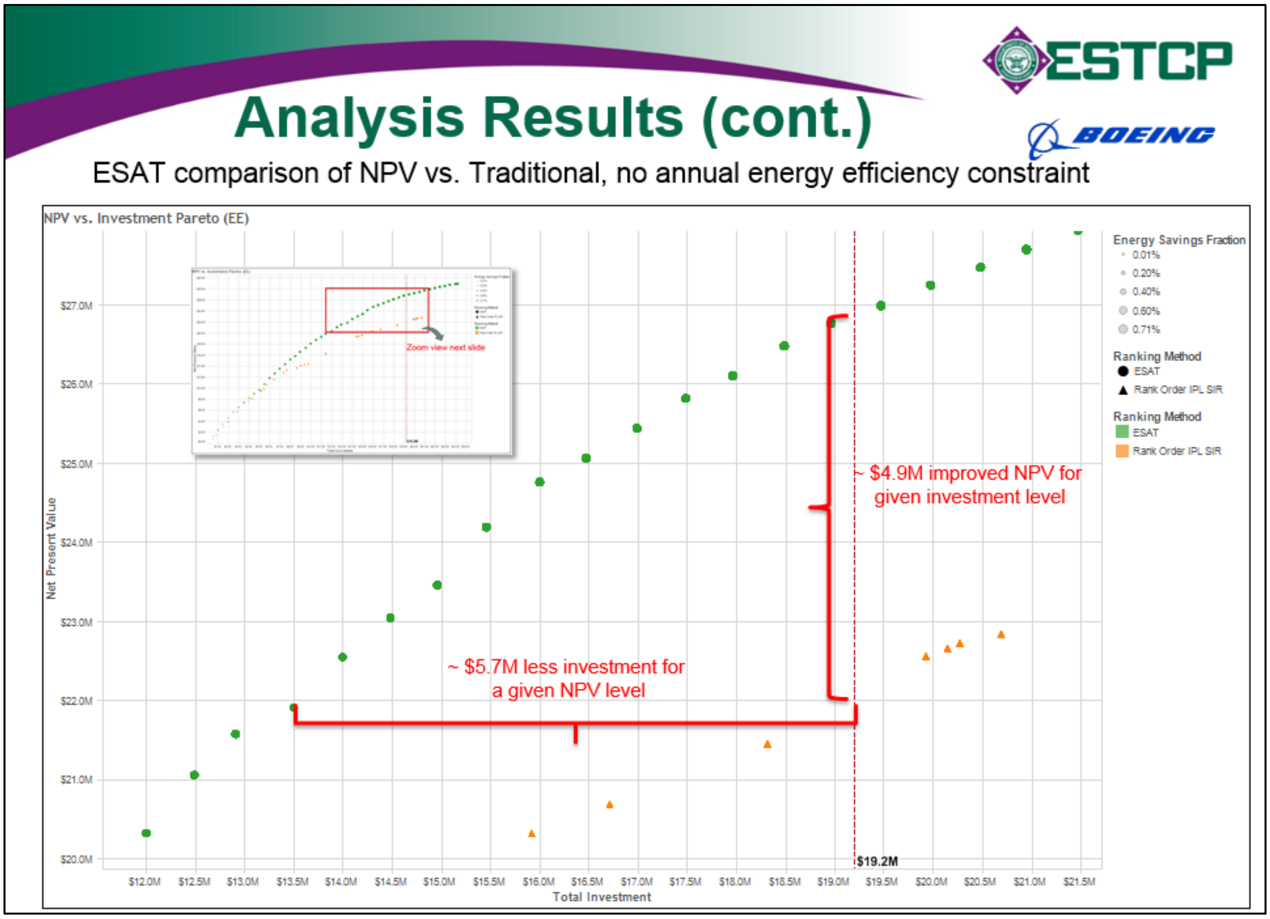


Figure 42. Portfolio Comparison Between ESAT Technology and Rank-order Approach, Showing the Pareto Tradeoff between NPV and Investment.

The inset in this chart is from Figure 41, whereas the main chart here is the magnified version of the portion highlighted by the red rectangle in the inset.

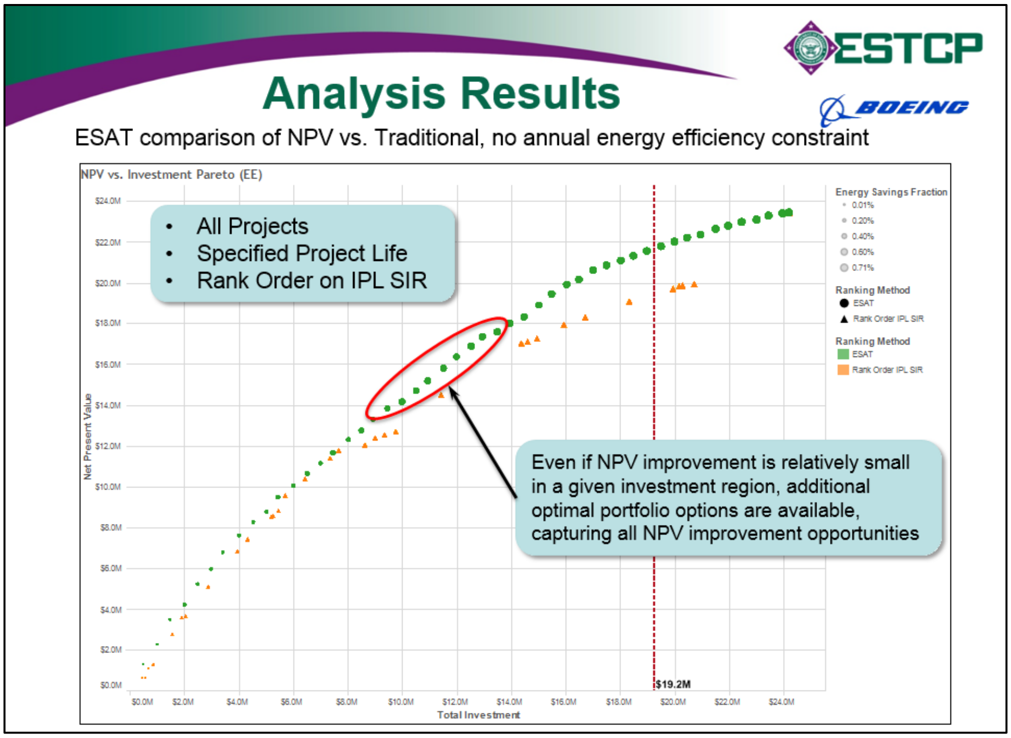


Figure 43. Portfolio Comparison Between ESAT Technology and Rank-order Approach, Showing the Pareto Tradeoff Between NPV and Investment.

The highlighted region shows the benefit of ESAT in producing portfolios for all investment levels, whereas the rank order approach may leave some money unallocated at certain investment levels.

The analysis results in Figure 41 and Figure 43 are based on maximizing NPV without the constraint of goals, for example percentage of annual energy savings improvements required. Figure 44 shows the analysis results when explicit energy savings improvement goals are considered during the optimization run. Each curve represents an incremental investment level, and demonstrates a tradeoff between NPV and energy savings fraction. The points on the curves are the Pareto optimal portfolios. For any given investment level, the decision maker can make an appropriate choice of an optimal portfolio taking into consideration all the explicit and implicit constraints. The NPV vs. energy savings tradeoff is clearer in the analysis done with FY14 energy projects, as there were a larger number of projects to consider for portfolio selection (see Figure 45). Decision makers frequently look for the proverbial “knee-in-the-curve” to make optimal, informed decisions. It is clear from Figure 45 that at any given investment level, there is an energy efficiency goal beyond which there is a sharper drop-off of NPV.

Further drilldown of a selected portfolio is provided by ESAT through different views. Figure 46 shows the portfolio project composition and distribution among major commands and their constituent installations, in terms of investment, number of projects, and/or NPV. Additional metrics at the service/agency and installation levels are computed and made available through hover-over documentation. Figure 47 shows the portfolio project composition and geographic distribution among the different states and countries. Once again, both investment and NPV are used to size the pie and tree map segments, and additional metrics at the major command and installation levels are computed and made available through hover-over documentation.

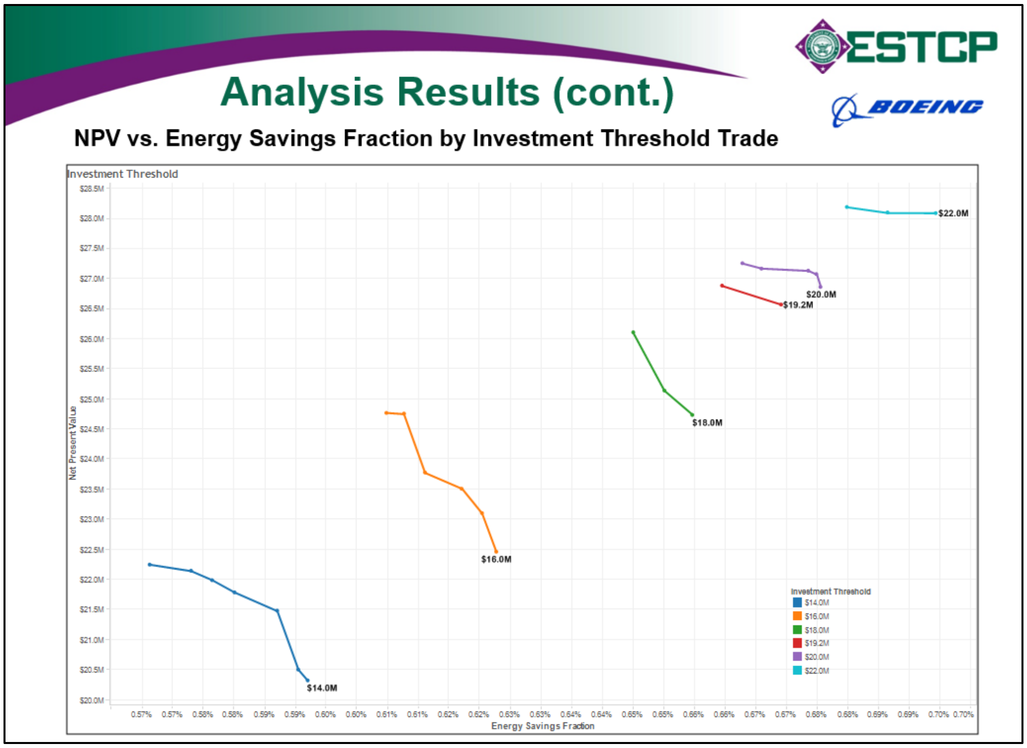


Figure 44. NPV vs. Energy Savings Fraction Trade-off Study at Multiple Investment Levels Helps the Decision Maker to Make an Appropriate Choice of an Optimal Portfolio Taking into Consideration all the Explicit and Implicit Constraints.

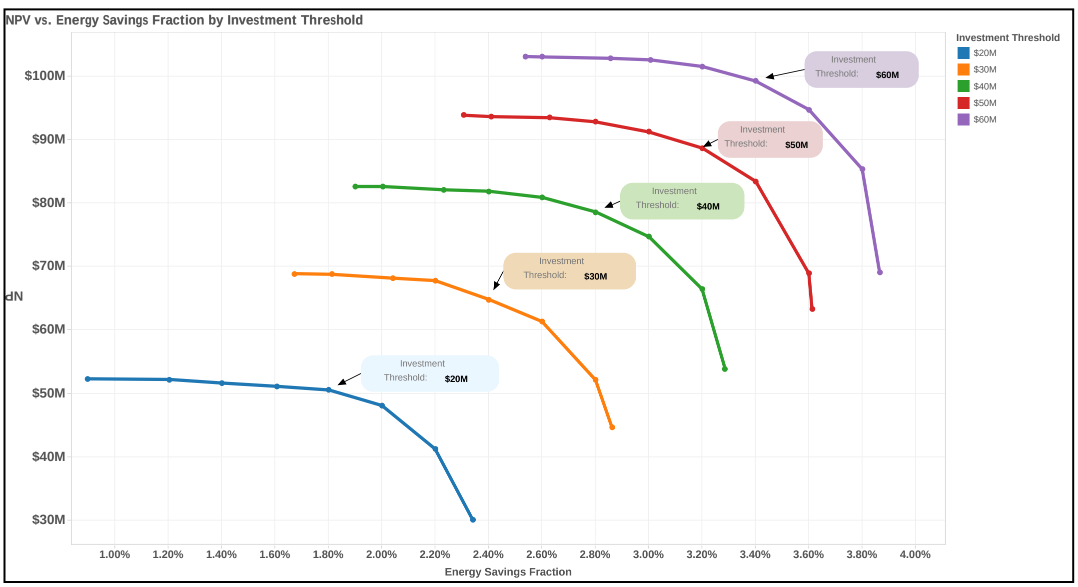


Figure 45. The Tradeoff Relationship Between NPV and Energy Savings Fraction for Different Investment Levels is Clearer in FY14 Data, Because of Larger Number of Projects Considered.

Decision makers frequently look for the proverbial "knee-in-the-curve" to make optimal, informed decisions.

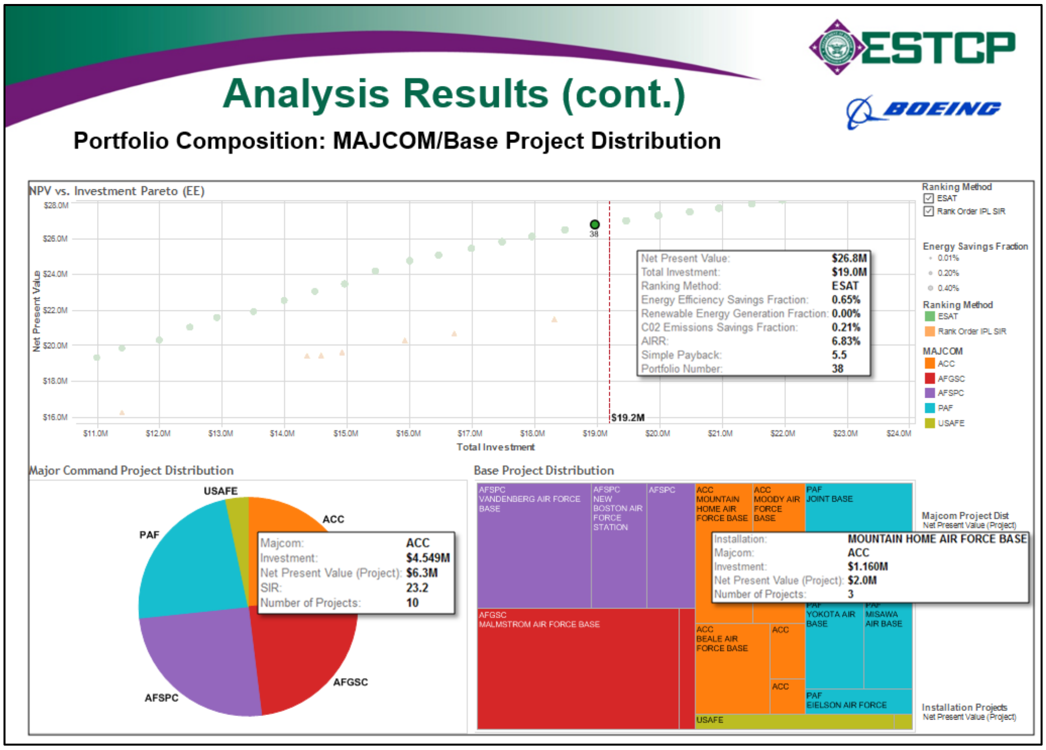


Figure 46. Portfolio Project Composition Distribution Among Major Commands and Installations, Filtered by Portfolio Choice.

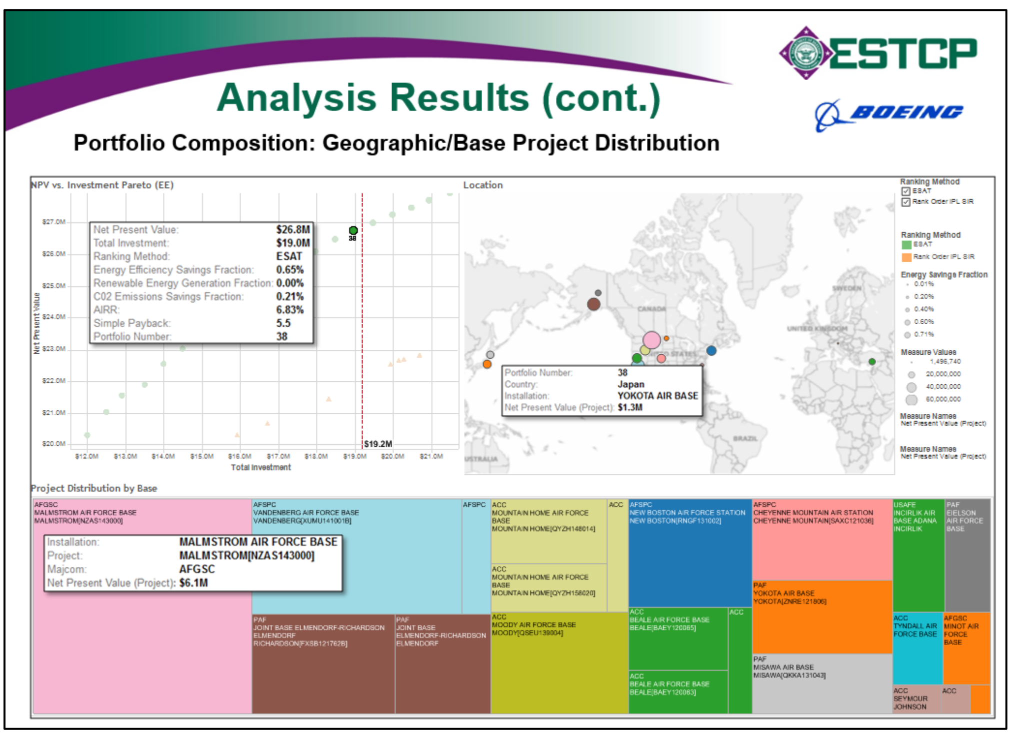


Figure 47. Portfolio Project Composition and Geographic Distribution Among Installations, Filtered by Portfolio Choice.

ESAT also provides several portfolio comparison views. Figure 48 shows one such view that lets the decision maker compare alternative portfolios in terms of several portfolio comparison measures. In this instance, eight different portfolios are being compared with respect to investment, NPV, SIR, energy savings fraction, and simple payback. The decision maker can use this view to compare the portfolios from multiple criteria simultaneously, in order to narrow down the exploration for a desired portfolio.

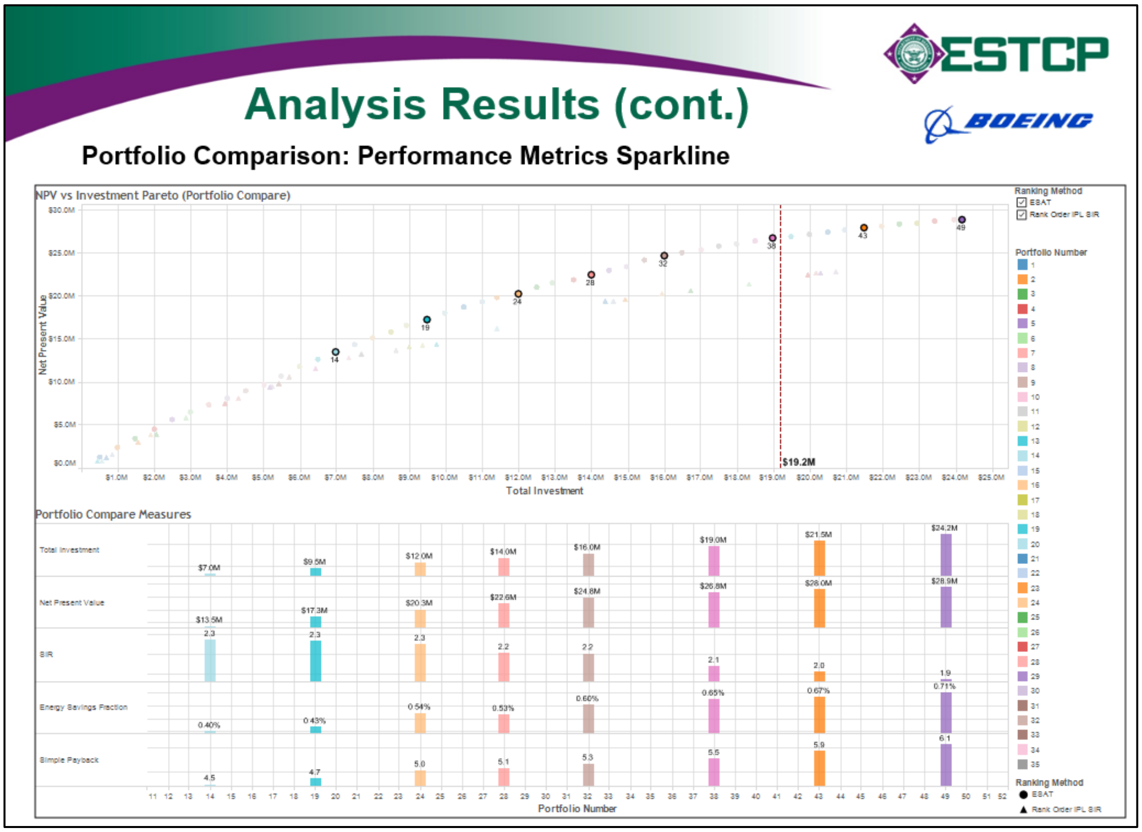


Figure 48. Sparkline Graph Showing Multiple Portfolios Compared Across Several Performance Metrics.

The next two views provide the decision maker the ability to drill down, by major command, and review how well the sub-portfolios perform relative to each other. Figure 49 shows how the sub-portfolios compare with respect to SIR and simple payback. Figure 50 shows how the sub-portfolios, for each major command, compare with respect to the present values of investment and savings, as well as NPV.

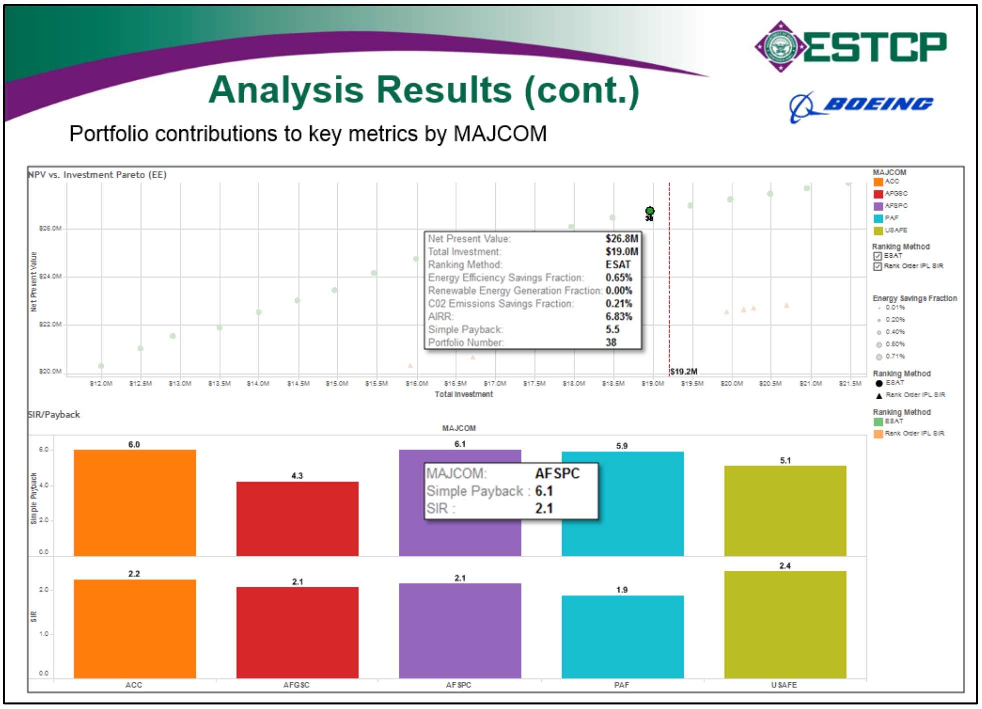


Figure 49. Major Command Specific Contribution to Selected Portfolio Performance Metrics.

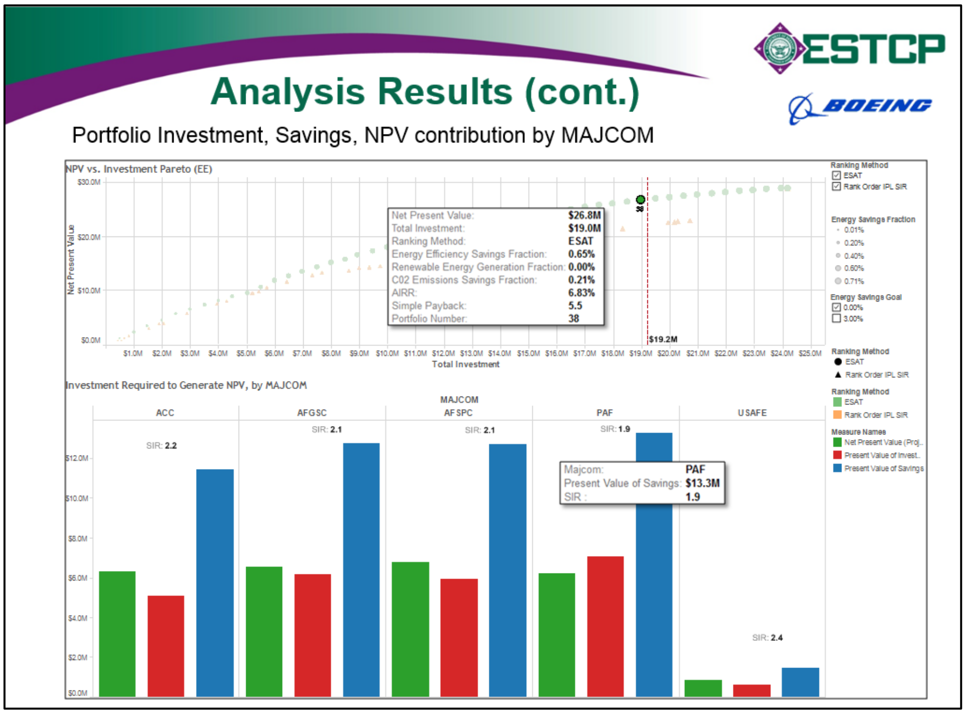
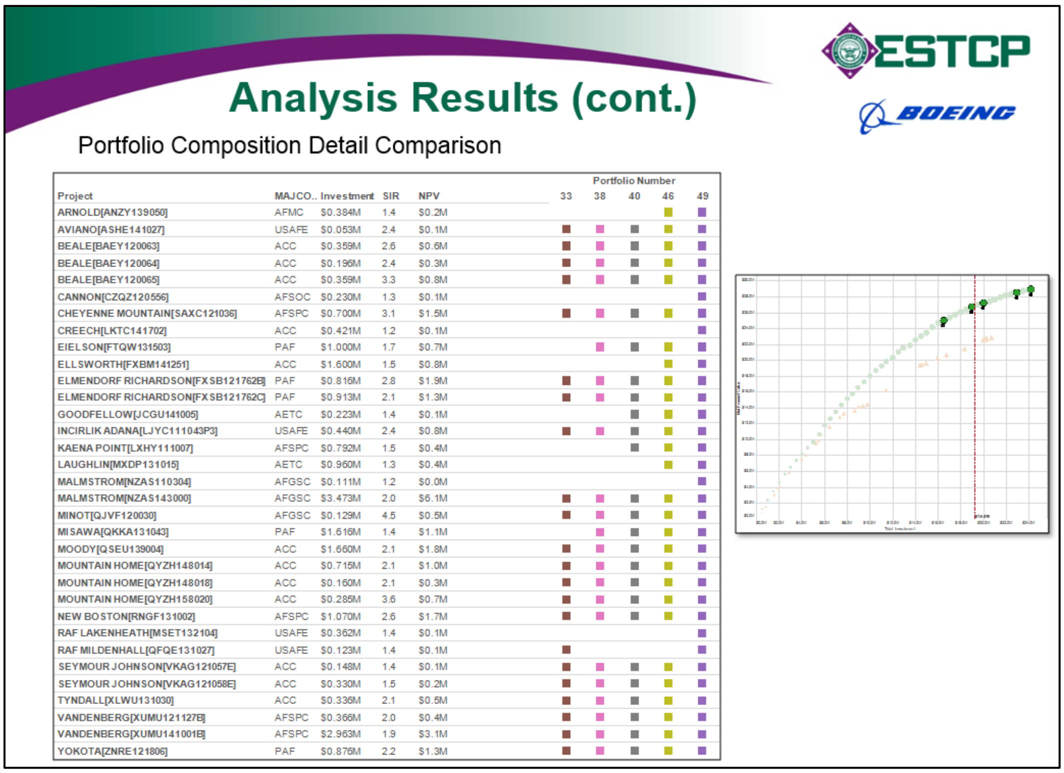


Figure 50. NPV, Present Value of Investment, and Present Value of Savings by Major Command, Filtered by Selected Portfolio.

The decision maker can also easily review all the projects that are included in one or more selected portfolios. Figure 51 shows the projects contained in five different selected portfolios. For each of the projects in the portfolio, this view also shows:

- Major command of the installation submitting the project
- Investment required
- Savings to investment ratio (SIR)
- 20-year net present value (NPV)

The metrics shown in Figure 51 are project level metrics, in contrast to the portfolio level metrics shown in Figure 48. The inset in Figure 51 shows the selected portfolios on the investment vs. NPV Pareto.



Project	MAJCO..	Investment	SIR	NPV	Portfolio Number 33	38	40	46	49
ARNOLD[ANZY139050]	AFMC	$0.384M	1.4	$0.2M				■	■
AVIANO[ASHE141027]	USAFE	$0.053M	2.4	$0.1M	■	■	■	■	■
BEALE[BAEY120063]	ACC	$0.359M	2.6	$0.6M	■	■	■	■	■
BEALE[BAEY120064]	ACC	$0.196M	2.4	$0.3M	■	■	■	■	■
BEALE[BAEY120065]	ACC	$0.359M	3.3	$0.8M	■	■	■	■	■
CANNON[CZQZ120556]	AFSOC	$0.230M	1.3	$0.1M					■
CHEYENNE MOUNTAIN[SAXC121036]	AFSPC	$0.700M	3.1	$1.5M	■	■	■	■	■
CREECH[LKTC141702]	ACC	$0.421M	1.2	$0.1M					■
EIELSON[FTQW131503]	PAF	$1.000M	1.7	$0.7M		■	■	■	■
ELLSWORTH[FXBM141251]	ACC	$1.600M	1.5	$0.8M				■	■
ELMENDORF RICHARDSON[FXSB121762B]	PAF	$0.816M	2.8	$1.9M	■	■	■	■	■
ELMENDORF RICHARDSON[FXSB121762C]	PAF	$0.913M	2.1	$1.3M	■	■	■	■	■
GOODFELLOW[JCGU141005]	AETC	$0.223M	1.4	$0.1M			■	■	■
INCIRLIK ADANA[LJYC111043P3]	USAFE	$0.440M	2.4	$0.8M	■	■	■	■	■
KAENA POINT[LXHY111007]	AFSPC	$0.792M	1.5	$0.4M			■	■	■
LAUGHLIN[MXDP131015]	AETC	$0.960M	1.3	$0.4M				■	■
MALMSTROM[NZAS110304]	AFGSC	$0.111M	1.2	$0.0M					■
MALMSTROM[NZAS143000]	AFGSC	$3.473M	2.0	$6.1M	■	■	■	■	■
MINOT[QJVF120030]	AFGSC	$0.129M	4.5	$0.5M	■	■	■	■	■
MISAWA[QKKA131043]	PAF	$1.616M	1.4	$1.1M		■	■	■	■
MOODY[QSEU139004]	ACC	$1.660M	2.1	$1.8M	■	■	■	■	■
MOUNTAIN HOME[QYZH148014]	ACC	$0.715M	2.1	$1.0M	■	■	■	■	■
MOUNTAIN HOME[QYZH148018]	ACC	$0.160M	2.1	$0.3M	■	■	■	■	■
MOUNTAIN HOME[QYZH158020]	ACC	$0.285M	3.6	$0.7M	■	■	■	■	■
NEW BOSTON[RNGF131002]	AFSPC	$1.070M	2.6	$1.7M	■	■	■	■	■
RAF LAKENHEATH[MSET132104]	USAFE	$0.362M	1.4	$0.1M					■
RAF MILDENHALL[QFQE131027]	USAFE	$0.123M	1.4	$0.1M	■				■
SEYMOUR JOHNSON[VKAG121057E]	ACC	$0.148M	1.4	$0.1M	■	■	■	■	■
SEYMOUR JOHNSON[VKAG121058E]	ACC	$0.330M	1.5	$0.2M	■	■	■	■	■
TYNDALL[XLWU131030]	ACC	$0.336M	2.1	$0.5M	■	■	■	■	■
VANDENBERG[XUMU121127B]	AFSPC	$0.366M	2.0	$0.4M	■	■	■	■	■
VANDENBERG[XUMU141001B]	AFSPC	$2.963M	1.9	$3.1M	■	■	■	■	■
YOKOTA[ZNRE121806]	PAF	$0.876M	2.2	$1.3M	■	■	■	■	■

Figure 51. Portfolio Comparison: Projects Included in Each Portfolio with Key Metrics Shown.

Figure 52 shows the energy savings profile for a selected portfolio. It shows different annual cash flow components, namely, upfront investment, savings, investment from annual savings, continuing operations costs, and reserves set aside to compensate for upfront investment. These annual cash flows are shown as stacked bars over the 20-year study period. Figure 52 shows the analysis results based on reinvestment and residual values (normalized life approach). This is evident by the reinvestment required (in years 11 and 16) in those projects that have economic lives shorter than the study period. Figure 53 provides an alternative view by plotting the cumulative cash flows relative to the baseline expenditure.

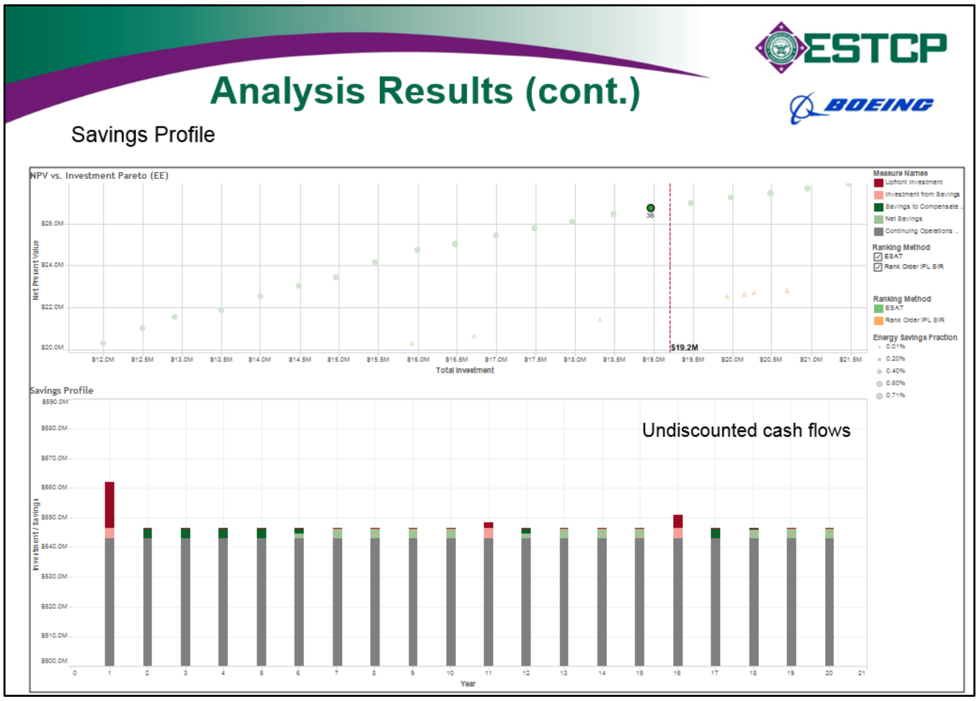


Figure 52. Energy Savings Profile Showing Annual Cash Flows, Including Investment, Savings, and Continuing Operations Cost for Selected Portfolio (stacked bars).

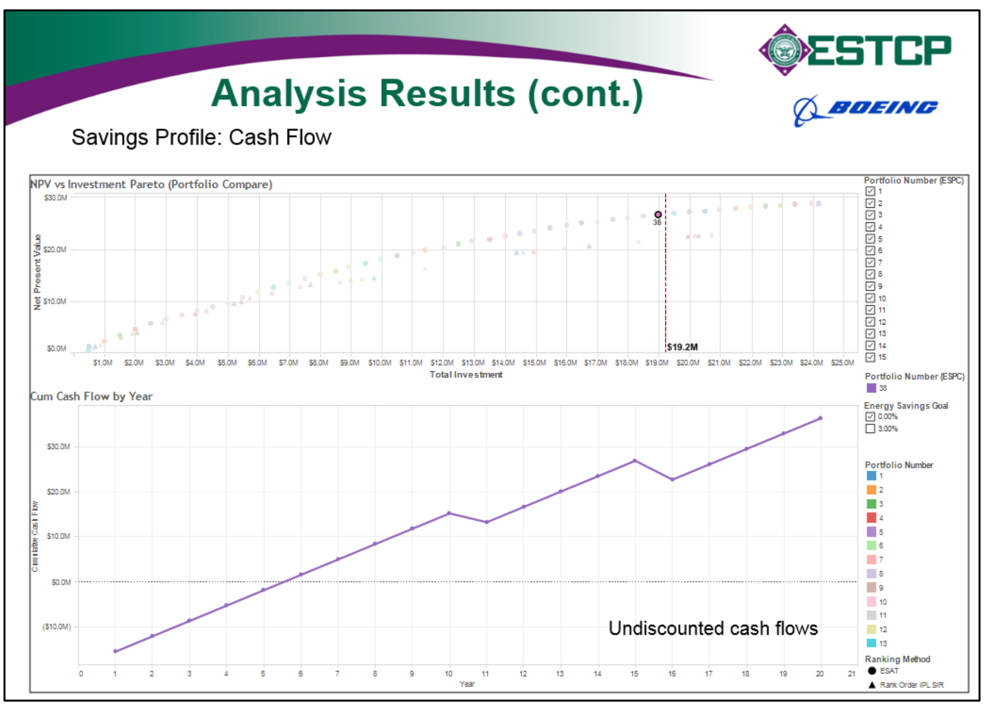


Figure 53. Energy Savings Profile Showing Annual Cash Flows, Including Investment, Savings, and Continuing Operations Cost for Selected Portfolio (cumulative).

ESAT is very flexible in providing the decision maker multiple views of the analysis results. Figure 54 depicts a single dashboard from ESAT that shows the same set of Pareto-optimal portfolios from three different perspectives – investment vs. NPV, investment vs. energy savings fraction, and investment vs. SIR. Portfolios for both ESAT technology and rank order approach are compared in this dashboard. This view is useful when trying to understand counterintuitive behavior in one of the views. In this specific dashboard view, the results appear mostly as expected. Some further investigation might be warranted in two instances: (1) In the middle graph (Energy Savings Fraction vs. Total Investment), notice the dips in energy savings fraction when investment increases (e.g. from $13.0M to $13.5M); (2) In the lower graph (SIR vs. Total Investment), notice the inverse behavior at lower investment levels (e.g. <$2.0M). These are two examples where drilling down into the underlying data further would help explain why the results present as they do.

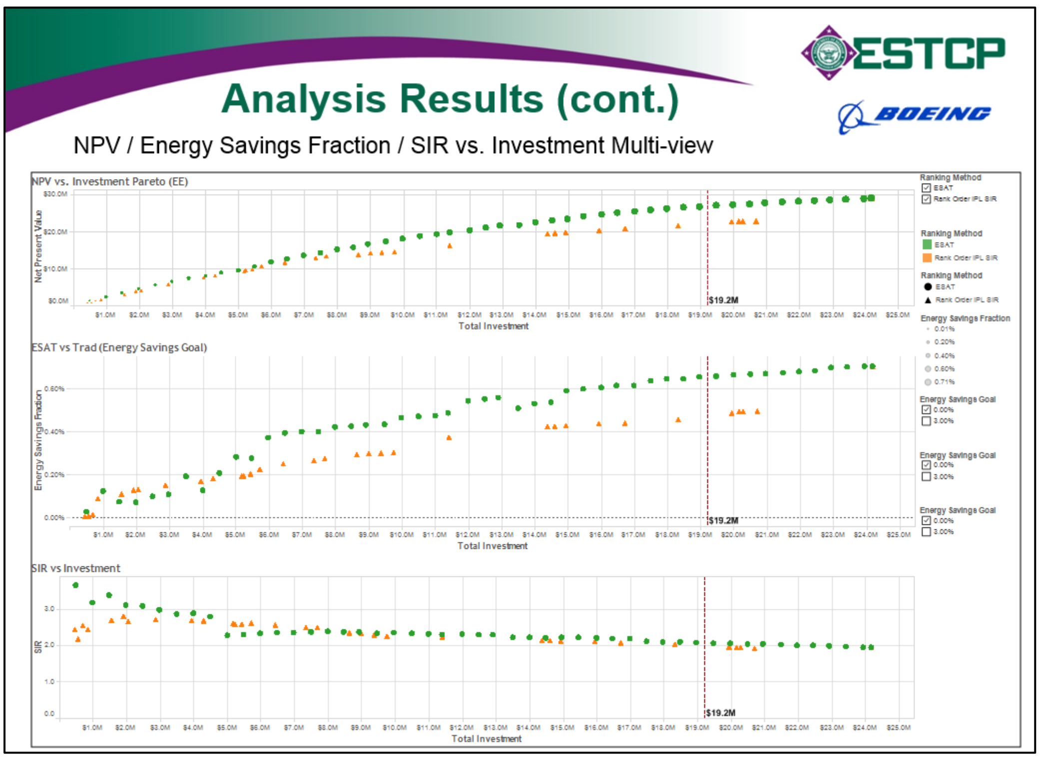


Figure 54. This Multiple View Dashboard Shows the Set of Pareto-optimal Portfolios from Three Different Perspectives – Investment vs. NPV, Investment vs. Energy Savings Fraction, and Investment vs. SIR.

Portfolios for both ESAT technology and rank order approach are shown.

6.4.2 FY16 Decision Cycle Analysis

6.4.2.1 Analysis Purpose

The analysis of FY16 project data was initially planned to be used ahead of the decision point for the FY16 budgeting cycle. However, data was provided to us after the portfolio decisions have already been made; therefore, this data was used to demonstrate the ESAT technology and further refine the ESAT AFCEC model.

6.4.2.2 *Data Collection & Analysis Assumptions*

Energy project data was obtained by Steve McLellan for the FY16 decision cycle analysis on April 24, 2015. Initially, a review of data was performed to identify any issues that needed to be addressed, following which the ground rules that will be used in the analysis were established. Figure 55 shows these ground rules and assumptions for the decision analysis.

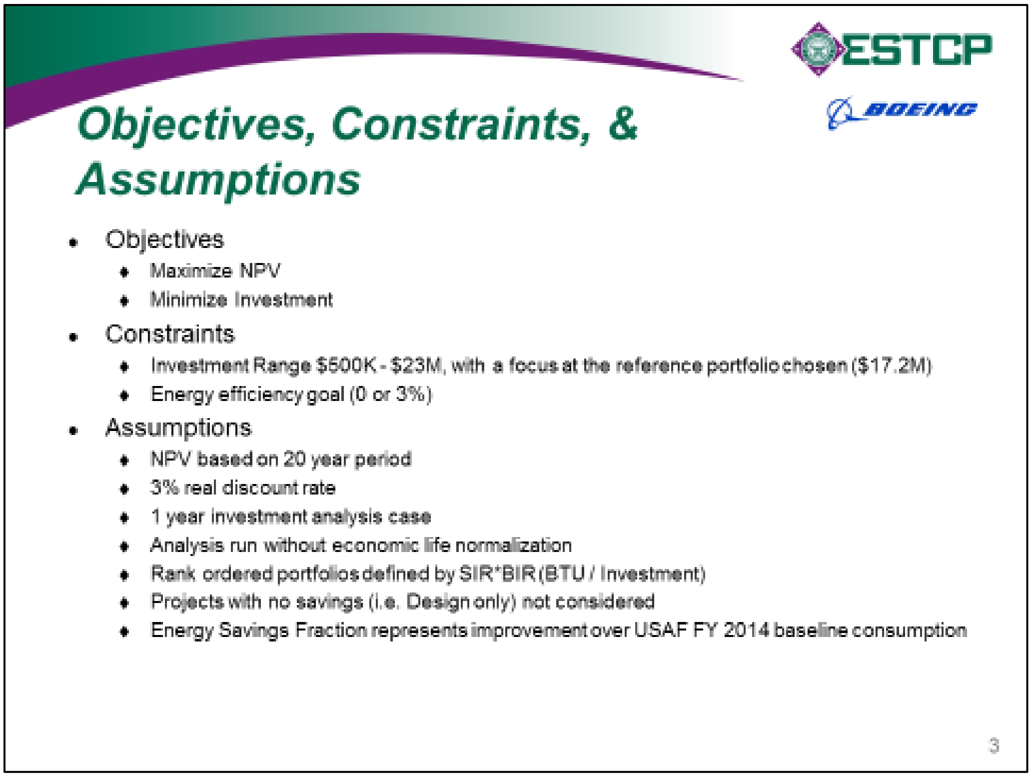


Figure 55. Ground Rules and Assumptions for FY16 AFCEC Analysis.

The NPV used in the analysis is based on 20-year study period. As some of the projects had economic lives that were different from 20 years, the approach was to not use reinvestment and residual life in NPV calculations as decided after the FY15 analysis. Further, there are still two values for SIR for each project that were provided in the data (IPL SIR and validated SIR). In comparing ESAT analysis to rank order analysis, we used validated SIR. Analysis was performed separately for two different situations – one considering all the submitted projects with validated SIR entry (Scenario 1), and one considering only the projects that were already selected (Scenario 2). Energy rate information was not available to be used in the analysis therefore average costs were used.

6.4.2.3 *Analysis Results*

Summary results for FY16 highlighting improvement (in terms of NPV) of the ESAT approach over the rank order approach are shown in Figure 56.

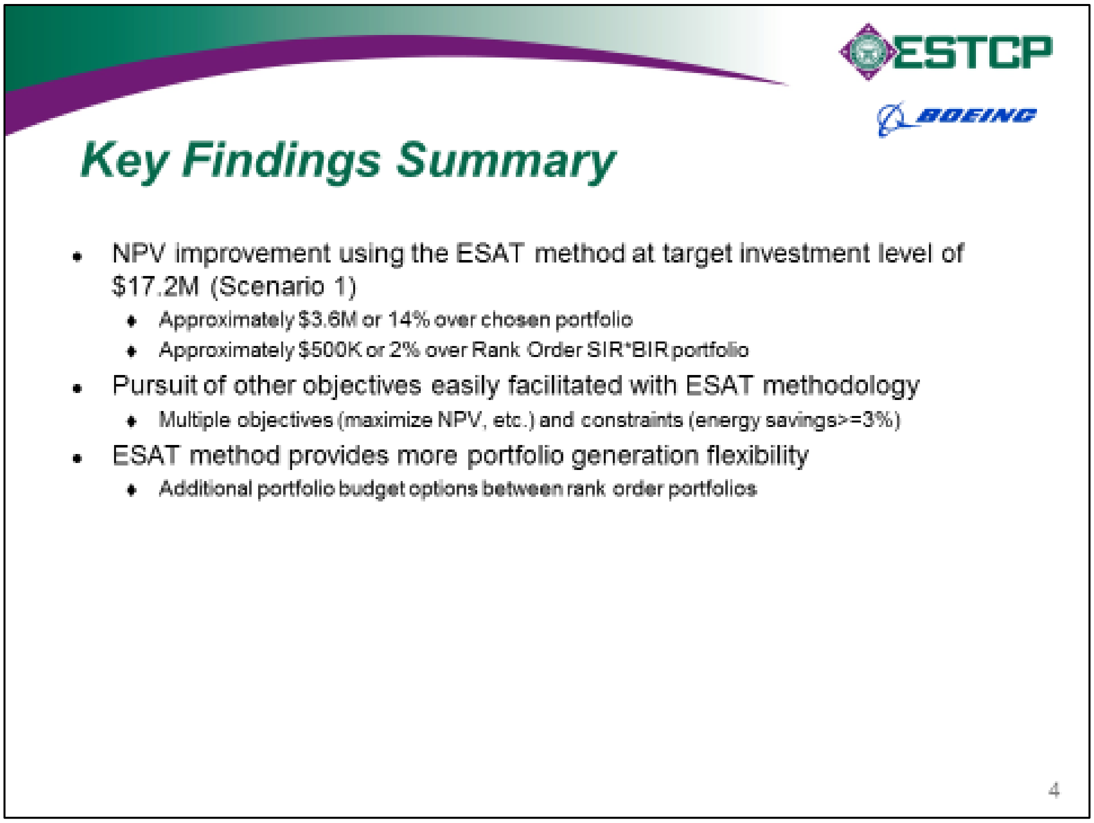


Figure 56. Summary Results of Trade-off Studies Indicating Benefits (in terms of NPV improvement) of ESAT Technology Over Rank-order Methods.

In this analysis, no special consideration was given to energy savings or renewable energy goals. As expected, there was minimal improvement relative to the rank order approach when the rank order metric was the validated SIR.

Unless otherwise noted, the charts that follow are based on the primary analysis run which considered all projects with valid data (as determined by reviews and analysis done by the demonstration site Point of Contact). The major assumptions underlying the analysis results presented are identified on the chart. Figure 57 shows the primary analysis results from ESAT along with the comparison to rank order approach. This figure shows the tradeoff between investment and NPV. The green circles represent ESAT generated portfolios, whereas the red crosses represent rank order generated portfolios. Note that an ESAT generated portfolio, at any given investment level, is the optimal portfolio with respect to the objectives under consideration.

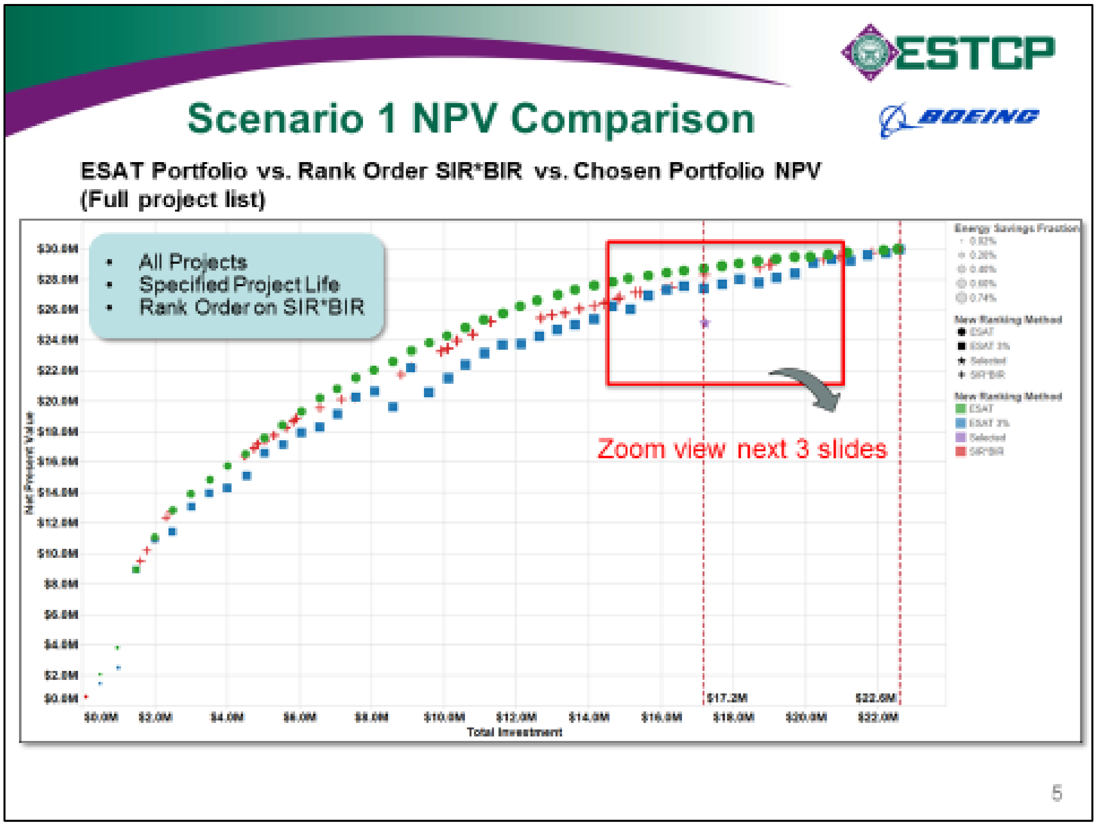


Figure 57. Portfolio Comparison Between ESAT Technology and SIR Rank Order Approach Shows the Tradeoff Between NPV and Investment.

There are two major advantages to the ESAT method over Rank Order SIR*BIR. The first advantage is the improvement in NPV that can be seen in Figure 58. Figure 59 highlights this more clearly.

The second advantage is that ESAT can generate optimal portfolios for selected interim investment levels, whereas the rank order approach cannot guarantee a portfolio that uses substantially all of any specified investment (notice the investment gaps between the portfolios using the rank order approach). This advantage is highlighted by Figure 59, which shows the additional optimal portfolios near the selected investment target and is circled in red.

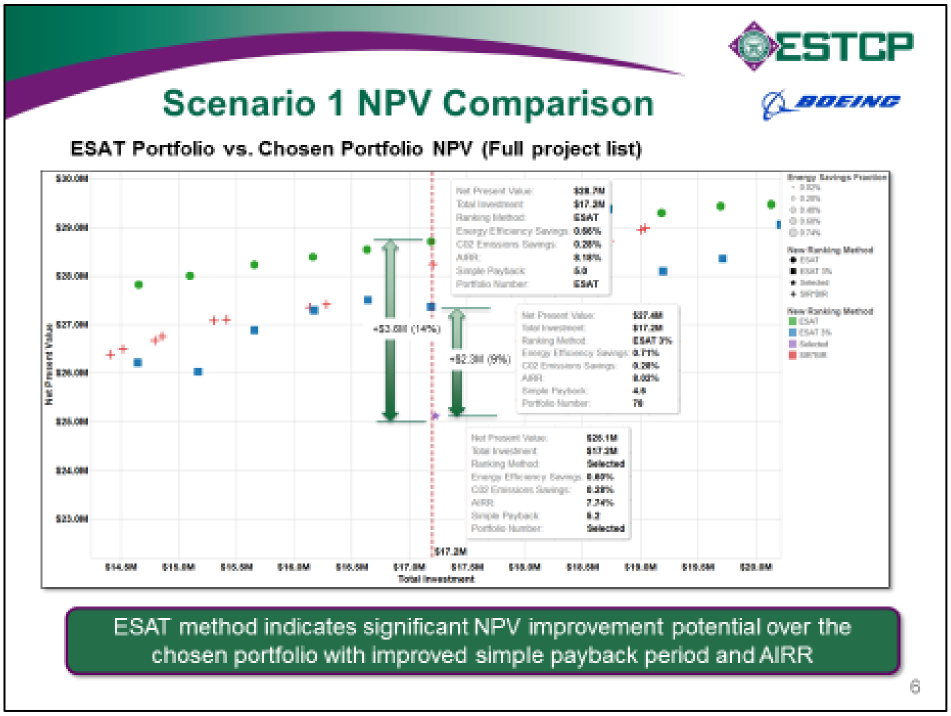


Figure 58. Portfolio Comparison Between ESAT Technology and Rank-order Approach, Showing the Pareto tradeoff Between NPV and Investment.

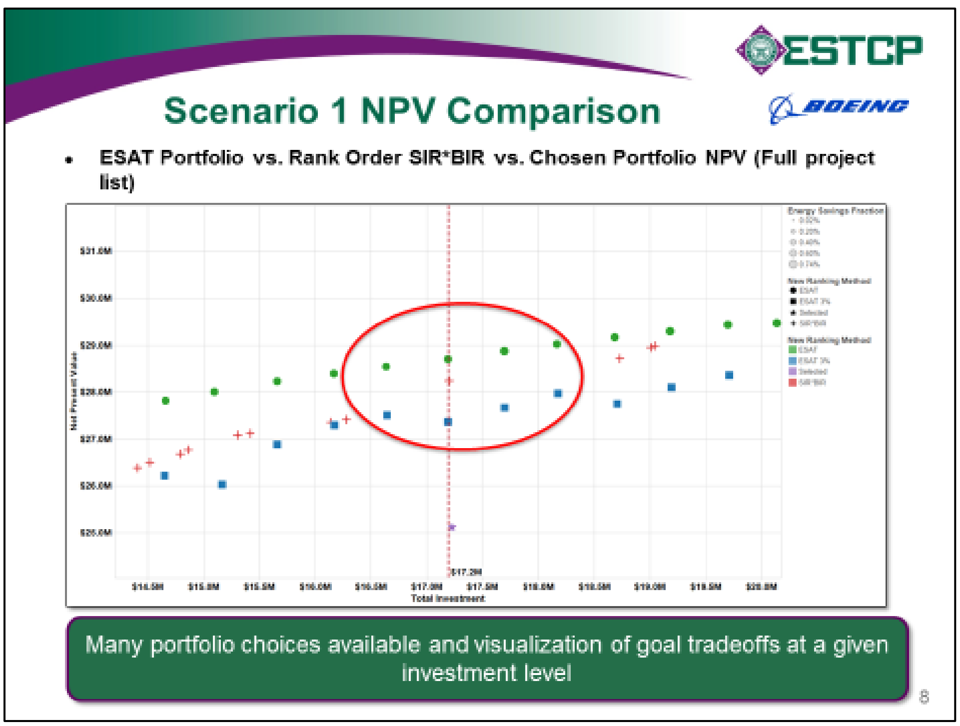


Figure 59. Portfolio Comparison Between ESAT Technology and Rank-order Approach, Showing the Pareto Tradeoff Between NPV and Investment.

The circled region shows the benefit of ESAT in producing portfolios for all investment levels, whereas the rank order approach may leave some money unallocated at certain investment levels.

Additionally, all three of these figures show portfolios where percentage of annual energy savings improvement goals are required at >=3.00% as blue squares.

Further drilldown of a selected portfolio is provided by ESAT through different views. Figure 60 shows the portfolio project composition and distribution among major commands and their constituent installations, in terms of investment, number of projects, and/or NPV. Additional metrics at the service/agency and installation levels are computed and made available through hover-over documentation. Figure 61 shows the portfolio project composition and geographic distribution across the different states, countries, and regions. Once again, both investment and NPV are used to size the pie and tree map segments, and additional metrics at the major command and installation levels are computed and made available through hover-over documentation.

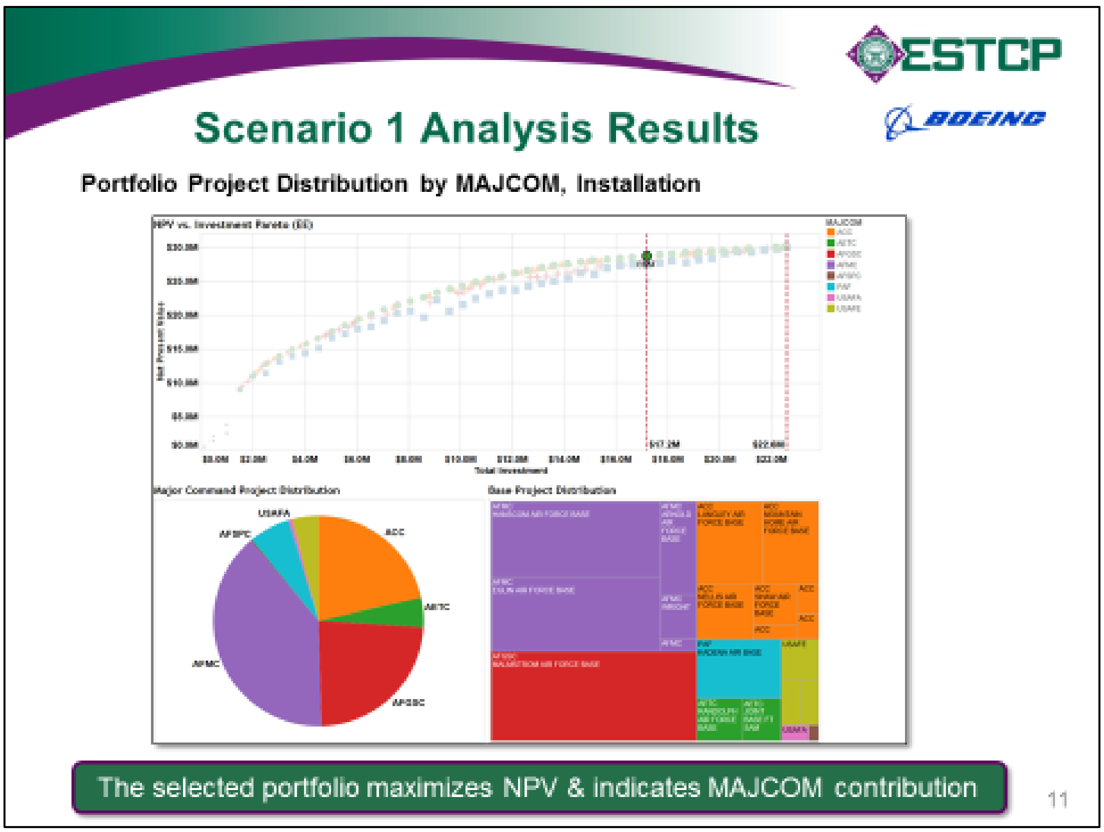


Figure 60. Portfolio Project Composition Distribution Among Major Commands and Installations, Filtered by Portfolio Choice.

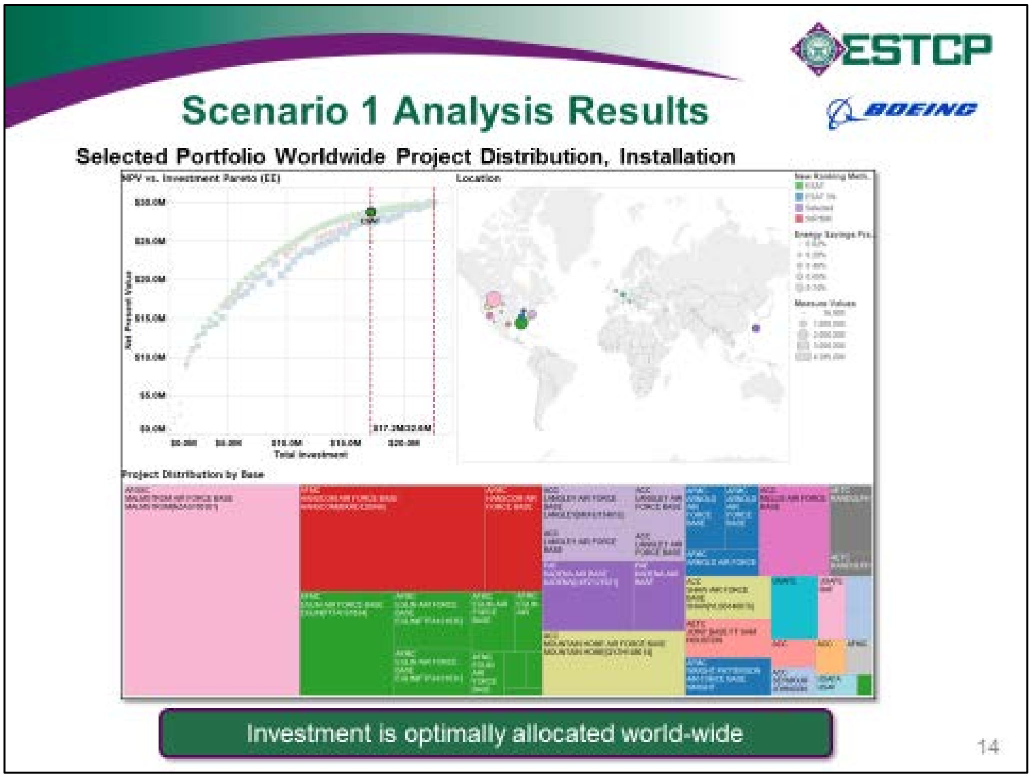


Figure 61. Portfolio Project Composition and Geographic Distribution Among Installations, Filtered by Portfolio Choice.

The next two views provide the decision maker the ability to drill down, by major command, and review how well the sub-portfolios perform relative to each other. Figure 62 shows how the sub-portfolios compare with respect to SIR and simple payback. Figure 63 shows how the sub portfolios, for each major command, compare with respect to the present values of investment and savings, as well as NPV.

The decision maker can also easily review all the projects that are included in one or more selected portfolios. Figure 64 shows the projects contained in three different selected portfolios. For each of the projects in the portfolio, this view also shows:

- Major command of the installation submitting the project
- Investment required
- Savings to investment ratio (SIR)
- 20-year net present value (NPV)

Figure 65 shows the energy savings profile for a selected portfolio. It shows different annual cash flow components, namely, upfront investment, savings, investment from annual savings, continuing operations costs, and reserves set aside to compensate for upfront investment. These annual cash flows are shown as stacked bars over the 20-year study period.

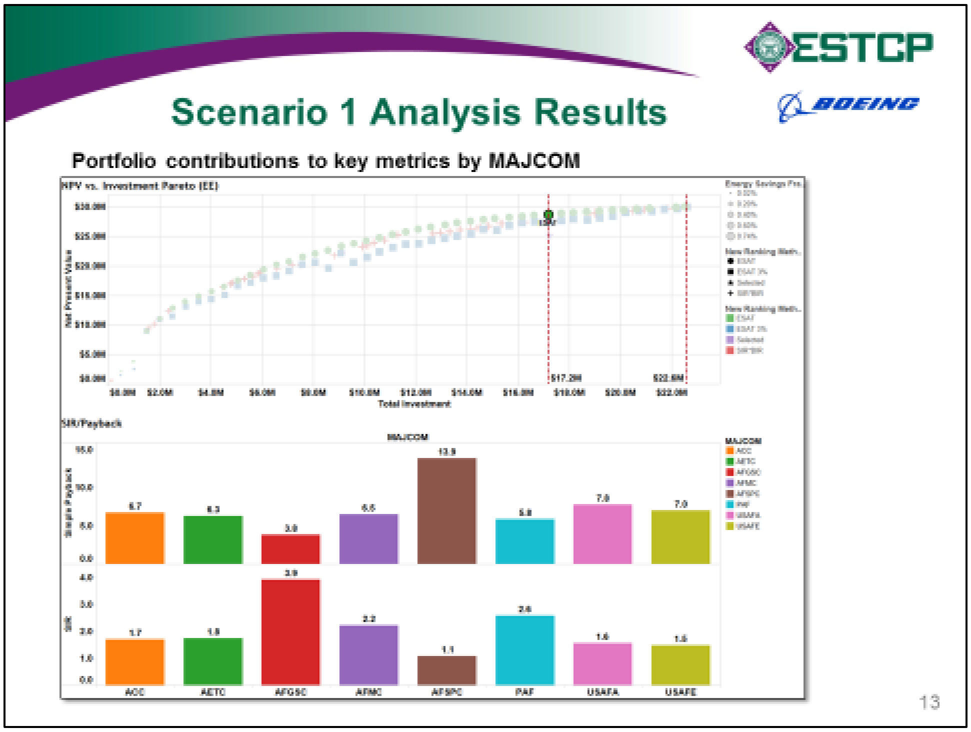


Figure 62. Major Command Specific Contribution to Selected Portfolio Performance Metrics.

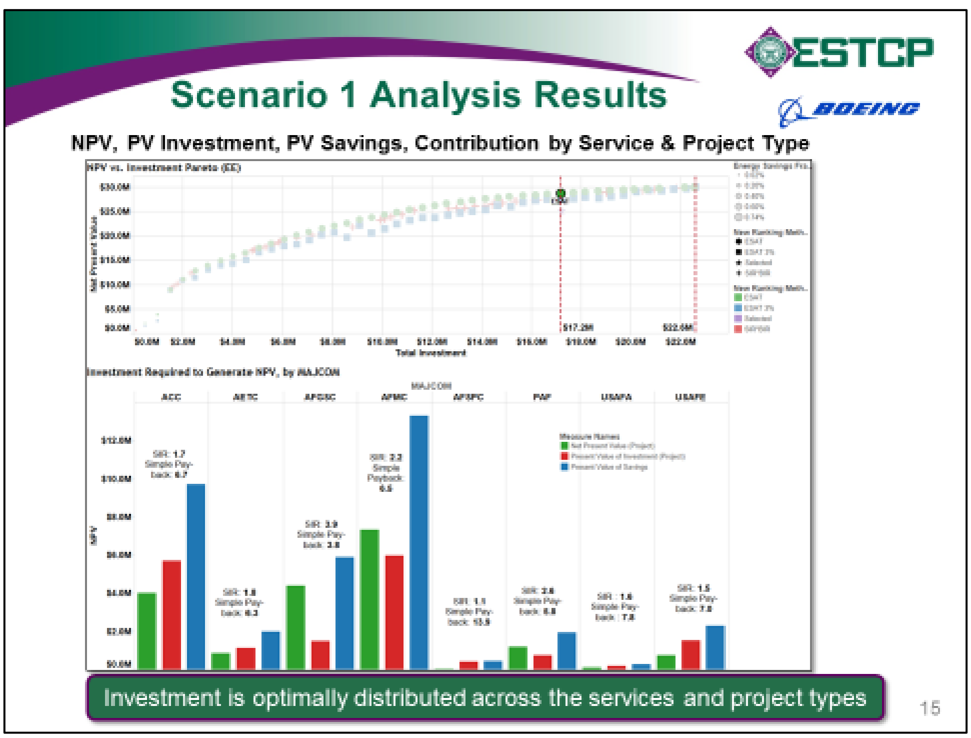


Figure 63. NPV, Present Value of Investment, and Present Value of Savings by Major Command, Filtered by Selected Portfolio.

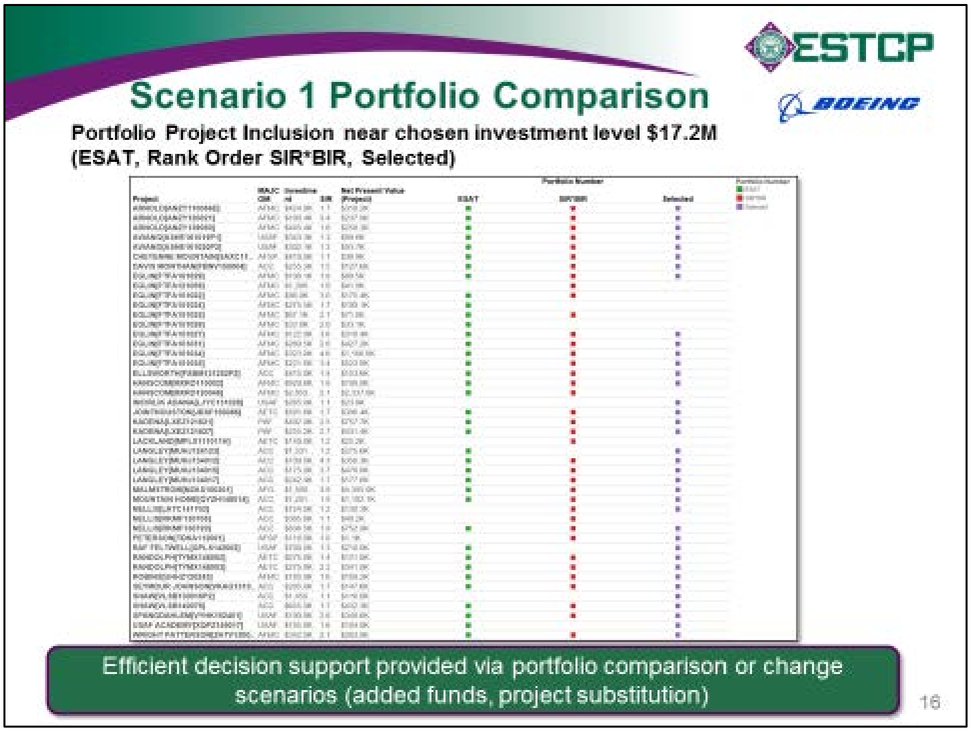


Figure 64. Portfolio Comparison: Projects Included in Each Portfolio with Key Metrics Shown.

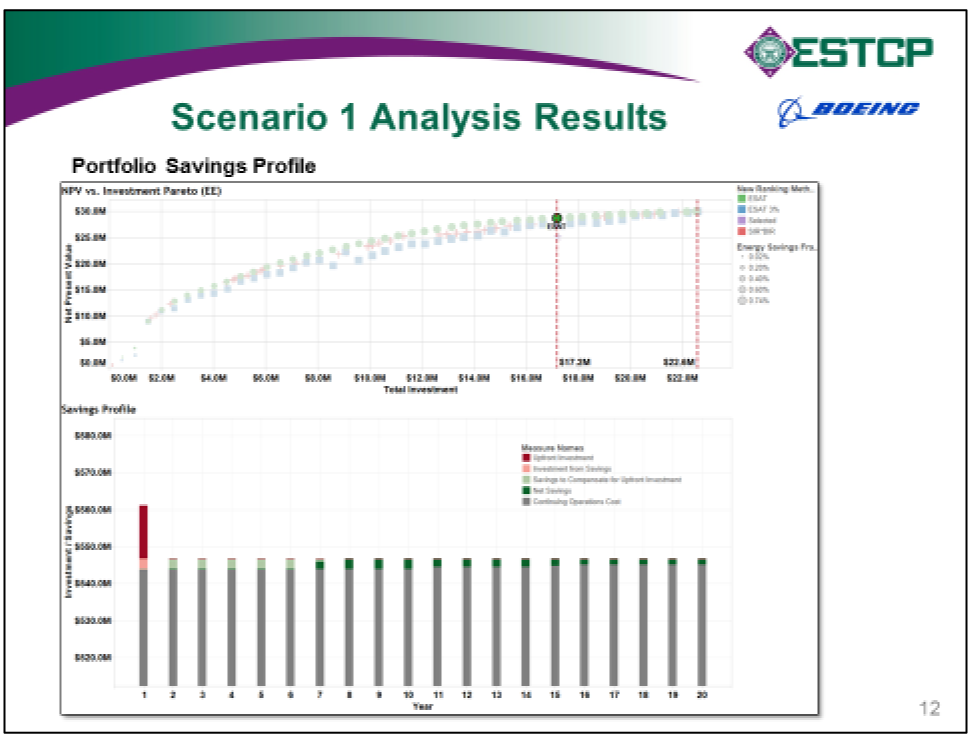


Figure 65. Energy Savings Profile Showing Annual Cash Flows, Including Investment, Savings, and Continuing Operations Cost for Selected Portfolio (stacked bars).

6.5 ENERGY CONSERVATION INVESTMENT PROGRAM DEMONSTRATION SITE

The Department of the Assistant Secretary of Defense – Installations & Environment administers the Energy Conservation Investment Program (ECIP). The decision maker in charge of ECIP is responsible for advising on the allocation of $150M (currently) to a portfolio of energy and water conservation as well as renewable energy projects. This demonstration is aimed at helping him with his decision-making process. We initiated this demonstration during a site visit on July 1, 2014. We collected information about the organization's current decision-making process as well as project data which was submitted during the FY14 and FY15 ECIP portfolio selection period.

During the three-month period between July-September 2014, we completed a series of analysis iterations on FY15 historical ECIP data. The optimization model was modified to accommodate many additional unique constraints and goals important to the ECIP program. Additional visualization techniques were concurrently developed to assist in the assessment of project portfolios, provide insight, and support decision-making.

Based on these iterations, the ECIP program decided to use this approach to guide decision making for the FY16 ECIP portfolio selection. The ECIP program incorporated multi-objective portfolio evaluation methodology and associated new data requirements into the FY16 project submission guidance memo.

Candidate ECIP FY16 project submissions were collected in December 2014 by the ECIP office and provided to us in the third week of December. We reviewed the data for consistency and completeness, and identified a few issues for clarification. We received updated data in the first week of January 2015. We applied ESAT technology to assist with the selection of the optimum portfolio of projects in which to invest, subject to the investment budget limit, while achieving several other organizational goals (e.g. minimum 2.0 portfolio SIR, maximize energy savings, agency/service and project type allocation goals, etc.). We completed the initial analysis and reviewed these results interactively with the decision maker during the early part of the second week of January. Based on his review, he requested additional sensitivity studies, followed by adjustment to the constraints, based on his *post priori* assessment of the Pareto-optimal portfolios. After several iterations, the decision maker completed his decision-making process and selected a portfolio by the end of the second week of January 2015.

We provided supporting documentation and drill-down charts for the selected portfolio to support congressional staffer review of the ECIP FY16 portfolio. We also performed additional analysis to prove the capability for future contingencies. These analyses included the selection of optimal portfolios for any additional funding increments, as well as a test case for replacing a project from the already selected portfolio with alternative projects. Upon completion of this activity, we collected feedback on the value of applying the technology, the process, time required, benefits, improvement suggestions, etc.

After extensive use, ESAT technology was proven and subsequently adopted as a part of the process by which ECIP investment decisions are made.

In November 2015, a new ECIP program manager was in place. The ESAT team subsequently worked with the new decision maker through four additional analysis decision cycles. These decision cycles included two annual investment decision cycles and two multi-year planning cycles. During the annual investment decision cycles, analysis exploration centers on how $150M will be invested across a portfolio of potential energy projects.

In multi-year planning analysis decision cycles, no monetary investment is committed. In this type of decision cycle, the primary purpose is to serve as a planning step to assess the current state of quality of the proposed projects and associated data, their likelihood of being included in future investment decision cycles, and to provide this feedback to the project submitters. Proposed projects with start years spanning a four-year time horizon are collected. Procedurally, the analysis steps are similar, as the collected project attributes are common and many of the analysis results visualizations are common as well. However, the solution space is expansive and more complex to solve for, given the large quantity of projects being considered and the extended analysis time horizon.

Over time, across many analysis iterations, efficiencies were implemented into the analysis process. Improvements in managing data, reducing manual steps, quickening results generation were all accomplished. This enabled many more analysis iterations to be conducted during the same decision cycle time window. We realized a five-fold increase in the number of analysis iterations which could be conducted during the decision cycle period.

The remainder of this section describes the decision cycle analyses that were performed during the contract study period, including details of inputs, metrics, constraints, assumptions, tradeoff studies and analysis results discussion.

6.5.1 Portfolio Selection Criteria: Metrics, Constraints, and Objectives

The overall goal is for projects to be competed against each other to find the best overall portfolio for DoD, using the following criteria:

- Maximize net present value of portfolio
- Maximize “qualitative” elements such as technology synergies, documented improvement plan and use of innovative test bed technologies
- Maximize progress toward legislated goals
- Heavy weighting toward projects with high “Service priority” (service project preference)
- Select a wide variety of project types with an overall portfolio Savings to Investment Ratio (SIR) > 2.0, including lighting, HVAC, steam decentralization, solar, wind and water reduction

In order to support this decision-making process, ESAT allows the decision maker to define relevant metrics, as well as objectives, targets, and constraints in terms of these metrics. Specifically, the following have been used for the FY16 decision support analysis:

- Objectives
  - Maximize NPV

  - Maximize Qualitative Score (Service Priority included)
  - Minimize Investment

- Target
  - Energy efficiency goal (0.3% - 0.35% improvement range over DoD baseline usage)
  - One of the following targets were used, the former was used during sensitivity studies, and the latter for final exploration.
    - Renewable Energy project investment goal (0% - 25%)
    - Minimum Renewable Energy project investment >25%

- Constraints (Some constraints restrict the design space before results are generated. Other constraints guide the trade space exploration after initial results are produced.) Some of the constraints used during the solution exploration process are listed below. Not all constraints were necessarily active during the final portfolio selection.
  - At least one project selected per submitting organization
  - An organization's #1 priority project prioritized for inclusion
  - Select at least one Water Conservation project

- Assumptions
  - NPV values for individual projects provided by the program manager
  - Appropriate NIST discount rate

Most of the metrics such as NPV, SIR, Payback, etc. are standard metrics used in project financial analyses, and will not be elaborated in this interim report. However, the following two metrics are specific to the ECIP portfolio selection and deserve explicit citation:

- Qualitative Score of a project is based on an evaluation of the project subjectively by the decision maker on how well it accomplishes three different objectives - synergies, document plan, and use of test bed technologies

- Service Priority is treated as part of the Qualitative Score (same as the approach used in previous year's portfolio selection process)
  - Current approach calculates service priority score from a priority rank, r as follows
    - SP = (11 - r)*2 for r <=10; 0, otherwise
  - SP is a number from 0 to 20
  - Qualitative Score is a number from 0 to 50

- Service Priority weight within Qualitative Score can be varied parametrically, but default weight = 40%

In contrast to the current practice, ESAT defines metrics for each portfolio, so that different portfolios can be compared relative to the objectives and constraints. To this end, we defined two portfolio level metrics. The first of these is the portfolio service priority rank (SPR), which is defined as follows:

- Rank all the projects under consideration by each service from 1 to N_s, where N_s are the number of projects submitted by services

- For a portfolio with n_s projects from service s, the service priority rank is defined as

$$R_s = \frac{\sum_{j=1}^{n_s} r_j}{\sum_{j=1}^{n_s} j}$$

where r_j are the ranks of the projects

- Ideal Priority Rank will be 1.0 – the more the value is greater than 1.0, the larger the difference from the originally stated service ranking
- Example: For any portfolio of selected projects, if service s has 3 projects, ideally projects ranked 1, 2, 3 are selected; however, let us assume the portfolio has projects 1, 2, 4 selected
  - Priority Rank for this service will be (1 + 2 + 4) / (1 + 2 +3) = 7/6 = 1.1667
- For Portfolio Service Priority, combine service specific priority ranks as a weighted average, with weights being investment allocated to each service, I_s

$$R = \frac{\sum_{s} I_s R_s}{\sum_{s} I_s}$$

The other metric is the portfolio quality score average (QSA) defined as follows:

- Let I_p and Q_p be investment and qualitative score for a project p
- Let P be the set of all projects in a portfolio
- Qualitative Score Average (QSA) is calculated as investment weighted average of qualitative scores of all projects in a portfolio

$$QSA = \frac{\sum_{p \in P} I_p Q_p}{\sum_{p \in P} I_p}$$

- QSA for a portfolio will be a number between 0 and 50, similar to the range for the Qualitative Score of a project

6.5.2 FY16 Decision Cycle Analysis

This section discusses the results of the analyses that were performed in support of the portfolio selection. There were several iterations that were performed to explore the solution space of alternative portfolios, with each iteration resulting in refinements for the next analysis iteration. As described earlier, these refinements included the narrowing down of constraints, and adding additional constraints. The results discussed here are from the final iteration, which resulted in the selection of the multi-criteria optimal portfolio by the decision maker. The summary characteristics for the selected portfolio are shown in Table 6.

Table 6. Summary of Portfolio Selected for FY16 ECIP Allocation.

Project Type	Count	Cost	SIR	Expected Annual Energy Benefit
Energy Efficiency	26	$107.3M	2.4	694,755 MMBTU
Renewable Energy	6	$41.6M	1.7	73,939 MMBTU
Water Conservation	1	$1.1M	1.5	30 Mgal Water
Grand Total	**33**	**$150M**	**2.2**	**768,694 MMBTU**

During each analysis iteration, ESAT produced a Pareto-optimal set of portfolios, with respect to the multiple objectives, namely minimizing investment, maximizing NPV, subject to targets/goals on energy savings and renewable fractions, qualitative score, and various constraints. Figure 66 is the primary view showing the tradeoff between investment and NPV from the Pareto-optimal portfolios produced by ESAT during the final iteration. The portfolios for two different energy savings targets and two different constraints on renewable energy investment are shown in this figure.

ESAT provides additional views for any of the portfolios that the decision maker would like to drill down further, for additional study. Figure 67 shows the Sparkline graph of several different portfolio level metrics for four different portfolios of interest. This view is especially useful when the decision maker needs to narrow down the portfolio choices that have similar metric profiles.

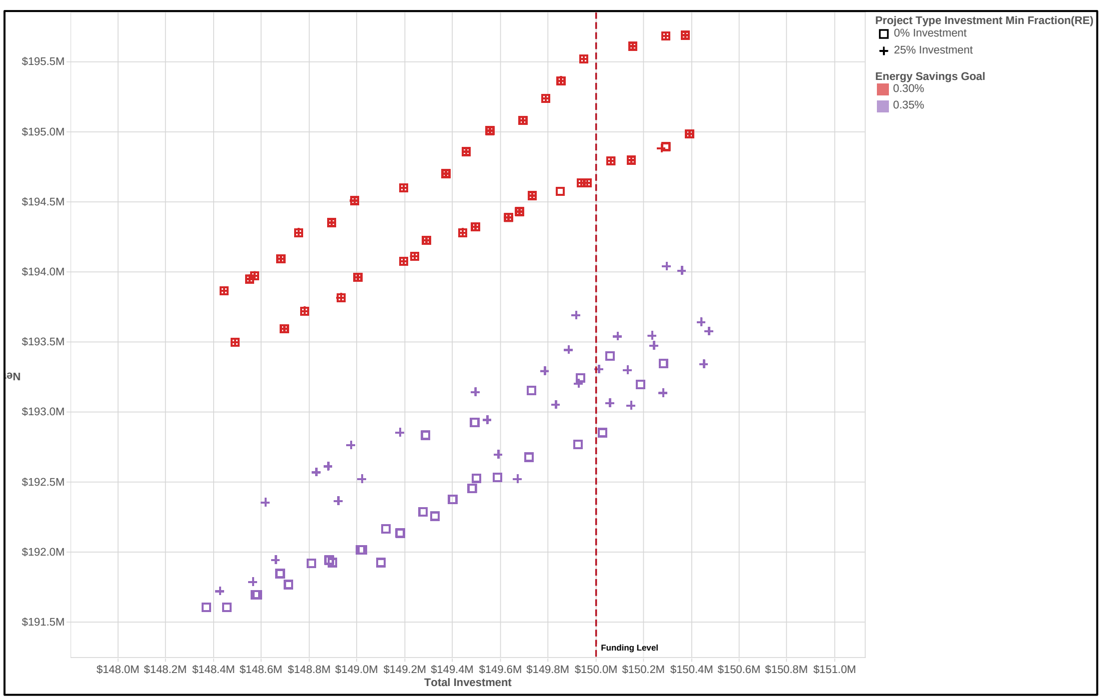


Figure 66. NPV vs. Investment Reflecting Trade Study Results Varying Energy Efficiency and Renewable Energy Production Targets. Every marker in this chart is an optimal portfolio, thus offering the decision maker many options from which to choose a final portfolio.

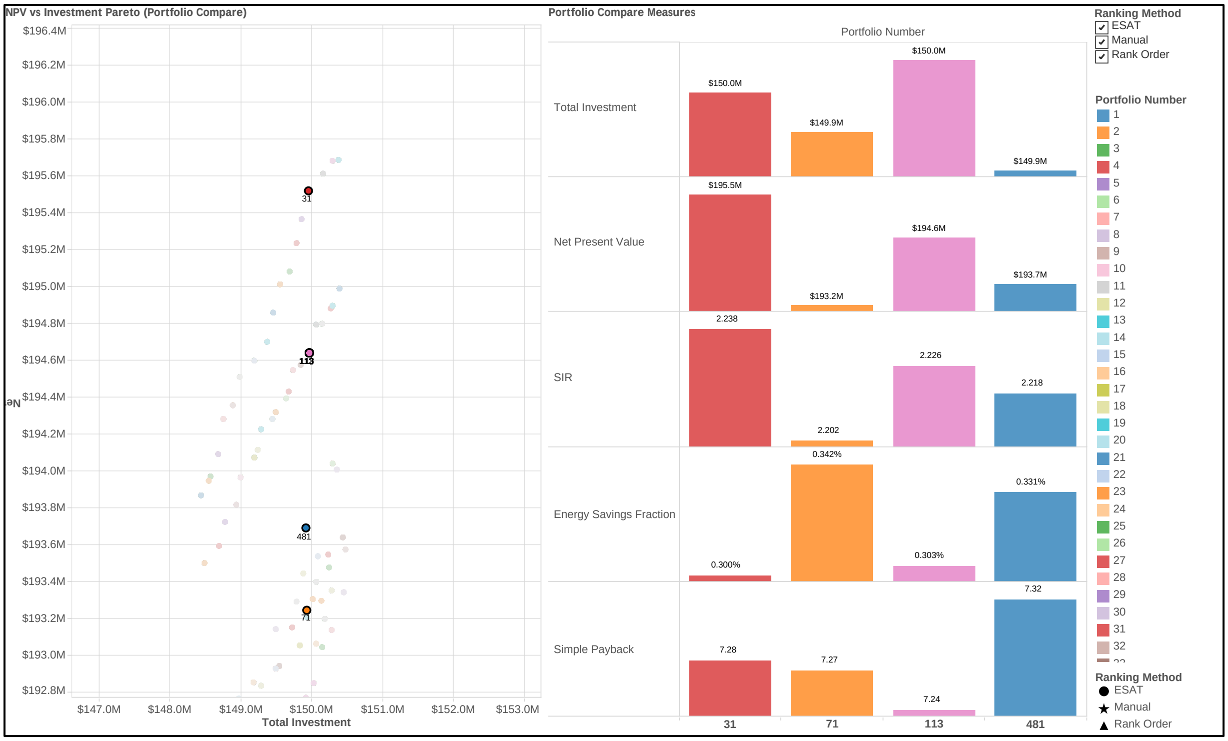


Figure 67. Sparkline Graph Showing Multiple Portfolios Compared Across Several Performance Metrics.

The decision maker can also easily review all the projects that are included in any selected portfolio. Figure 68 shows the projects in the portfolio that the decision maker eventually selected. For each of the projects in the portfolio, this view also shows:

- Service submitting the project
- Project type (energy efficiency, renewable energy or water conservation)
- Investment/project cost
- Savings to investment ratio (SIR)
- 20-year net present value (NPV)

The metrics shown in Figure 68 are project level metrics in contrast to the portfolio level metrics shown in Figure 67.

Project	Service	Project Type	Investment	SIR	Net Present Value (Project)	Total Score (Project)	Portfolio Number 113
[illegible]	[illegible]	EE	$0.58M	2.72	$0.9M	37.2	■
[illegible]	[illegible]	RE	$5.50M	1.84	$4.6M	30.4	■
[illegible]	[illegible]	EE	$12.94M	3.28	$37.6M	67.8	■
[illegible]	[illegible]	EE	$4.55M	2.22	$7.1M	39.2	■
[illegible]	[illegible]	EE	$0.80M	1.91	$0.7M	44.1	■
[illegible]	[illegible]	EE	$2.40M	2.00	$4.2M	40.0	■
[illegible]	[illegible]	RE	$22.00M	1.53	$10.4M	32.3	■
[illegible]	[illegible]	EE	$1.60M	1.60	$1.7M	26.0	■
[illegible]	[illegible]	EE	$2.80M	2.47	$3.7M	39.7	■
[illegible]	[illegible]	EE	$0.47M	2.19	$0.5M	34.9	■
[illegible]	[illegible]	EE	$2.01M	2.05	$2.1M	35.5	■
[illegible]	[illegible]	EE	$2.54M	2.00	$2.5M	35.0	■
[illegible]	[illegible]	EE	$14.74M	2.85	$27.3M	43.5	■
[illegible]	[illegible]	EE	$13.78M	2.08	$14.9M	55.8	■
[illegible]	[illegible]	EE	$4.26M	2.00	$7.4M	30.0	■
[illegible]	[illegible]	RE	$1.70M	1.56	$0.9M	50.6	■
[illegible]	[illegible]	RE	$5.74M	1.63	$3.6M	36.3	■
[illegible]	[illegible]	EE	$2.10M	2.50	$4.0M	44.0	■
[illegible]	[illegible]	EE	$6.47M	2.14	$7.4M	37.4	■
[illegible]	[illegible]	EE	$2.65M	2.10	$2.9M	38.0	■
[illegible]	[illegible]	WC	$1.09M	1.50	$0.5M	27.0	■
[illegible]	[illegible]	EE	$1.16M	2.00	$1.2M	32.0	■
[illegible]	[illegible]	EE	$5.33M	1.96	$5.1M	54.6	■
[illegible]	[illegible]	EE	$10.99M	2.98	$21.8M	54.8	■
[illegible]	[illegible]	EE	$2.19M	1.90	$1.8M	44.0	■
[illegible]	[illegible]	EE	$4.53M	1.93	$4.2M	37.3	■
[illegible]	[illegible]	EE	$1.07M	2.55	$1.7M	35.5	■
[illegible]	[illegible]	EE	$4.40M	2.10	$4.8M	40.0	■
[illegible]	[illegible]	EE	$0.66M	1.66	$0.8M	26.6	■
[illegible]	[illegible]	EE	$0.80M	2.12	$0.9M	38.2	■
[illegible]	[illegible]	RE	$1.40M	1.95	$1.3M	37.5	■
[illegible]	[illegible]	EE	$1.40M	2.04	$1.3M	37.4	■
[illegible]	[illegible]	RE	$5.33M	1.93	$5.0M	39.3	■

Figure 68. Selected Portfolio Showing Included Projects, Along with Key Performance Metrics.

Further drilldown is provided by four different views. Figure 69 shows the portfolio project composition and distribution among the services/agencies and their constituent installations, in terms of investment, number of projects, and/or NPV. Additional metrics at the service/agency and installation levels are computed and made available through hover-over documentation. Figure 70 shows the portfolio project composition and geographic distribution among the different states and countries. Once again, both investment and NPV are used to size the different views, and additional metrics at the service/agency and installation levels are computed and made available through hover-over documentation.

Figure 71 shows the regional geographic investment distribution by service/agency segment. The sizes of the circles indicate the investment in the geographic region whereas the sizes of the pie segments indicate the split between the services/agencies in each region. Figure 72 shows the geographic distribution of project investment by project type. The sizes of the circles indicate the investment in the geographic region, whereas the sizes of the pie segments indicate the split between energy efficiency, renewable energy, and water conservation projects. Finally, Figure 73 and Figure 74 show two different views of the how the NPV, present value of investment, and present value of savings are distributed across service/agency, and by project type for the selected portfolio. The purpose of these visualizations is to encourage the decision maker to view the tradeoffs from multiple perspectives, then choose a Pareto-optimal design that satisfies both the explicit and implicit criteria.

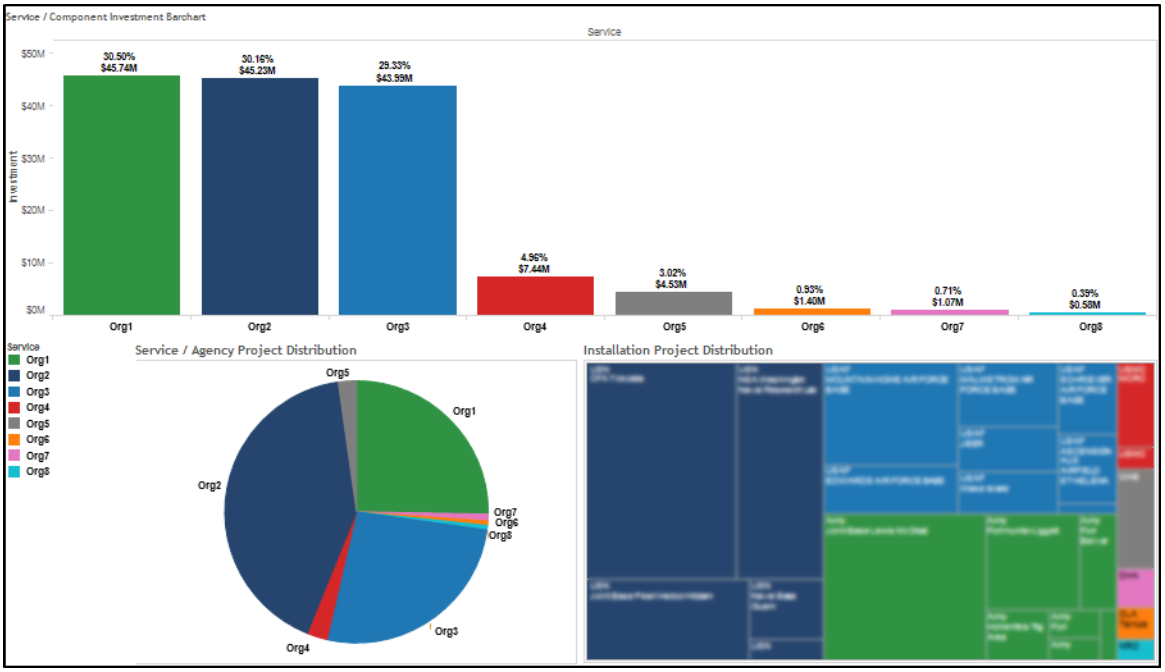


Figure 69. Selected Portfolio Project Composition and Distribution Among Services/Agencies and Installations.

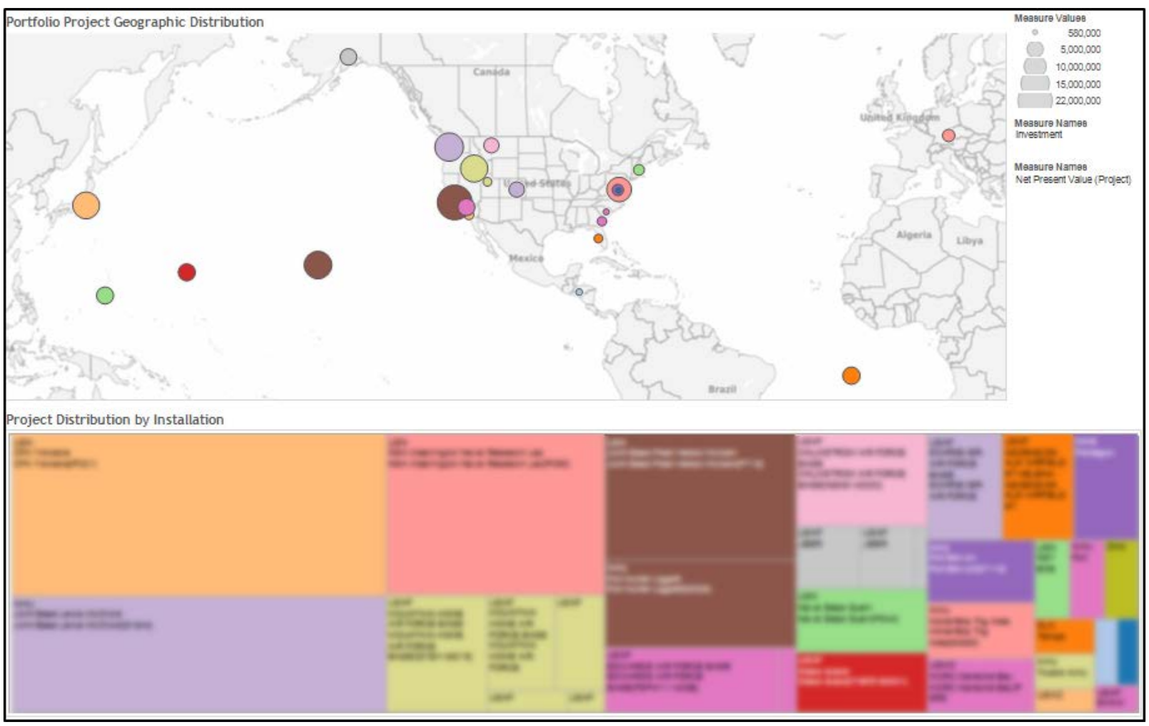


Figure 70. Selected Portfolio Project Composition and Geographic Distribution Among Installations.

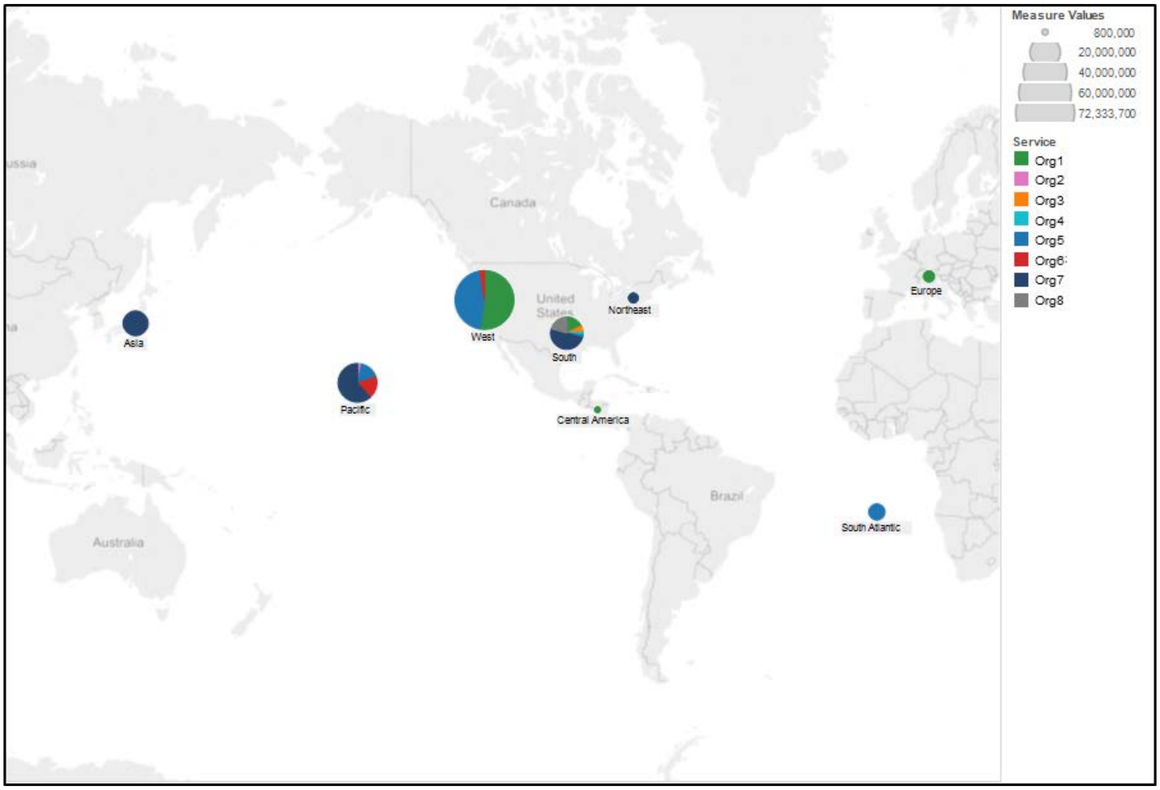


Figure 71. Regional Geographic Investment Distribution by Service/Agency Segment.

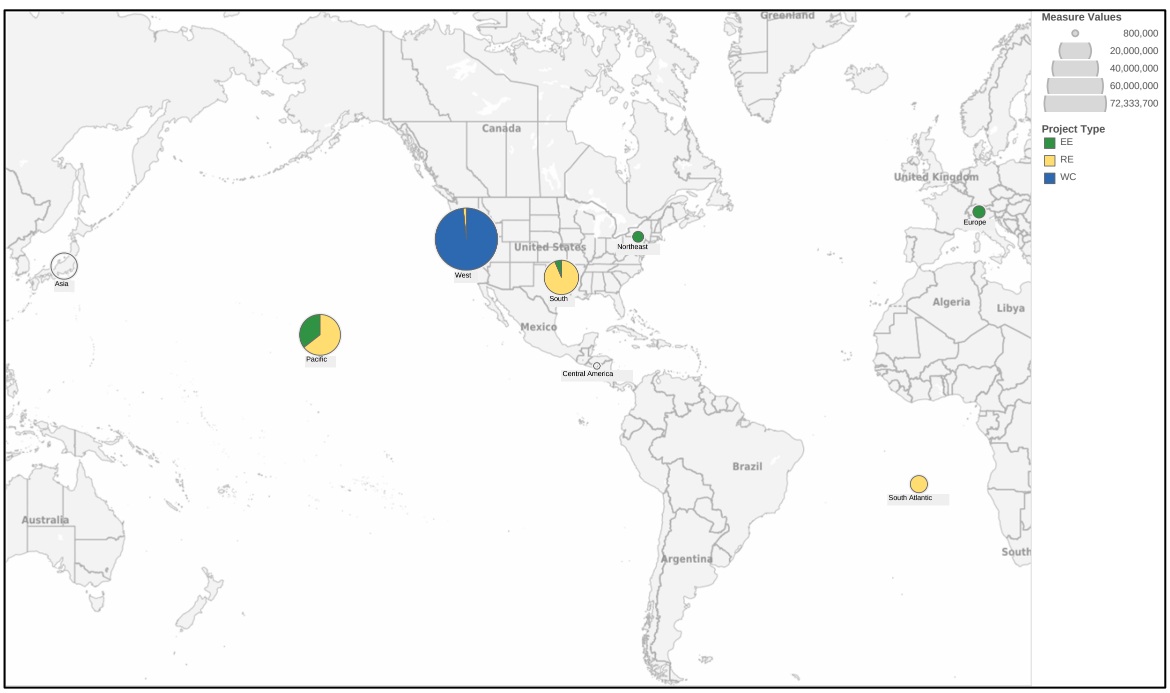


Figure 72. Geographic Distribution of Project Investment by Project Type (energy efficiency, renewable energy, and water conservation).

Figure 73. NPV, Present Value of Investment, and Present Value of Savings by Service/Agency, and by Project Type for Selected Portfolio.

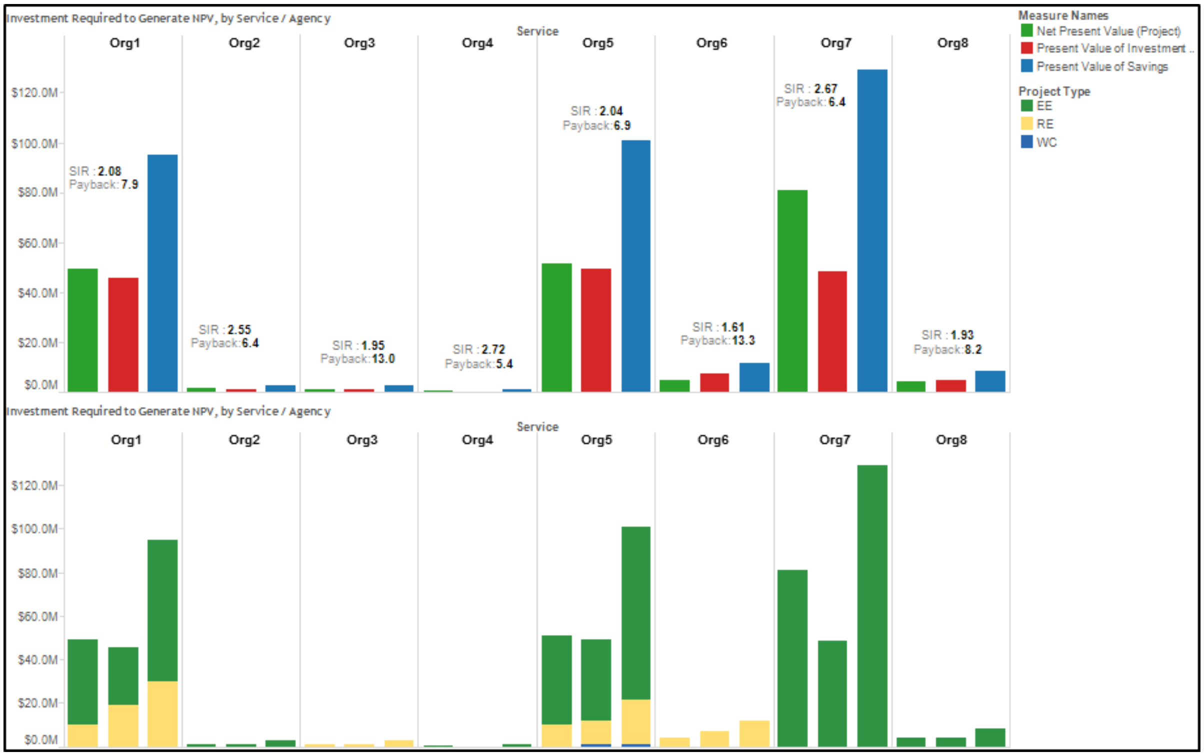


Figure 74. NPV, Present Value of Investment, and Present Value of Savings by Service/Agency, and by Project Type for Selected Portfolio (alternate view – stacked bars).

6.5.3 FY 16 Decision Cycle Feedback

A performance feedback form was created and delivered to the decision maker to collect his observations and experience using ESAT in the FY16 decision cycle. Feedback was requested on four topics: (1) Analysis Cycle Labor Effort Required; (2) Analysis Cycle Duration Required; (3) Insight Gained; (4) Budget Justification.

In each area, ESAT earned high marks in meeting or exceeding expectations, and consequently the relevant performance objectives outlined in Table 1. Summary of Performance Objectives.

The full set of performance feedback detail can be found in Appendix F: ECIP FY16 Performance Objectives Feedback.

6.5.4 FY17 Decision Cycle Analysis

Subsequent to the FY16 decision cycle, we provided analysis results via the Tableau Enterprise Server through the Boeing Portal Network, to the ECIP program. This enables 24/7 access to our analysis for reference, as needed, without requiring specific software licenses or applications

We completed the FY17 decision cycle in January 2016. We conducted eight analysis iterations before the decision maker selected a final portfolio recommendation. This section discusses the results of these analyses that were performed in support of the portfolio selection. Each iteration that was performed explored the solution space of alternative portfolios and resulted in refinements for the next analysis iteration. These refinements included the narrowing down of constraints, and adding additional constraints.

The portfolio selection criteria, metrics, constraints, and objectives was very similar to the FY16 set. The differences were:

- Target
  - Project Type Funding Allocation – either no target, or:
    - Energy Efficiency: 50-65% or better
    - Renewable Energy: 25% or better
    - Water Conservation: 2% or better
- Constraints
  - Forced inclusion of one or more specific projects
  - Qualitative Score goal (19-21)
  - One of the following:
    - At least one project selected per submitting organization
    - Proportion of investment allocated to submitting agency (to study sensitivity of portfolio quality to such allocation)

Once again, some of the constraints were only active during solution space exploration, and not necessarily during final portfolio selection. At the conclusion of all the analysis iterations, the final selected portfolio had the following characteristics, as shown in Table 7.

Table 7. Summary of Portfolio Selected for FY17 ECIP Allocation.

Project Type	Count	Cost	SIR	Expected Annual Energy Benefit
Energy Efficiency	34	$98.3M	2.5	766,442 MMBTU
Renewable Energy	5	$46.3M	1.3	4,146,525 MMBTU
Water Conservation	1	$5.4M	1.5	33 Mgal Water
Grand Total	**40**	**$150.0M**	**2.1**	**4,912,967 MMBTU**

Figure 75 shows the initial analysis iteration, which spans the complete potential investment range, from zero to the full aggregate value of all projects, in $10M investment increments. The value of ESAT decision making support can be easily observed by noting the area between the ESAT (orange triangles) and rank order (blue circles) data set curves. The vertical distance represents the NPV improvement that is generated through ESAT's optimization model. Of special interest is the red dashed vertical line indicating the FY17 $150M allocated investment budget. Portfolios near this area are prime candidates for initial exploration. Note that, at this early stage, fewer and coarser constraints were employed to create the results. Therefore, future analysis iterations will add to, and further refine these constraints to satisfy the decision maker's goals.

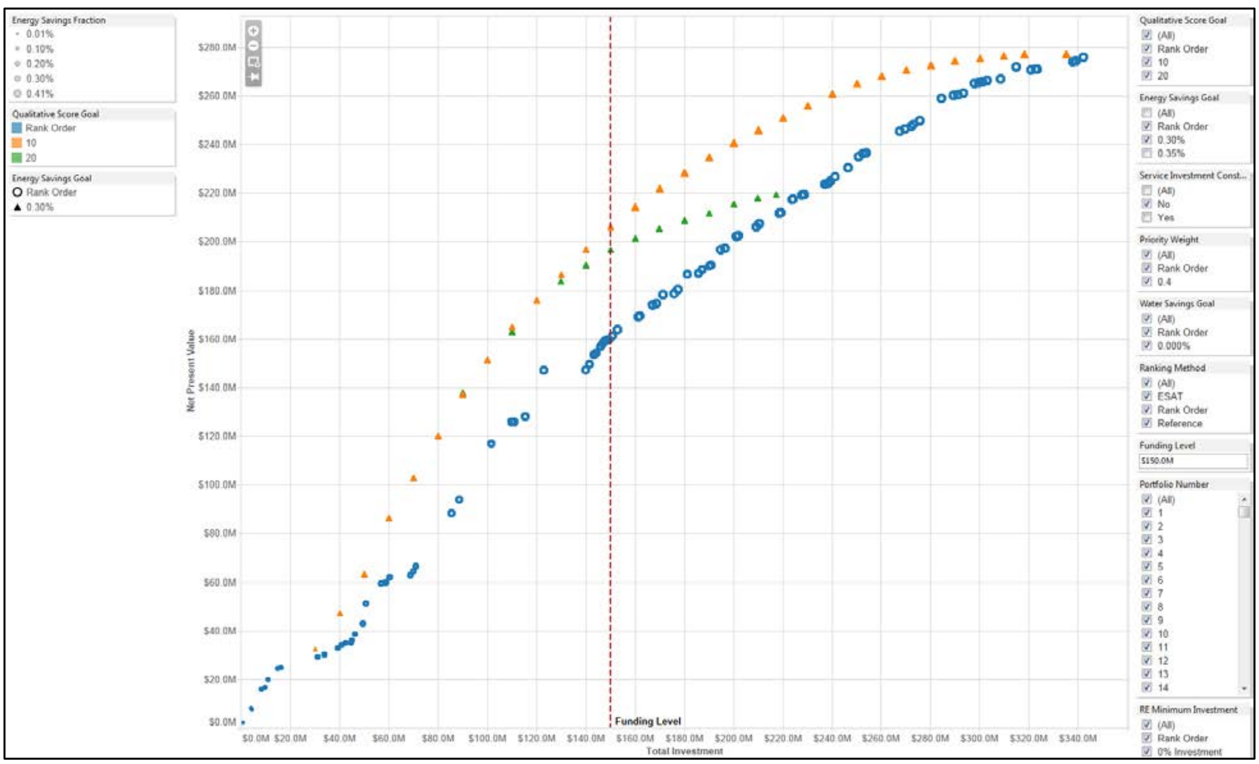


Figure 75. NPV vs. Total Investment. Initial Analysis Iteration Over Full Investment Range, with Comparison to Rank Order Approach.

In Figure 76, key portfolio details can be observed. Sensitive information has been either anonymized or blurred in this and other figures in this report. Noteworthy at this point are (1) there are large differences between service/agency investment levels (see upper right hand quadrant graph), and (2) there is a significant discrepancy between investment allocation across project type achieved vs. goal (see upper right hand margin). These two observations serve to guide future analysis iterations (constraints and sensitivity analysis) to improve the results.

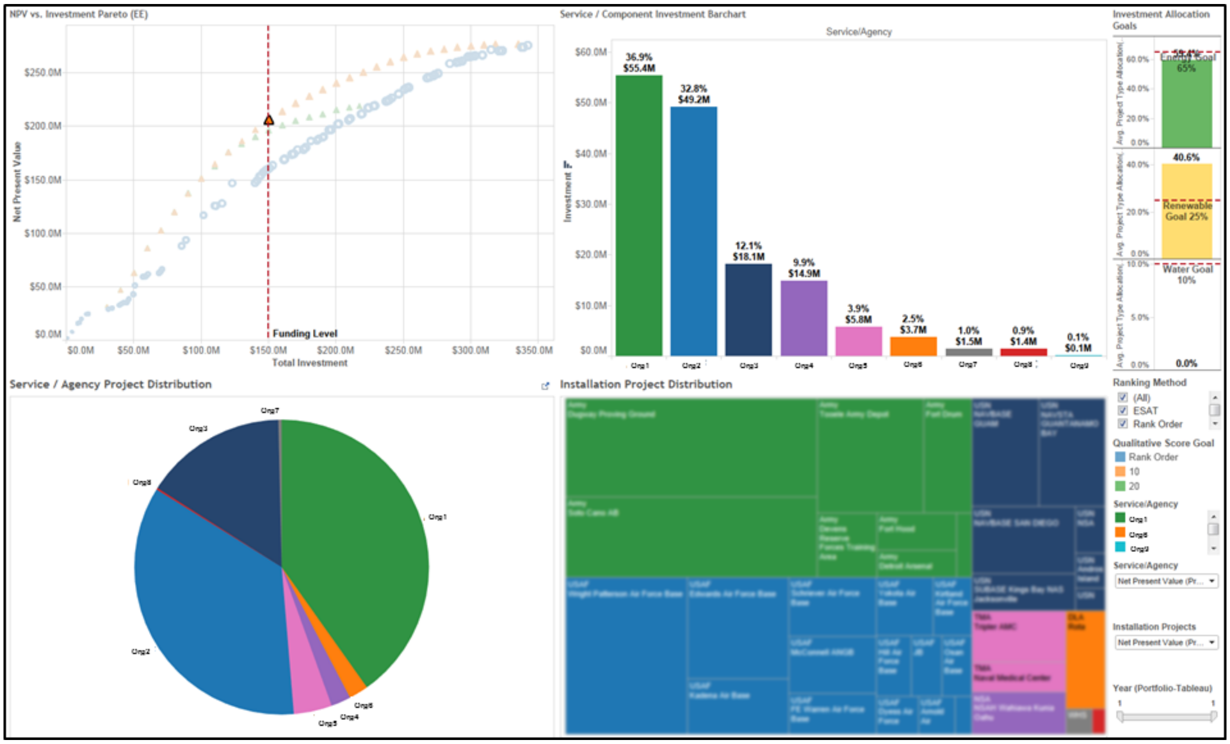


Figure 76. Selected Portfolio Project Composition and Distribution Among Services/Agencies and Installations. Early iteration, indicating disproportionate service investment and goal accomplishment.

In Figure 77, a Sparkline dashboard shows several candidate portfolios have been selected for comparison purposes. A set of ESAT generated portfolios are included, and the two right-most portfolios were created via the traditional rank-order approach. Several key comparison metrics are shown. As can be seen, ESAT provides consistently stronger results across NPV, SIR, and Simple Payback metrics.

In Figure 78, a trade sensitivity was performed to determine how the pursuit of improved portfolio qualitative metric affects NPV. This enables the decision maker to be more fully informed when making his final portfolio selection. It also illustrates the versatility ESAT offers. Many more management questions can be answered with ESAT compared to the rank order approach. This type of analysis is not possible with the rank order approach.

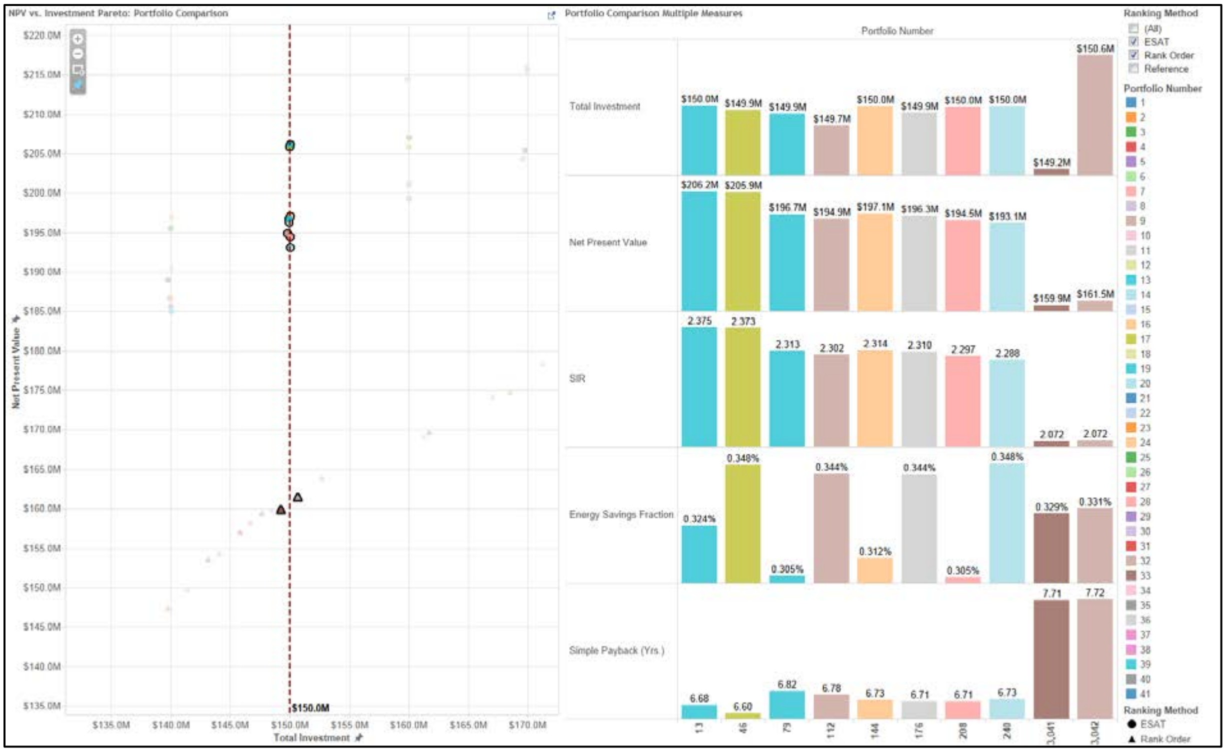


Figure 77. Sparkline Graph Showing Multiple Portfolios Compared Across Several Performance Metrics. Right most portfolios represent rank order approach.

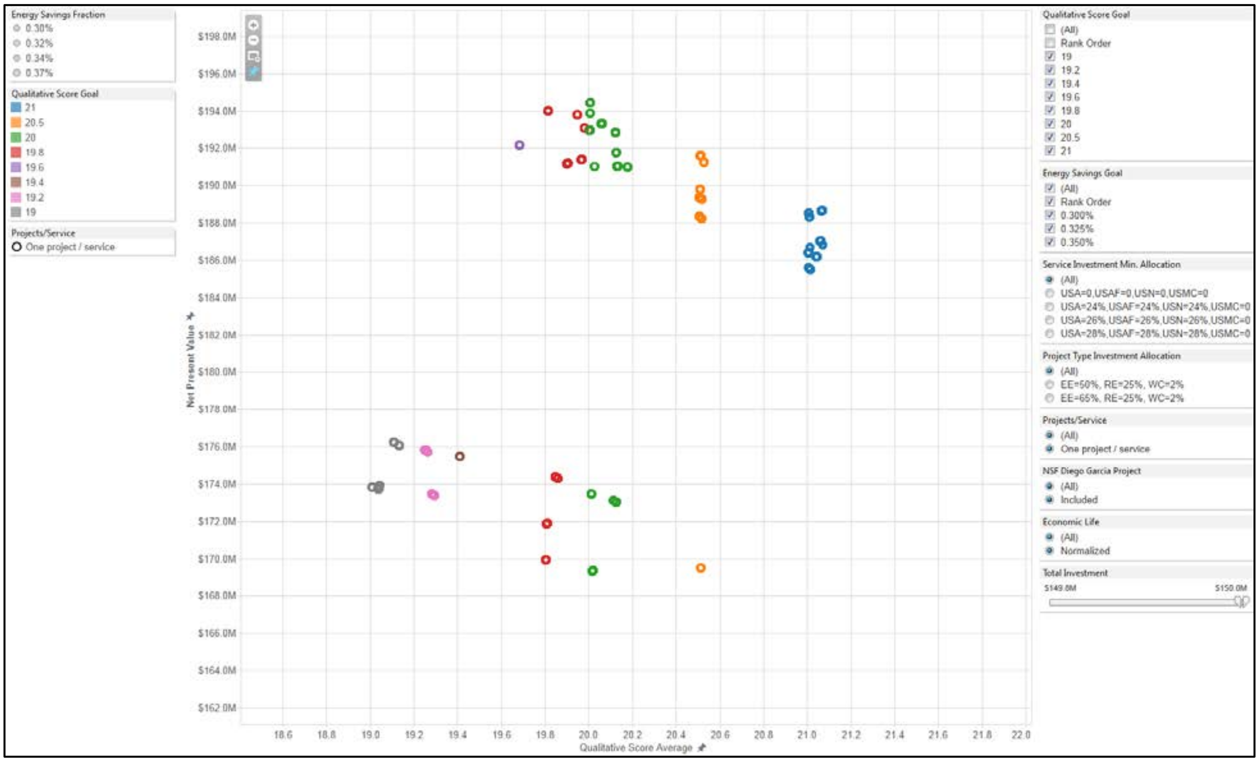


Figure 78. NPV vs. Qualitative Score Average for a range of Qualitative Score Goals.

Figure 79 was a popular dashboard to use during FY17 decision cycle. This is a new dashboard since FY16 decisions cycle. It has some similarities to the Sparkline dashboard, but offers portfolio comparisons in several formats. Line chart, bar chart, and tabular results are all offered. This rich set of comparison metrics have been selected to satisfy many potential decision makers, and can be easily customized.

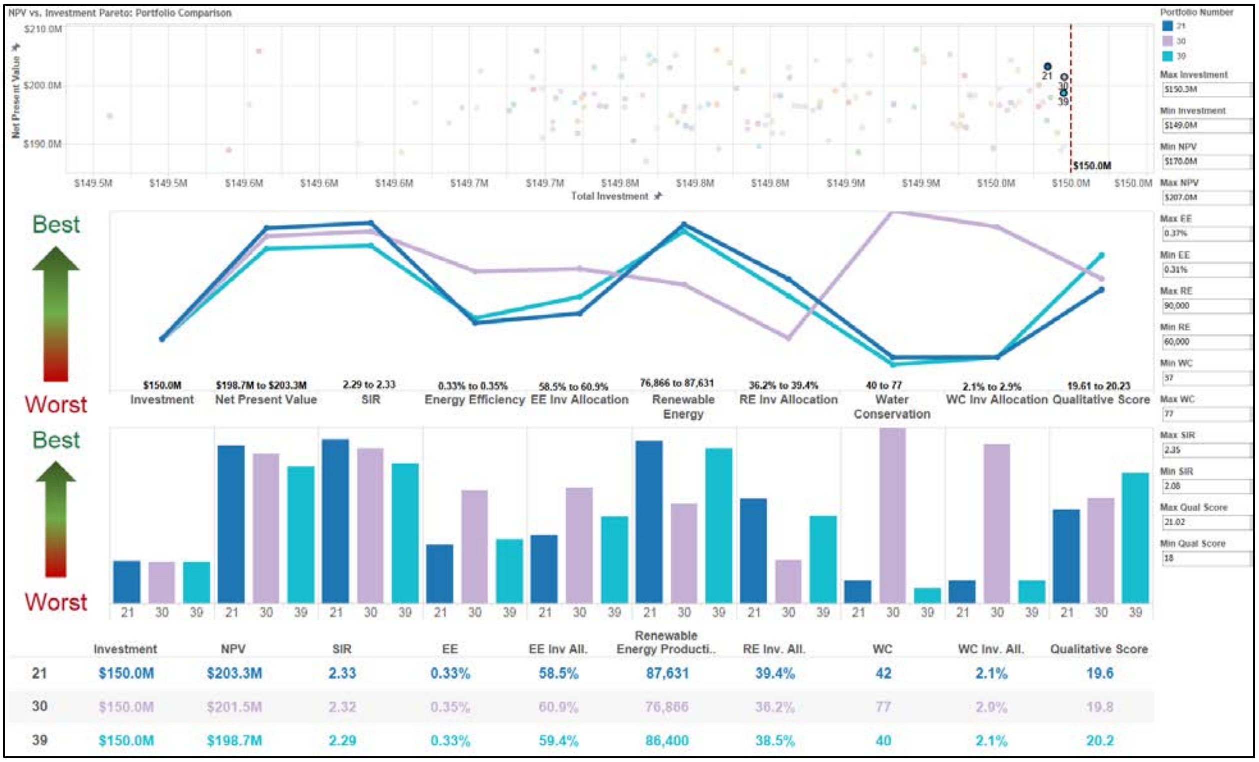


Figure 79. Multi-dimensional Metric Portfolio Comparison.

Figure 80 is similar to Figure 76, in that it is the same dashboard. However, this dashboard contains the results of the final analysis iteration conducted. The investment allocation across project type is better matching the target (horizontal red dashed line) than the initial analysis iteration.

Figure 81 shows the geographic distribution of the constituent portfolio projects chosen. The circle's center indicates the installation's geo-location. The circle size indicates the investment level for that project, and the size in the tree map chart underneath indicates the NPV that the project is generating.

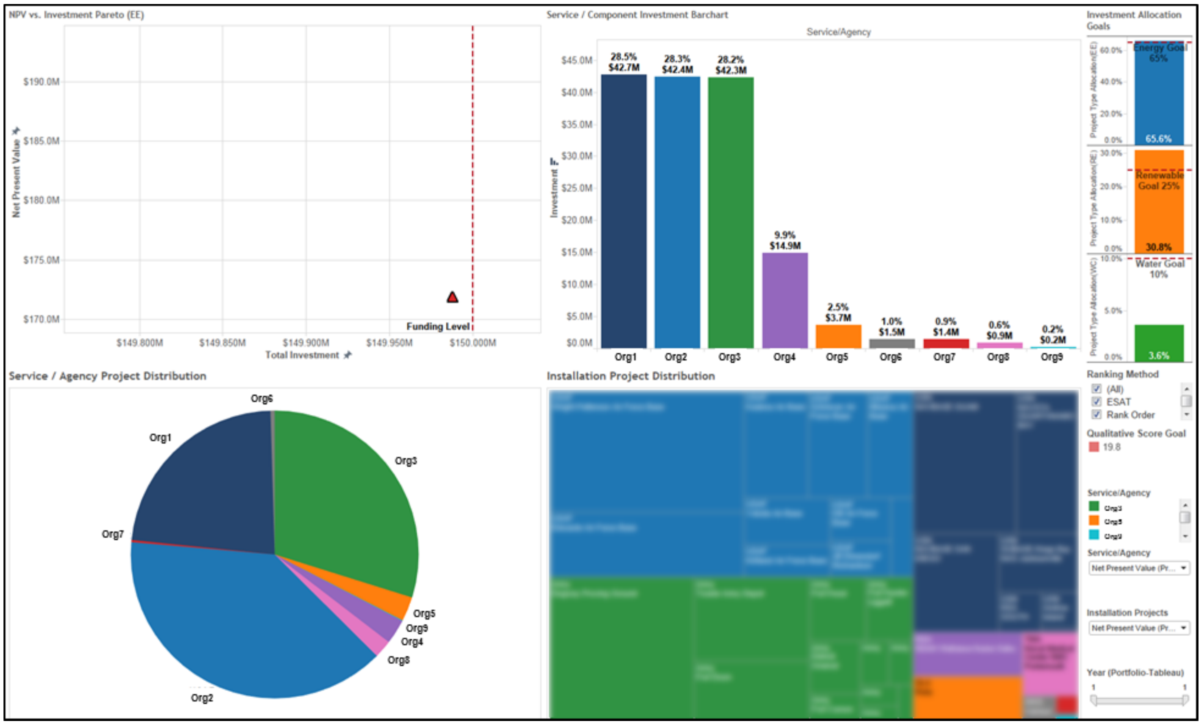


Figure 80. Selected Portfolio Project Composition and Distribution Among Services/Agencies and Installations. Later iteration, indicating improved service investment and goal accomplishment.

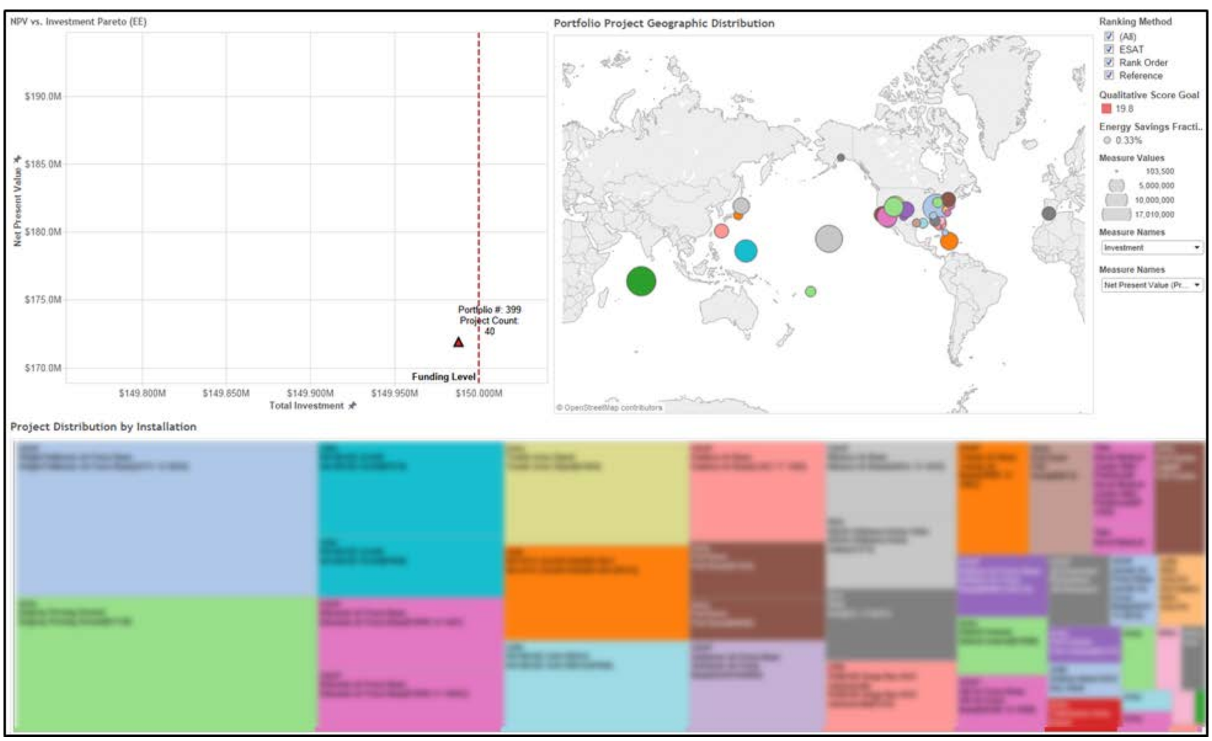


Figure 81. Selected Portfolio Project Composition and Geographic Distribution Among Installations.

Figure 82 shows a detail, project-by-project comparison between portfolios. In the instance shown, the final FY17 selected portfolio (Portfolio 399) generated by ESAT is compared to the most comparable (by investment) rank order produced portfolio (Portfolio 3,041). This enables the decision maker to determine exactly how ESAT is generating its value by noticing which project were and were not included in each portfolio. Key metrics are shown (table columns) and can be customized. If a colored square is present underneath the portfolio number, it indicates that the project is included in the portfolio. If there is no square present, then that project is not included in the portfolio.

Figure 83 is a tabular summary of the chosen portfolio of projects. Although the final form is MS Excel spreadsheet, it is generated from an ESAT exported report. This represents a key budget exhibit that ECIP provides US Congress to substantiate their portfolio investment decision. It shows the investments being made across the services/agencies, the projects selected, the installation location where the project will be implemented and their key metrics: SIR, and Simple Payback.

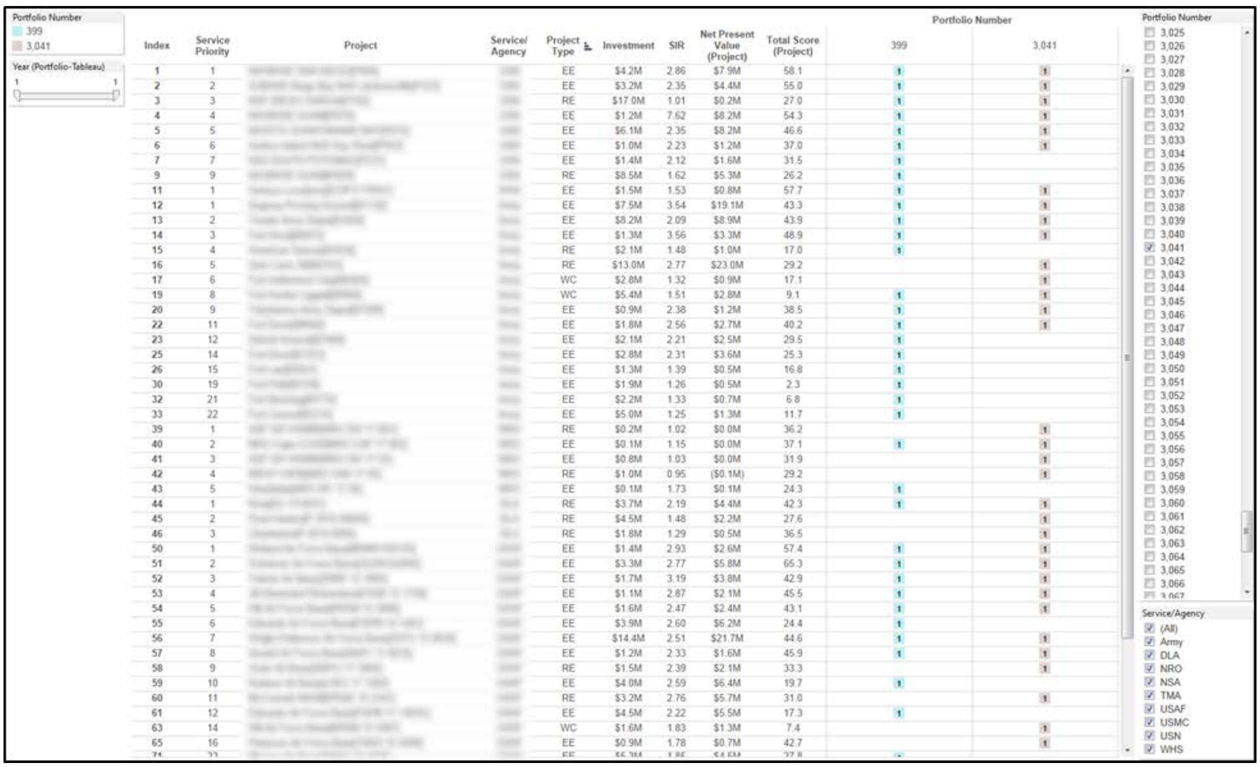


Figure 82. Selected ESAT and Rank Order Selected Portfolios Showing Included Projects, Along with Key Performance Metrics.

FY2017 Energy Conservation Investment Program, Congressional Notification FY2017 ECIP Project List					
Project No.	Project Description	Project Cost ($000)	SIR*	Payback	Project Type
Organization #1					
10001	Install a Microgrid Control System	$7,500	3.5	4.2	Energy Efficiency
10002	Install Gas Lines and Fuel Swapping	$8,200	2.1	9.4	Energy Efficiency
10003	Control System	$1,300	3.6	3.4	Energy Efficiency
10004	Install PV System	$2,100	1.5	12.6	Renewable Energy
10005	Wastewater Treatment Facility	$5,400	1.5	13.2	Water Conservation
10006	Retro Commission Facilities	$850	2.4	4.1	Energy Efficiency
10007	Retrocommission Phase II	$1,750	2.6	6.7	Energy Efficiency
10008	Recirculating Air	$2,050	2.2	8.1	Energy Efficiency
10009	LED Lighting	$2,750	2.3	6.5	Energy Efficiency
10010	Interior & Exterior Lighting	$1,250	1.4	9	Energy Efficiency
10011	Energy-Efficient Chillers, Lighting	$1,900	1.3	14.4	Energy Efficiency
10012	Retrofit Chillers	$2,200	1.3	12.8	Energy Efficiency
10013	Install High-Efficiency Boilers	$5,000	1.3	14.5	Energy Efficiency
Organization #1 Program Totals	**13 Projects**	**$42,250**	2.1	7.6	
Organization #2					
10014	Construct Solar Array	$3,708	2.2	8.6	Renewable Energy
Organization #2 Program Totals	**1 Projects**	**$3,708**	2.2	8.6	
Organization #3					
10016	LED Lighting	$104	1.2	2.1	Energy Efficiency
10017	Lighting Upgrade	$146	1.7	8.6	Energy Efficiency
Organization #3 Program Totals	**2 Projects**	**$250**	1.5	3.8	
Organization #4					
10018	Renewable Energy System Installations	$14,889	1.3	13	Renewable Energy
Organization #4 Program Totals	**1 Projects**	**$14,889**	1.3	13.0	
Organization #5					
10019	Facility Energy Improvements	$273	4	3.5	Energy Efficiency
10020	Retro Commissioning	$608	5	1.8	Energy Efficiency
Organization #5 Program Totals	**2 Projects**	**$881**	4.7	2.1	

Figure 83. Standard Budget Exhibit Tabular Report Showing Key Summary Service Project Data for Selected Portfolio.

6.5.5 FY 17 Decision Cycle Feedback

A performance objective feedback form was sent to the decision maker to collect his observations and experience using ESAT for the FY17 decision cycle. It was the same form as sent to his predecessor, therefore covering the same topics. The feedback provided was favorable. Comments cited analysis labor hours saved, accelerated analysis results, ability to interactively review the results, and mature visualizations offering better insights than the legacy approach. The full set of performance feedback detail can be found in Appendix G: ECIP FY17 Performance Objectives Feedback.

6.5.6 FY18-FY21 Multi-year Planning Analysis

In addition to the annual single year investment decision cycle (e.g. FY16, FY17) conducted during the early part of the fiscal year, a second decision cycle occurs a few months later. This second decision cycle is conducted for planning purposes and addresses a multiple year investment planning window – in this case FY18-FY21. It examines a larger set of candidate projects with different implementation start years, which are in the early stages of planning and development, and are submitted by the same services and agencies as the single year decision cycle. This is the first time that ESAT was applied to the ECIP multi-year planning process.

The decision analysis was based on very similar objectives, targets, constraints, and assumptions (full set shown below) as used in the single year analysis. The exception is that some of the constraints, which are typically used in later analysis iterations to refine a final selection, were relaxed as indicated.

- Objectives
  - Maximize NPV
  - Maximize Qualitative Score (Service Priority included)
  - Minimize Investment
- Target
  - Energy efficiency savings goal – 0.12%, 0.15% and 0.18%
  - Project Type Funding Allocation – 65% Energy Efficiency, 25% Renewable Energy, 10% Water Conservation
- Constraints
  - Qualitative Score goal – 10, 12, 14, 16, 18
  - One of the following:
    - At least one project selected per Service/Agency – not set
    - Minimum per Service/Agency investment requirement – not set
- Assumptions
  - NPV based on 20-year period
  - 3% real discount rate

The project data collected for the analysis is the same as that which is collected for single year analysis; however, the data is somewhat less mature, as the projects are not as advanced in their development as those being readied for near term funding as in the single year analysis. As a result, more effort than expected was spent on attempting to validate the data, though ultimately only limited validation was possible due to time constraints and agency response resource constraints.

Several new visualization dashboards were created or expanded for the multi-year planning analysis scenario. Although ESAT had a pre-existing capability to do multi-year analysis, some customizing for the ECIP scenario was necessary. ESAT's existing capability defines a portfolio of projects, invested over multiple years, and uniquely identifies the year in which the project is invested (assuming that the particular project is selected for investment). However, ECIP's primary need is not to determine and fix the investment over the four year period, but instead to provide guidance to the submitting installations as to the likelihood of its project submission being included in future single year optimized portfolios. This required the creation of a project "likelihood" metric that would provide this information. It is called "Inclusion Likelihood".

Figure 84 shows the new dashboard that conveys this information. The first column labeled "Inclusion Likelihood" is this indicator. It is the quantified probability that this project will be selected, subject to the objectives and constraints of the analysis trade study that produced the results. The next seven columns are key project attributes, including the submitting Service/Agency, Project Type (Energy Efficiency, Renewable Energy, Water Conservation), Investment, Net Present Value, Service Priority, FY Start (the earliest year in which the project can start), and finally the Installation and Project ID. Notice that this last column is also color shaded. The green color indicates a project more likely to be selected, the red color indicates a project which is less likely to be selected. This color indicator provides a quick visual guide as to a project's selection likelihood without having to read tabular vales. Note that the dashboard screenshot was taken midway through the project list to better illustrate the color indicator.

Inclusion Likeliho..	Service	Project Type	Investment	Net Present V..	SIR	Service Priority	FY Start	
0.65	[illegible]	RE	$1.800M	$0.900M	1.50	33	2021	[illegible]
0.64	[illegible]	RE	$3.050M	$0.457M	1.15	3	2021	[illegible]
0.64	[illegible]	RE	$1.100M	$0.209M	1.19	4	2021	[illegible]
0.64	[illegible]	EE	$3.400M	$1.700M	1.50	63	2020	[illegible]
0.63	[illegible]	EE	$2.904M	$1.016M	1.35	56	2020	[illegible]
0.62	[illegible]	EE	$9.100M	$4.277M	1.47	54	2020	[illegible]
0.60	[illegible]	RE	$8.170M	$4.167M	1.51	6	2021	[illegible]
	[illegible]	EE	$2.850M	$2.252M	1.79	71	2020	[illegible]
			$10.800M	$0.756M	1.07	45	2018	[illegible]
		RE	$6.900M	$0.345M	1.05	27	2020	[illegible]
			$7.100M	$7.171M	2.01	47	2018	[illegible]
	[illegible]	EE	$0.693M	$0.347M	1.50	33	2021	[illegible]
			$12.000M	$10.800M	1.90	27	2021	[illegible]
			$13.000M	$8.450M	1.65	51	2020	[illegible]
		RE	$5.900M	($1.180M)	0.80	24	2018	[illegible]
0.58	[illegible]	EE	$1.408M	$0.352M	1.25	70	2020	[illegible]
0.57	[illegible]	RE	$2.110M	$0.338M	1.16	7	2019	[illegible]
0.57	[illegible]	WC	$2.500M	$0.675M	1.27	75	2021	[illegible]
0.55	[illegible]	EE	$1.500M	$1.875M	2.25	109	2021	[illegible]
0.55	[illegible]	EE	$4.217M	$0.295M	1.07	62	2019	[illegible]
0.53	[illegible]	EE	$1.970M	$1.458M	1.74	9	2021	[illegible]
0.52	[illegible]	EE	$1.350M	$1.296M	1.96	93	2021	[illegible]
0.51	[illegible]	RE	$2.001M	$1.461M	1.73	9	2019	[illegible]
0.50	[illegible]	WC	$1.200M	$0.360M	1.30	57	2020	[illegible]
0.46	[illegible]	RE	$1.487M	$1.428M	1.96	42	2019	[illegible]
0.45	[illegible]	RE	$0.801M	$0.168M	1.21	19	2021	[illegible]
0.44	[illegible]	RE	$5.926M	$3.733M	1.63	62	2018	[illegible]
0.43	[illegible]	EE	$3.450M	$4.306M	2.25	96	2021	[illegible]
0.42	[illegible]	RE	$5.500M	$0.605M	1.11	35	2020	[illegible]
0.40	[illegible]	RE	$18.700M	$59.840M	4.20	4	2021	[illegible]
	[illegible]	RE	$1.400M	$2.590M	2.85	77	2019	[illegible]
			$6.300M	$4.788M	1.76	72	2020	[illegible]
0.36	[illegible]	RE	$4.000M	$4.600M	2.15	94	2021	[illegible]
0.36	[illegible]	EE	$1.086M	$0.543M	1.50	71	2021	[illegible]
0.34	[illegible]	RE	$17.000M	$10.200M	1.60	61	2018	[illegible]
0.31	[illegible]	RE	$2.600M	$1.092M	1.42	38	2018	[illegible]

Figure 84. Inclusion Likelihood for Multi-year Planning Analysis

Figure 85 is a new dashboard which illustrates investment distribution over the multi-year period. In the upper left quadrant of the dashboard, the portfolio of interest is selected. This selection filters and defines the remainder of the portfolio metric detail shown in the dashboard. In the upper right quadrant, the total annual investment amount for each of the planning years is indicated. Also, the funding allocation split across project types is indicated using different colors. The bottom half of the dashboard describes the project level detail for the portfolio. The key project attributes are shown as well as the year in which the project was selected to be invested in. The same project type color is retained.

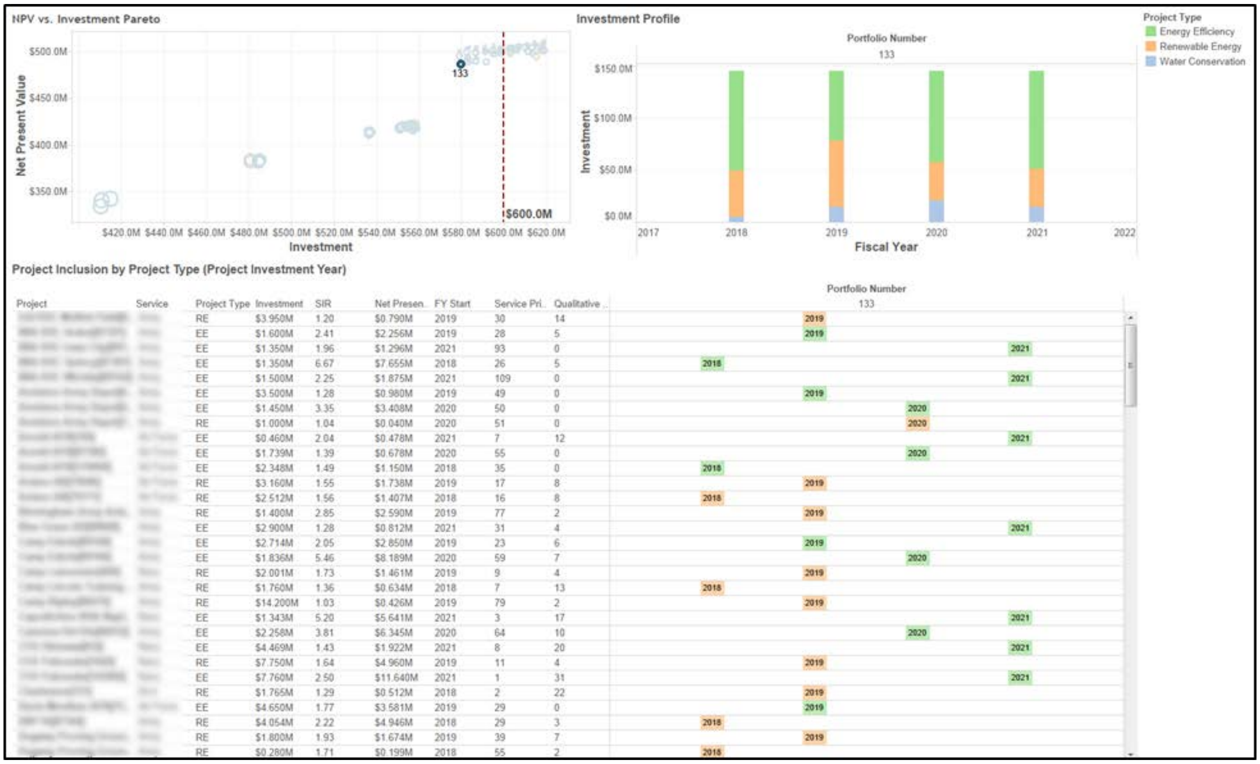


Figure 85. Project Inclusion for Multi-year Planning Analysis

The portfolio comparison dashboard, shown in Figure 86, has been upgraded and expanded compared to the single year analysis previously reviewed. Expanding the analysis from single year to multi-year introduces more complexity regarding the intermediate/annual metric values as well as how investment across various dimensions are allocated. As usual, the upper left quadrant is where the portfolio of interest is selected to learn more about the characterization of that portfolio. This selection defines what data is presented in the other graphs in this dashboard. In the upper right quadrant, the number of projects invested in for each of the years is shown. In the lower left quadrant, there is a grouping of comparison financial metrics – SIR, NPV, Investment, and Service Priority Rank, which are shown for each portfolio of interest and for each planning year. Finally, in the lower right quadrant, the same portfolios are compared but now energy metrics are compared – energy savings, water savings, and renewable energy generation. Here, the colors indicate and are unique to the portfolio selected, and are common across all the graphs in this dashboard.

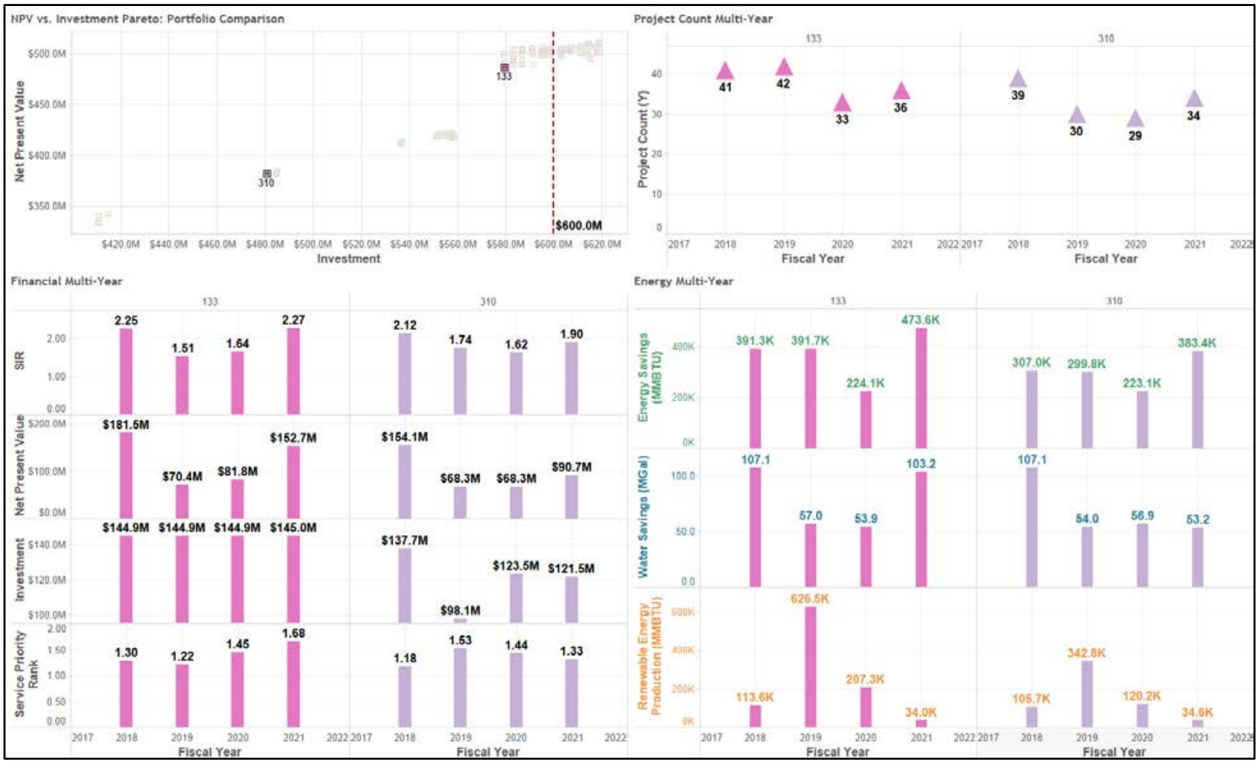


Figure 86. Portfolio Comparison for Multi-year Planning Analysis

Figure 87 is also a portfolio comparison dashboard, including data representing multiple years of investment. In this case, the dashboard's focus is on the progress towards energy goals. The upper left quadrant is where the portfolios of interest is selected for comparison. The other graphs in the dashboard are updated with these selections. The upper right quadrant indicates the annual investment level for each of the years, including the cumulative amount. Note that this is a dual axis bar chart. The left y-axis measures the annual investment, while the right y-axis measures the cumulative investment. The lower half of the dashboard contains the energy goal measures charts: Annual Energy Efficiency Achieved vs. Goal, Renewable Energy Achieved vs. Goal, and Annual Water Savings vs. Goal. These improvement goals are relative to DoD baseline energy/water usage and renewable energy generation.

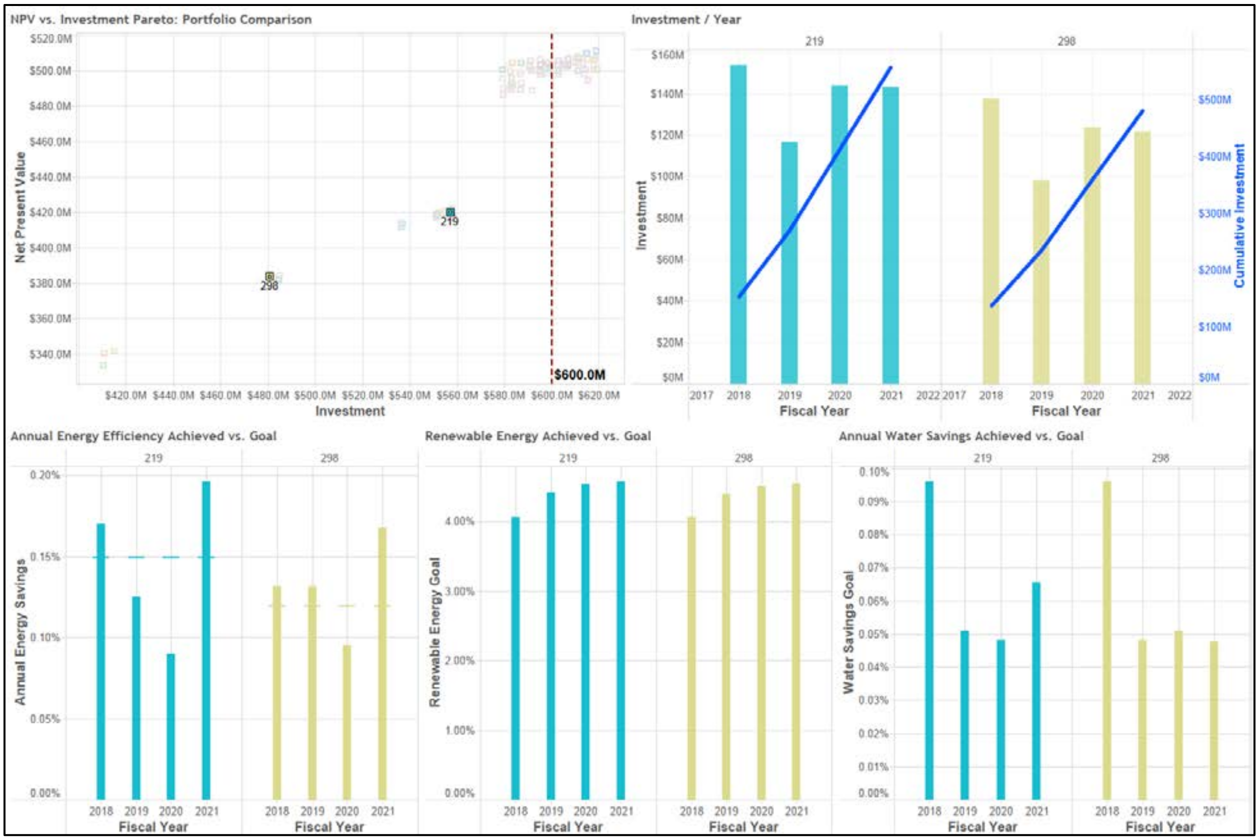


Figure 87. Portfolio Comparison Relative to Meeting Project Goals for Multi-year Planning Analysis

The energy savings profile dashboard shown in Figure 88 is not new, and versions of it have been presented earlier in this report. However, it can be more useful to review this dashboard in the multi-year analysis scenario vs. the single year investment scenario because it is a more complex scenario and has potential additional interactions which occur with multiple year considerations. Thus, a clear visualization helps clarify this interaction and can offer significant assistance.

Here, each year of investment, cost, and savings is shown in a stacked bar format. Note that in order to better show all data elements more clearly, the graph doesn't start at the origin. This was due to the large continuing operations cost value, which would have obscured other data elements due to its relatively large value had this not been done.

The red color segment represents the upfront investment – the investment ECIP allocates each year in its decision cycle. The pink color segment represents savings realized from the improvement projects, counteracting their required investment and indicating that they are beginning to payback. The light green segment represents continued savings from implementing the projects, but these savings are still in process of paying off the original investment. When these savings eventually payback the whole of the original investment, all future savings (dark green color segment) are realized fully by the organization. The result is a net reduction in energy related operations cost and these savings persist for the economic life of the underlying projects in the portfolio.

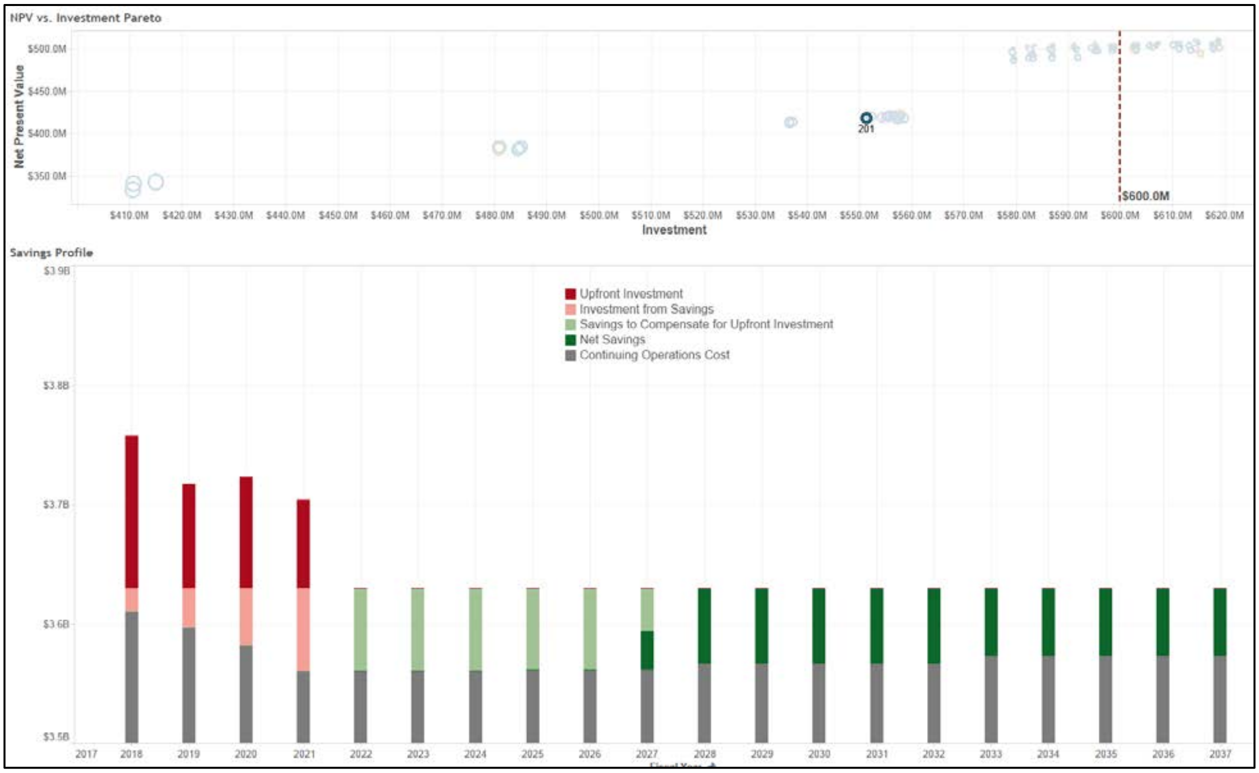


Figure 88. Energy Savings Profile for Multi-year Planning Analysis

As mentioned, no actual investment is being made during this planning analysis, so any identified improvements, benefits, or savings are preliminarily conceptual. However, ESAT is still providing meaningful value:

- By looking ahead at what projects are being considered, the decision maker can encourage and influence the types of projects that he wants submitted in upcoming single year decision cycles.
- The project selection likelihood metric, provided as feedback to the submitting service/agency, will likely improve the quality of projects submitted in the long term. This claim is based on the logic that submitters will get an early indication whether the project they are proposing needs improvement or is worth developing further. This will naturally weed out weaker projects over time and encourage those candidate projects which hold more promising results. This preliminary review of projects provides an intrinsic quality filter. Therefore, when the time comes for real investment decisions to be made and real money spent, many poorer quality projects will have never been submitted and the better quality projects will have been improved because of the previous review cycles.
- It demonstrates the benefits of a holistic investment approach. Although real monetary savings aren't immediately realized in this planning process, they could be if the investment process were changed to align with the planning process. If the benefits of multi-year investment optimization could be presented to decision makers who *provides* the investment funds (vs. the decision maker who *allocates* the funds), perhaps out-year commitment could be made as to the expected investment available to fund the multi-year scenario and the additional savings and benefits could then be captured. This savings results from the additional flexibility of more options (start year slots) to position projects.

6.5.7 FY18 Decision Cycle Analysis

A contract extension was approved to undertake additional FY17 work, the majority of effort to be focused on applying ESAT in support of an additional ECIP portfolio optimization decision cycle (FY18) and an additional cycle of multi-year planning analysis (FY19-FY22).

In preparation for these decision cycles, the model was enhanced, incorporating a new energy resilience metric into the portfolio optimization analysis. Currently, this is a qualitative metric (assigned by the ECIP team, based on the inputs provided by the project submitters) that assesses how well a project addresses energy resilience at their installation. This portfolio metric is called "Resilience Score Average" (RSA). It combines the individual resilience metrics of the portfolio's constituent projects into a portfolio level metric. Resilience is now an additional objective that is being pursued by ESAT in its multi-objective analysis.

To support this new metric, an additional visualization dashboard was created to enables a side-by-side comparison of the Resilience and Qualitative Score metrics. Figure 89 shows this new dashboard. Each of these metrics is measured against NPV. A selection in either worksheet automatically highlights the same portfolio in the opposite worksheet, so that it is easier to simultaneously consider both the Qualitative and Resilience score metrics.

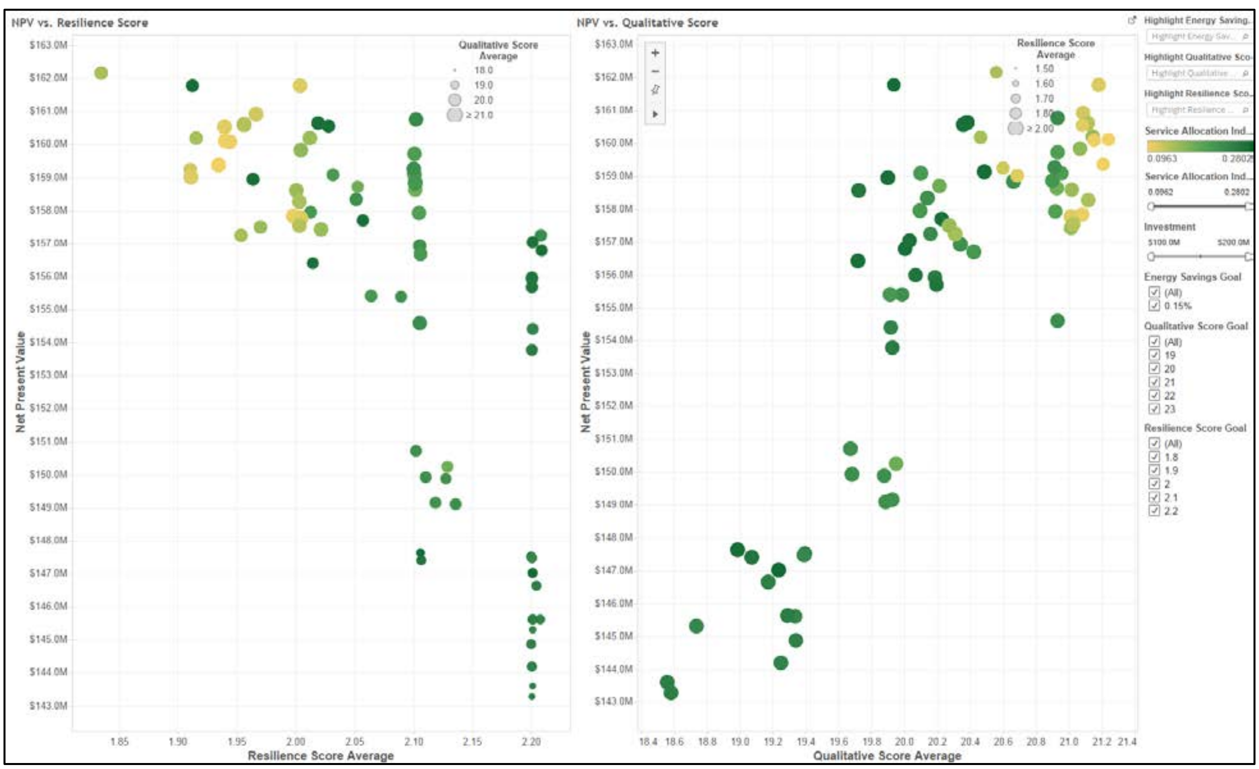


Figure 89. NPV vs. Resilience and Qualitative Score

Additionally, a metric called "Service Allocation Index" was created. This is a metric that enables assessing how close a portfolio is adhering to the intended service investment allocation defined in the analysis run.

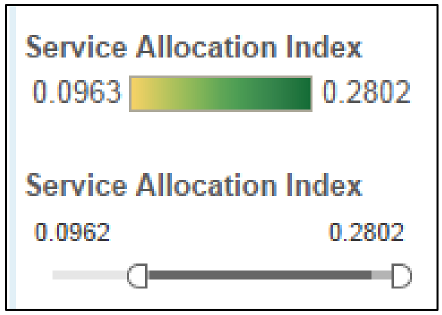


Figure 90. Enlarged Service Allocation Index Legend

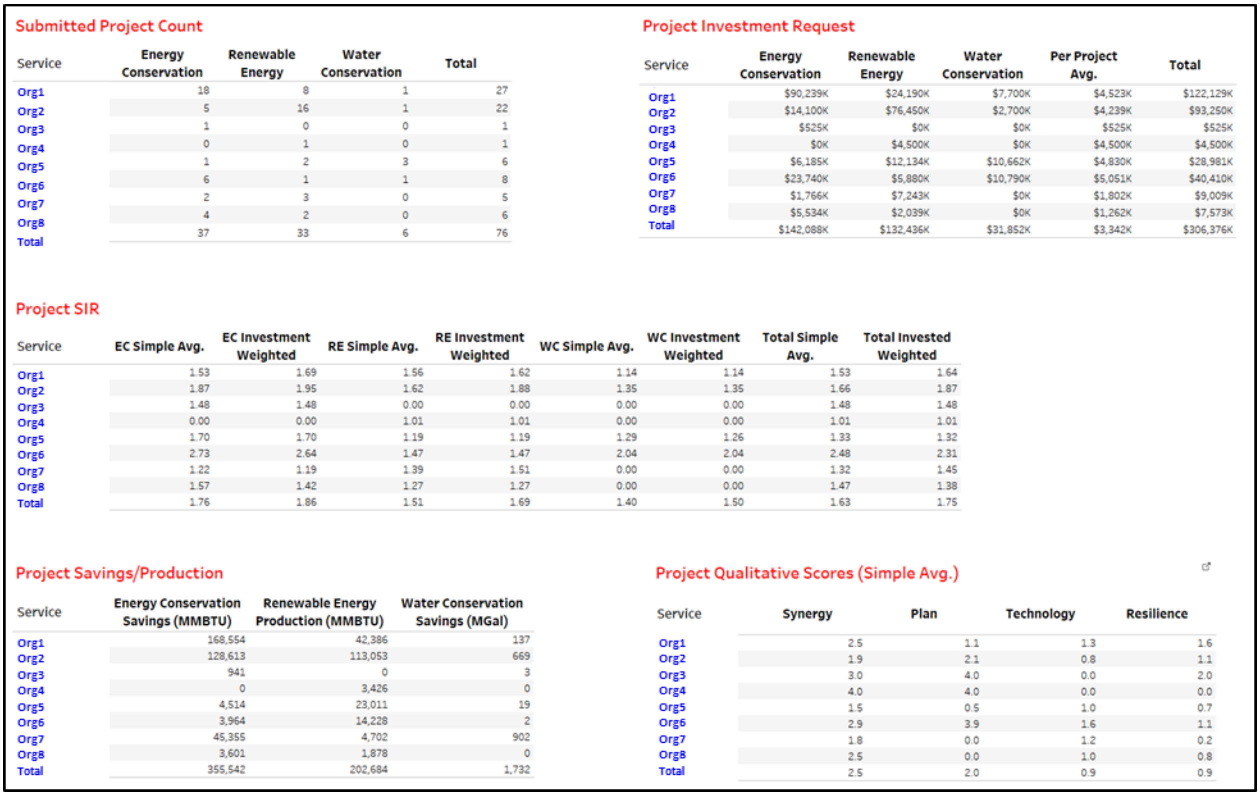
In Figure 90, an enlarged image of the dashboard legend from Figure 89 is shown. This legend indicates how the coloring of the portfolio symbols (circles) represent the Service Allocation Index value. In this instance, the yellow coloring designates a smaller difference between the service investment allocation goal and the actual portfolio allocation result, and green represents larger differences from goal.

The size of the symbol represents the opposite worksheet metric's value – for example, in the NPV vs. Resilience Score Average worksheet, the size of the circles represents the value of Qualitative Score Average. The larger the circle's diameter, the higher the Qualitative Score Average value. Similarly, in the NPV vs. Qualitative Score Average worksheet, the size of the circles represents the value of Resilience Score Average. The larger the circle's diameter, the higher the value Resilience Score Average.

We streamlined the process of generating multi-objective analyses, trade studies, and producing interactive analysis results. This substantially improved the turnaround time for producing new decision support analysis. Streamlining activities included data restructuring which enabled faster load time of results, and automating the generation of results files via Python script. In addition to the speed of generating the results, the automating of these processes also improved their reliability and quality, as fewer manual transactions now occur in creating the results, thus reducing the opportunity for human error.

Other additional reference dashboards were created to help support the decision process. The visualization set evolves over time as the decision criteria and decision maker preferences evolve. Three of these dashboards are shown here.

The first dashboard, Figure 91, is referred to as the "Descriptive Statistics" dashboard. It is common that while browsing the portfolio results, one wonders why the results are as they are. Questions may arise such as, "Why did Service X have so many/few projects selected", or "Why are so many/few of Project Type X projects selected?" By examining this dashboard, which summarizes the raw project data in many ways – in conjunction with the analysis results, some of these questions can be answered more easily. Note that this dashboard is not portfolio dependent. It is created once at the beginning of the decision cycle before portfolio analysis begins.



Submitted Project Count

Service	Energy Conservation	Renewable Energy	Water Conservation	Total
Org1	18	8	1	27
Org2	5	16	1	22
Org3	1	0	0	1
Org4	0	1	0	1
Org5	1	2	3	6
Org6	6	1	1	8
Org7	2	3	0	5
Org8	4	2	0	6
Total	37	33	6	76

Project Investment Request

Service	Energy Conservation	Renewable Energy	Water Conservation	Per Project Avg.	Total
Org1	$90,239K	$24,190K	$7,700K	$4,523K	$122,129K
Org2	$14,100K	$76,450K	$2,700K	$4,239K	$93,250K
Org3	$525K	$0K	$0K	$525K	$525K
Org4	$0K	$4,500K	$0K	$4,500K	$4,500K
Org5	$6,185K	$12,134K	$10,662K	$4,830K	$28,981K
Org6	$23,740K	$5,880K	$10,790K	$5,051K	$40,410K
Org7	$1,766K	$7,243K	$0K	$1,802K	$9,009K
Org8	$5,534K	$2,039K	$0K	$1,262K	$7,573K
Total	$142,088K	$132,436K	$31,852K	$3,342K	$306,376K

Project SIR

Service	EC Simple Avg.	EC Investment Weighted	RE Simple Avg.	RE Investment Weighted	WC Simple Avg.	WC Investment Weighted	Total Simple Avg.	Total Invested Weighted
Org1	1.53	1.69	1.56	1.62	1.14	1.14	1.53	1.64
Org2	1.87	1.95	1.62	1.88	1.35	1.35	1.66	1.87
Org3	1.48	1.48	0.00	0.00	0.00	0.00	1.48	1.48
Org4	0.00	0.00	1.01	1.01	0.00	0.00	1.01	1.01
Org5	1.70	1.70	1.19	1.19	1.29	1.26	1.33	1.32
Org6	2.73	2.64	1.47	1.47	2.04	2.04	2.48	2.31
Org7	1.22	1.19	1.39	1.51	0.00	0.00	1.32	1.45
Org8	1.57	1.42	1.27	1.27	0.00	0.00	1.47	1.38
Total	1.76	1.86	1.51	1.69	1.40	1.50	1.63	1.75

Project Savings/Production

Service	Energy Conservation Savings (MMBTU)	Renewable Energy Production (MMBTU)	Water Conservation Savings (MGal)
Org1	168,554	42,386	137
Org2	128,613	113,053	669
Org3	941	0	3
Org4	0	3,426	0
Org5	4,514	23,011	19
Org6	3,964	14,228	2
Org7	45,355	4,702	902
Org8	3,601	1,878	0
Total	355,542	202,684	1,732

Project Qualitative Scores (Simple Avg.)

Service	Synergy	Plan	Technology	Resilience
Org1	2.5	1.1	1.3	1.6
Org2	1.9	2.1	0.8	1.1
Org3	3.0	4.0	0.0	2.0
Org4	4.0	4.0	0.0	0.0
Org5	1.5	0.5	1.0	0.7
Org6	2.9	3.9	1.6	1.1
Org7	1.8	0.0	1.2	0.2
Org8	2.5	0.0	1.0	0.8
Total	2.5	2.0	0.9	0.9

Figure 91. Descriptive Statistics

The second dashboard, Figure 92, is a matrix plot. It consists of multiple scatter plots, representing a variety of parameter combinations and their relationships. This format has the advantage of enabling the simultaneous examination of portfolio metrics in a single view, without having to navigate among several dashboards and remember what was recently seen elsewhere. The disadvantage is that as the number of plots increase, the physical dimensions of each plot decreases, eventually becoming more difficult to see details and extract insights due to its smaller size. Nevertheless, a lot of information is contained within the dashboard, and it is available for the decision maker to reference while contemplating his next decision, whether interim or final.

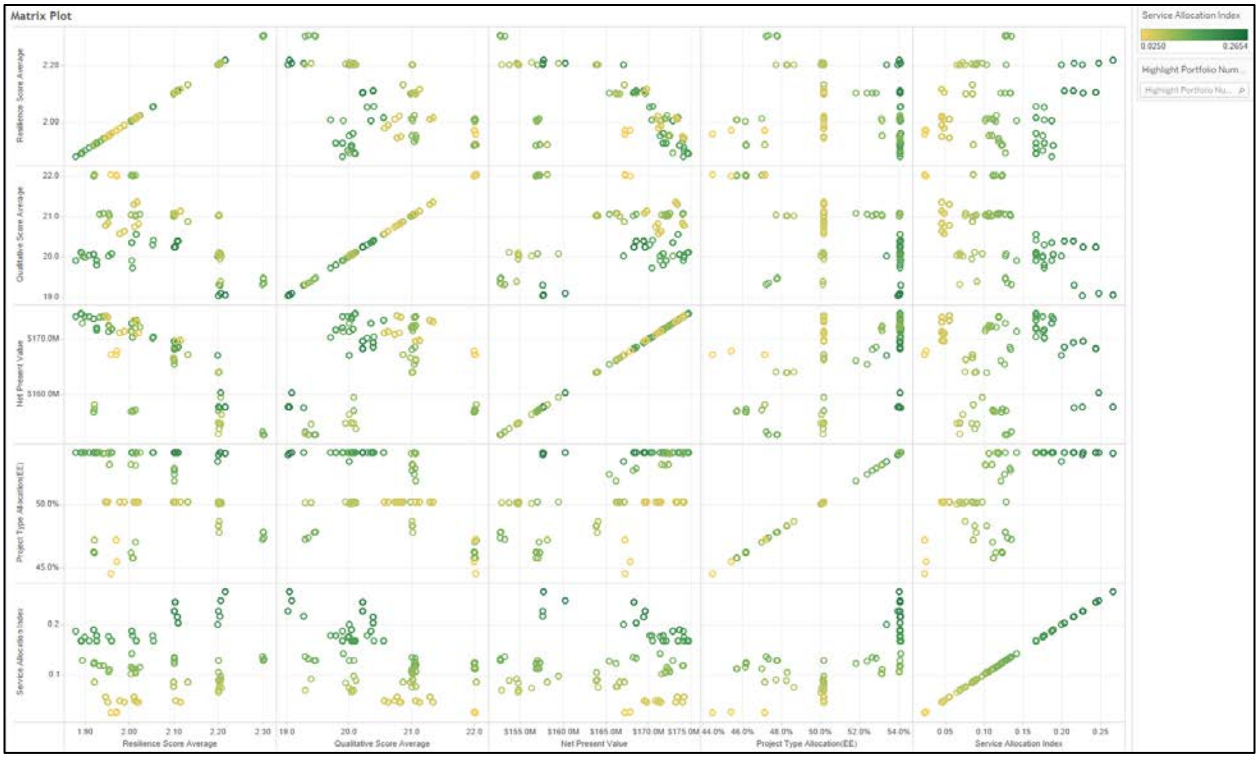


Figure 92. Matrix Plot

Figure 93 is a custom table that was created to function as another portfolio comparison option. In this case, all portfolio information is tabular. Any number of portfolios can be simultaneously compared within this table using the portfolio filter selector. Many key portfolio attributes are contained in the table, such as Investment, NPV, Qualitative Score Average, Resilience Score Average, Project Type investment, Service investment allocation, etc.

Portfolio Comparison Table

												Service							
												Org1	Org2	Org3	Org4	Org5	Org6	Org7	Org8
Portfolio Number	Investment	Net Present Value	Qualitative Score Average	Resilience Score Average	Project Type Allocation(EE)	Project Type Allocation(RE)	Project Type Allocation(WC)	Energy Savings	Renewable Energy Production	Water Savings	SIR	Investment	Investment	Investment	Investment	Investment	Investment	Investment	Investment
1	$149.9M	$171.7M	19.8	1.93	54.1%	36.9%	9.0%	248,502	71,235	982.0	2.15	$60.6M	$45.0M		$0.5M		$9.8M	$33.1M	$1.0M
15	$150.0M	$156.9M	22.0	1.92	46.2%	43.8%	9.9%	210,364	76,591	983.0	2.05	$52.5M	$45.1M	$3.8M	$0.5M	$4.5M	$11.2M	$31.5M	$1.0M
25	$149.9M	$172.5M	21.1	1.95	54.1%	36.9%	9.0%	232,462	68,666	982.0	2.15	$55.3M	$45.1M	$3.8M	$0.5M		$9.8M	$34.5M	$1.0M
40	$150.1M	$172.9M	20.4	2.01	54.1%	36.9%	9.0%	248,673	80,055	979.7	2.15	$61.4M	$45.1M				$9.8M	$33.1M	$0.8M
75	$150.0M	$152.8M	19.5	2.30	47.8%	45.0%	7.2%	213,860	91,818	930.0	2.02	$57.5M	$45.8M	$2.1M	$0.5M		$9.8M	$34.3M	
100	$149.9M	$169.6M	21.1	2.11	50.2%	40.8%	9.0%	221,135	79,972	979.3	2.13	$54.8M	$45.0M				$9.8M	$40.4M	
120	$150.0M	$169.8M	21.1	2.12	50.2%	40.8%	9.0%	221,628	79,972	982.0	2.13	$54.3M	$45.0M		$0.5M		$9.8M	$40.4M	
137	$150.0M	$154.8M	20.0	2.20	50.0%	41.0%	9.0%	221,319	85,631	982.4	2.03	$54.3M	$45.3M	$1.8M	$0.5M		$9.8M	$37.7M	$0.8M
138	$150.1M	$156.4M	20.0	2.21	50.1%	41.0%	9.0%	220,776	85,631	982.0	2.04	$56.1M	$45.3M		$0.5M		$9.8M	$38.4M	

Figure 93. Portfolio Comparison Table

We completed 21 optimization and decision support iterations in the January - March 2017 time period, in support of the FY18 ECIP portfolio selection. These iterations were generally produced in themed analysis groupings, with the intent to explore specific impacts of input parameter variations on portfolio results and their performance metrics.

1. **Baseline –** this consisted of the initial unconstrained model runs using the raw project data and subsequent revisions to project data as they were updated and improved.

2. **Service Investment Allocation –** this analysis explored the impacts of service investment allocation minimums and how it affected portfolio metrics and project distribution across the services. The investment range was also narrowed to explore portfolios nearer the expected final $150M investment level. The Service Investment Allocation definition sets were eventually reduced as their impact was better understood.
3. **Resiliency –** this analysis explored the impact on portfolio SIR and other metrics when investing in select resilience focused projects.
4. **Project investment and selection –** this analysis explored the impacts of force selecting or excluding individual projects or groups of projects. Additionally, partial funding of projects was explored.

6.5.8 FY19-FY22 Multi-year Planning Analysis

A second multi-year planning analysis was conducted on the FY19-FY22 project set, over the April-July 2017 period. Projects submitted totaled 179, representing $843M of investment. Over the study period, eight data revisions were made to complete or correct project data.

Five analysis iterations were completed:

- The first three analysis iterations were baseline analyses – meaning that the solution space was represented by a full investment range with the primary difference between the analyses being that each was conducted with newly revised data.
- The fourth analysis iteration had a narrower focus, constraining the four year total investment to $600M, plus or minus $20M. This represents a more likely decision scenario, whereby approximately $150M (the current annual investment level) is invested each year over a four year period.
- The fifth analysis was intended as an early view of what a FY19 single year investment analysis might look like. Note that this analysis does not include the projects with starting years beginning in FY20-FY22.

No new visualizations were needed to be created for these analyses, either for the single year or the multi-year. Previously used visualizations were sufficient.

The fourth and final multi-year analysis was based on very similar objectives, targets, constraints, and assumptions (full set shown below) as used in single year analysis. The exception is that some of the constraints, which are typically used in later analysis iterations to refine a final selection, were relaxed as indicated.

- Objectives
  - Maximize NPV
  - Maximize Qualitative Score (Service Priority included)
  - Minimize Investment
- Target
  - Energy efficiency savings goal – 0, 0.3%
  - Renewable energy production goal – not set
  - Water conservation goal – not set

- – Project Type Funding Allocation – 65% Energy Efficiency, 25% Renewable Energy, 10% Water Conservation
- Constraints
  - – Qualitative Score goal – 0, 4, 6, 8
  - – Resilience Score goal – 0
  - – One of the following:
    - ▪ At least one project selected per Service/Agency – not set
    - ▪ Minimum per Service/Agency investment requirement – not set
- Assumptions
  - – NPV based on 20 year period
  - – 3% real discount rate

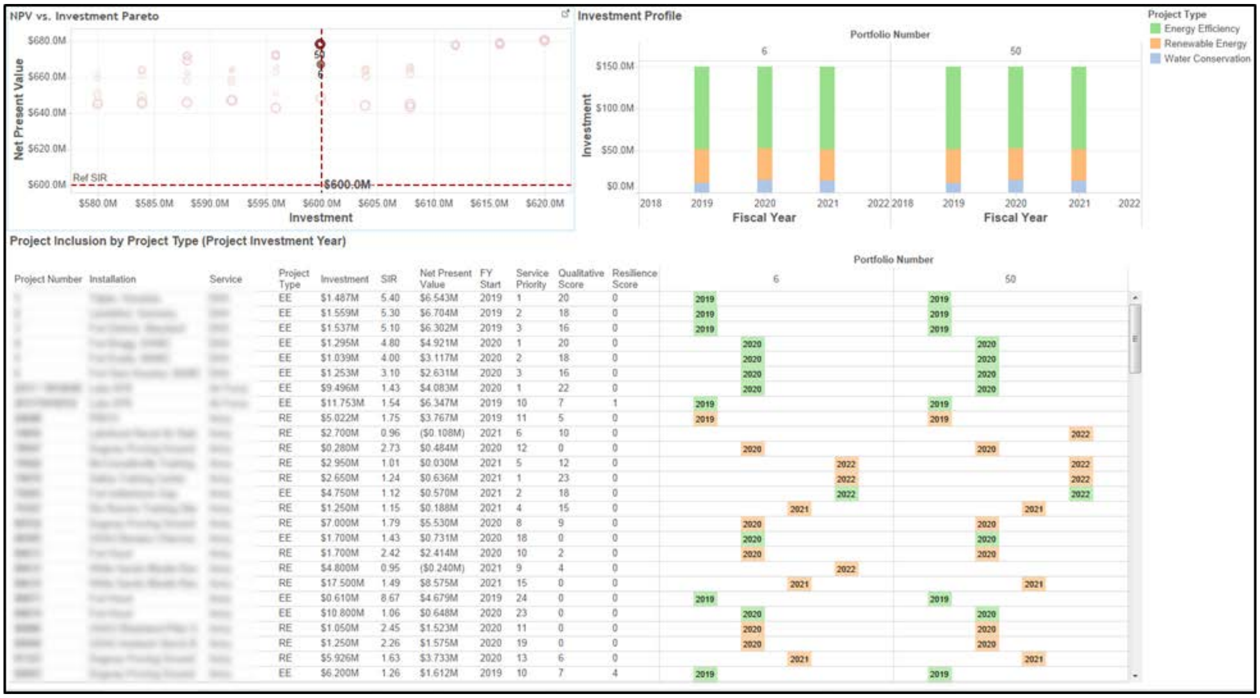
Figure 94 is the Project Inclusion Likelihood dashboard. A sample set of "middle range" likelihood projects is shown, with their associated inclusions likelihood values. The inclusion likelihood is the quantified probability that a given project will be selected for a portfolio, subject to the objectives and constraints of the analysis trade study that produced the results.

Inclusion Likelihood	Service	Project Type	Investment	Net Present Value	SIR	Service Priority	FY Start	
0.76	[illegible]	RE	$2.100M	$0.084M	1.04	19	2021	[illegible]
0.75	[illegible]	EE	$4.640M	($1.253M)	0.73	3	2020	[illegible]
0.72	[illegible]	RE	$1.250M	$0.188M	1.15	4	2021	[illegible]
			$2.950M	$0.030M	1.01	5	2021	[illegible]
0.70	[illegible]	RE	$2.720M	$1.795M	1.66	4	2019	[illegible]
0.68	[illegible]	EE	$1.360M	$0.054M	1.04	4	2020	[illegible]
0.67	[illegible]	RE	$2.700M	($0.108M)	0.96	6	2021	[illegible]
	[illegible]	WC	$7.006M	$1.331M	1.19	1	2019	[illegible]
0.66	[illegible]	EE	$1.850M	$0.278M	1.15	24	2021	[illegible]
0.65	[illegible]	EE	$0.603M	$0.295M	1.49	2	2022	[illegible]
		RE	$4.100M	$0.000M	1.00	8	2021	[illegible]
	[illegible]	EE	$1.700M	$0.340M	1.20	23	2021	[illegible]
0.63	[illegible]	RE	$0.581M	$0.218M	1.38	8	2019	[illegible]
	[illegible]	EE	$4.750M	$0.570M	1.12	2	2021	[illegible]
0.62	[illegible]	EE	$6.100M	($1.586M)	0.74	2	2020	[illegible]
0.61	[illegible]	EE	$7.000M	$1.400M	1.20	8	2022	[illegible]
0.59	[illegible]	EE	$3.213M	$0.739M	1.23	8	2022	[illegible]
	[illegible]	RE	$1.000M	$0.380M	1.38	4	2020	[illegible]
	[illegible]	EE	$3.429M	$0.411M	1.12	7	2021	[illegible]
0.58	[illegible]	EE	$4.370M	$0.000M	1.00	2	2021	[illegible]
		RE	$0.289M	$0.017M	1.06	11	2020	[illegible]
	[illegible]	EE	$7.000M	$1.400M	1.20	6	2022	[illegible]
	[illegible]	WC	$7.700M	$1.078M	1.14	5	2020	[illegible]
0.56	[illegible]	WC	$6.878M	($0.894M)	0.87	4	2021	[illegible]
	[illegible]	WC	$2.230M	$1.271M	1.57	1	2020	[illegible]
0.54	[illegible]	WC	$6.300M	$0.630M	1.10	1	2021	[illegible]
0.53	[illegible]	RE	$4.800M	($0.240M)	0.95	9	2021	[illegible]
0.48	[illegible]	EE	$0.896M	($0.152M)	0.83	10	2021	[illegible]
		WC	$15.000M	$7.500M	1.50	7	2022	[illegible]
	[illegible]	RE	$0.785M	$0.275M	1.35	11	2019	[illegible]
0.47	[illegible]	RE	$0.131M	($0.029M)	0.78	6	2022	[illegible]
		WC	$15.560M	$25.207M	2.62	4	2022	[illegible]
	[illegible]	RE	$2.750M	($0.963M)	0.65	2	2022	[illegible]
0.41	[illegible]	EE	$0.567M	($0.244M)	0.57	5	2022	[illegible]
	[illegible]	RE	$3.950M	($0.474M)	0.88	17	2021	[illegible]
0.35	[illegible]	EE	$7.800M	$1.170M	1.15	9	2021	[illegible]
	[illegible]	RE	$1.850M	$0.851M	1.46	1	2020	[illegible]
0.33	[illegible]	RE	$2.149M	$1.203M	1.56	6	2019	[illegible]
0.25	[illegible]	RE	$1.250M	$0.388M	1.31	10	2020	[illegible]
	[illegible]	RE	$7.000M	($3.640M)	0.48	4	2022	[illegible]

Figure 94. Inclusion Likelihood for Multi-year Planning Analysis

Figure 95 shows a comparison of portfolios and their investment distribution over the multi-year period. Two portfolios have been selected around the $600M investment level. In the upper right quadrant, the total annual investment amount for each of the planning years is indicated. Also, the funding allocation split across project types is indicated using unique colors. The bottom half of the dashboard describes the project level detail of the portfolio. The key project attributes are shown as well as the year in which the project was selected to be invested.

Figure 96 displays the intermediate, annual portfolio metric values as well as how investment across various dimensions are allocated. In the upper right, the number of projects invested in for each of the years is shown. In the lower left, there is a grouping of comparison financial metrics for each planning year. In the lower right, the same portfolios are compared across key energy metrics.



Project Number	Installation	Service	Project Type	Investment	SIR	Net Present Value	FY Start	Service Priority	Qualitative Score	Resilience Score
[illegible]	[illegible]	[illegible]	EE	$1.487M	5.40	$6.543M	2019	1	20	0
[illegible]	[illegible]	[illegible]	EE	$1.559M	5.30	$6.704M	2019	2	18	0
[illegible]	[illegible]	[illegible]	EE	$1.537M	5.10	$6.302M	2019	3	16	0
[illegible]	[illegible]	[illegible]	EE	$1.295M	4.80	$4.921M	2020	1	20	0
[illegible]	[illegible]	[illegible]	EE	$1.039M	4.00	$3.117M	2020	2	18	0
[illegible]	[illegible]	[illegible]	EE	$1.253M	3.10	$2.631M	2020	3	16	0
[illegible]	[illegible]	[illegible]	EE	$9.496M	1.43	$4.083M	2020	1	22	0
[illegible]	[illegible]	[illegible]	EE	$11.753M	1.54	$6.347M	2019	10	7	1
[illegible]	[illegible]	[illegible]	RE	$5.022M	1.75	$3.767M	2019	11	5	0
[illegible]	[illegible]	[illegible]	RE	$2.700M	0.96	($0.108M)	2021	6	10	0
[illegible]	[illegible]	[illegible]	RE	$0.280M	2.73	$0.484M	2020	12	0	0
[illegible]	[illegible]	[illegible]	RE	$2.950M	1.01	$0.030M	2021	5	12	0
[illegible]	[illegible]	[illegible]	RE	$2.650M	1.24	$0.636M	2021	1	23	0
[illegible]	[illegible]	[illegible]	EE	$4.750M	1.12	$0.570M	2021	2	18	0
[illegible]	[illegible]	[illegible]	RE	$1.250M	1.15	$0.188M	2021	4	15	0
[illegible]	[illegible]	[illegible]	RE	$7.000M	1.79	$5.530M	2020	8	9	0
[illegible]	[illegible]	[illegible]	EE	$1.700M	1.43	$0.731M	2020	18	0	0
[illegible]	[illegible]	[illegible]	RE	$1.700M	2.42	$2.414M	2020	10	2	0
[illegible]	[illegible]	[illegible]	RE	$4.800M	0.95	($0.240M)	2021	9	4	0
[illegible]	[illegible]	[illegible]	RE	$17.500M	1.49	$8.575M	2021	15	0	0
[illegible]	[illegible]	[illegible]	EE	$0.610M	8.67	$4.679M	2019	24	0	0
[illegible]	[illegible]	[illegible]	EE	$10.800M	1.06	$0.648M	2020	23	0	0
[illegible]	[illegible]	[illegible]	RE	$1.050M	2.45	$1.523M	2020	11	0	0
[illegible]	[illegible]	[illegible]	RE	$1.250M	2.26	$1.575M	2020	19	0	0
[illegible]	[illegible]	[illegible]	RE	$5.926M	1.63	$3.733M	2020	13	6	0
[illegible]	[illegible]	[illegible]	EE	$6.200M	1.26	$1.612M	2019	10	7	4

Figure 95. Project Inclusion for Multi-year Planning Analysis

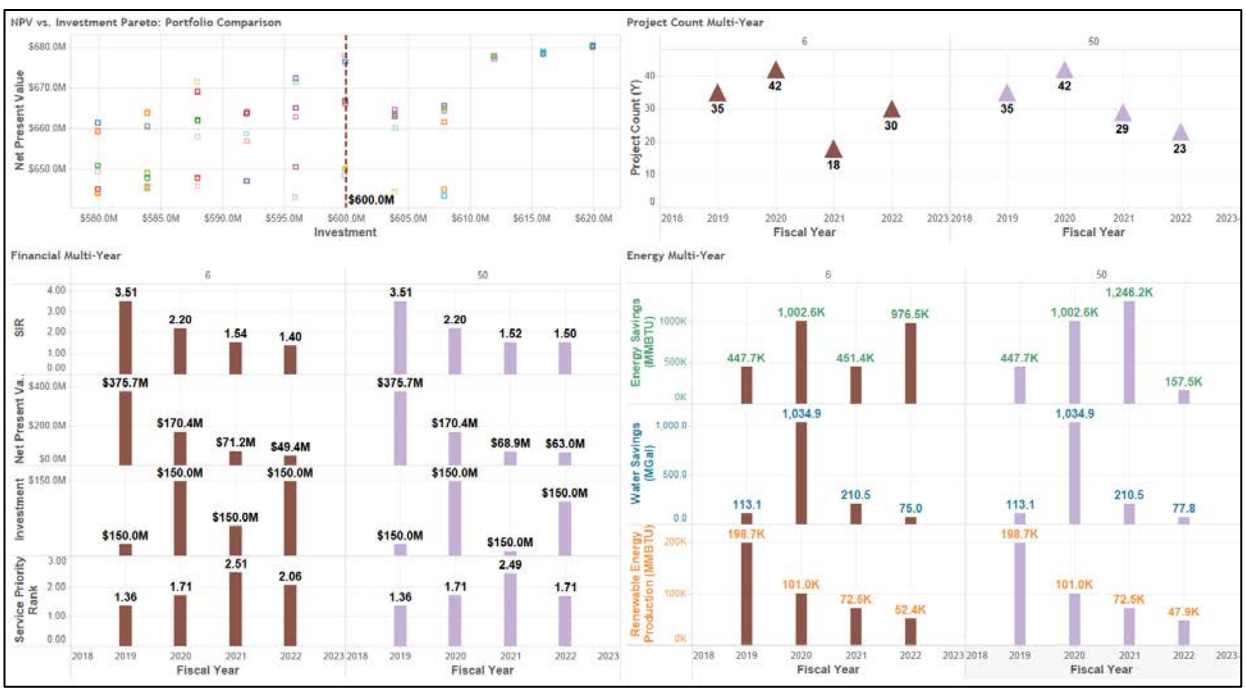


Figure 96. Portfolio Comparison for Multi-year Planning Analysis

Figure 97 is another portfolio comparison dashboard. The dashboard focus is on progress towards meeting energy goals. The upper right worksheet indicates the annual investment level for each year, including the cumulative amount. The lower half of the dashboard contains the energy goal measures charts. These improvement goals are relative to DoD baseline values.

In Figure 98, the cash flows from investment and recovery of investment are shown over the study period to better understand the payback profile.

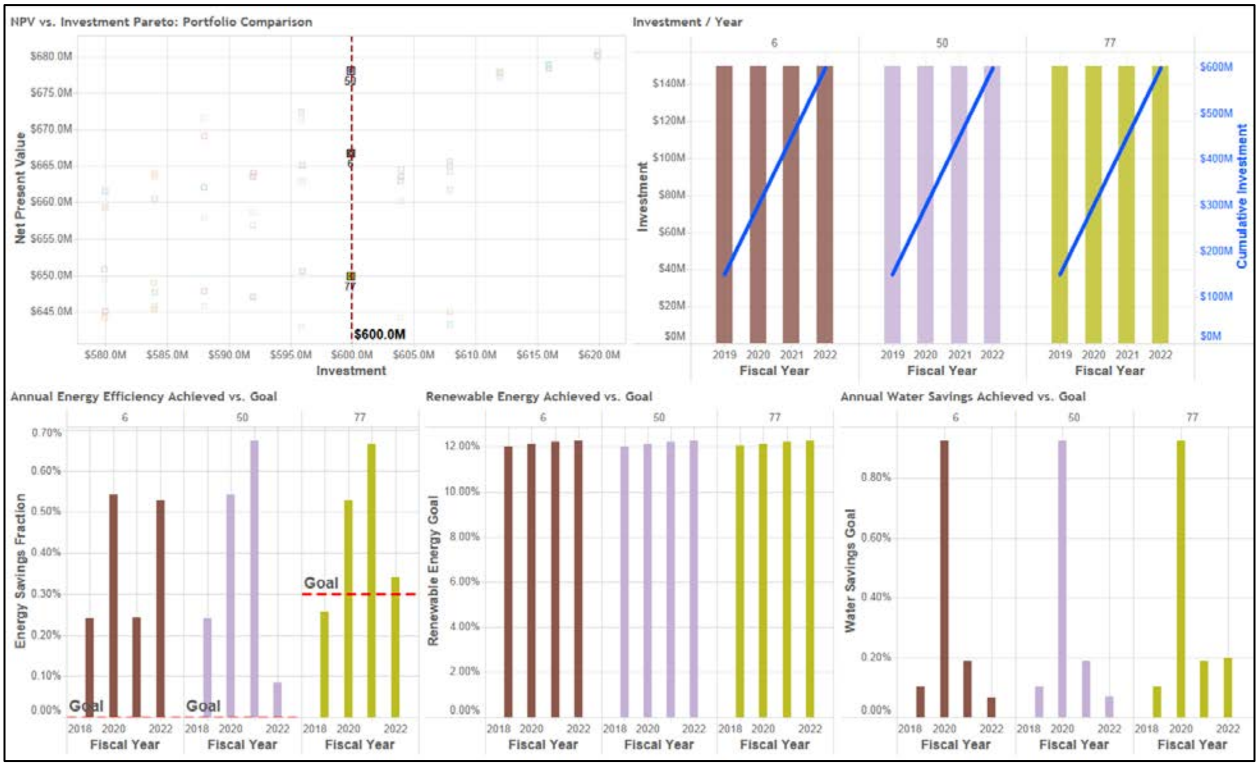


Figure 97. Portfolio Comparison Relative to Meeting Project Goals for Multi-year Planning Analysis

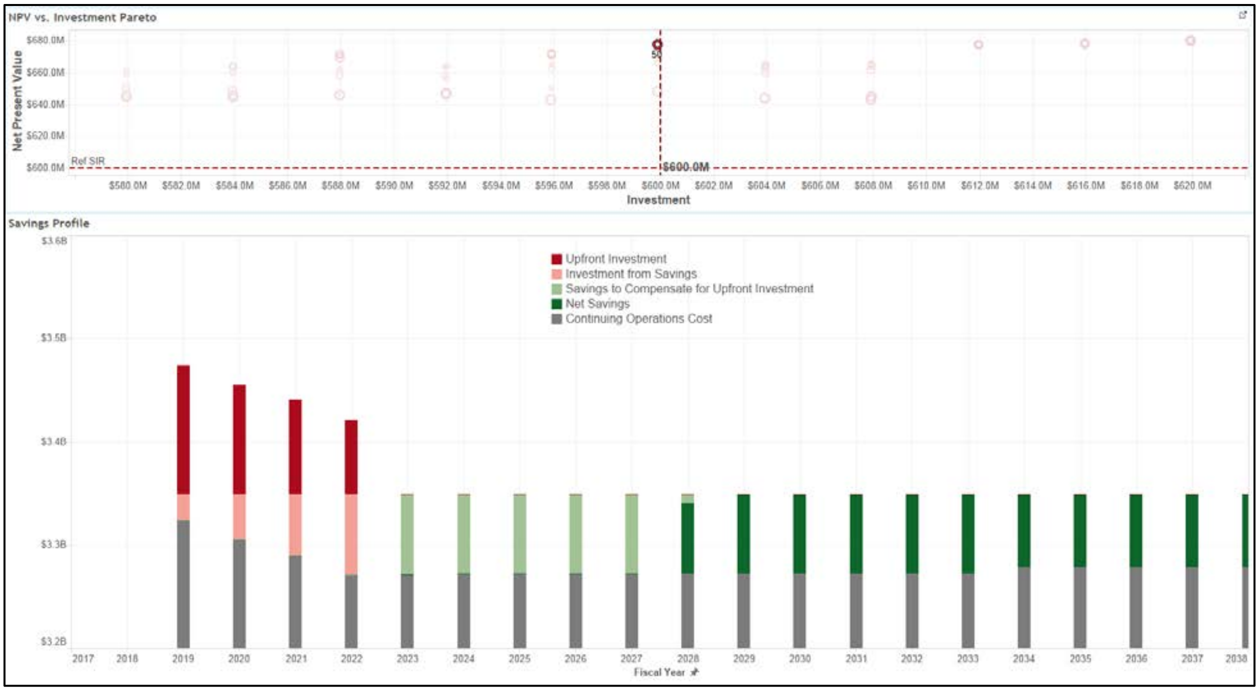


Figure 98. Energy Savings Profile for Multi-year Planning Analysis

6.6 PERFORMANCE ASSESSMENT RELATIVE TO OBJECTIVES

This section summarizes the assessment of the performance of the demonstration program relative to the objectives outlined in Table 1.

6.6.1 Analysis Effort

This objective measures the labor hours spent to provide optimized energy portfolio decision support. The success criterion is whether the increased savings due to optimized analysis over current practice exceeds the cost of additional effort by 50%.We successfully met this metric. A summary of the benefits are shown in Table 8. For both the AFCEC and ECIP demonstration sites, the data is based on two decision cycles, whereas for Luke AFB and Davis-Monthan AFB, it is based on one decision cycle. The supporting details are contained in Section 7.0.

Applying ESAT typically provides an improvement that is proportional to investment, and the cost of using ESAT is relatively independent of the total investment. For this reason, the larger the investment, the greater the benefit realized. Luke and Davis-Monthan AFB installations have relatively smaller annual energy investment portfolios compared to AFCEC, whose investment portfolio is larger, as it covers all of USAF. AFCEC (Air Force only) investment is itself smaller than the portfolio annual investment level of ECIP, which provides funding support to many submitting DoD services, which results in the greatest annual energy portfolio investment of any of our demonstration sites. In addition to the larger investment, multi-installation analysis is more complex because it has to consider many more objectives than NPV, energy savings fraction, and renewable energy fraction. So there is a broad set of benefits realized in these more complex scenarios.

Table 8. ESAT Analysis Benefit

Demonstration Site	Analysis Cost	NPV Improvement	Benefit Ratio
Luke AFB	$53,000	$182,000	3.4
Davis-Monthan AFB	$282,000	$2,800,000	9.9
AFCEC	$124,000	$8,400,000	67.7
ECIP	$387,000	$42,000,000	108.5

At both Luke AFB and Davis-Monthan AFB, the analysis effort included the assessment of individual project recommendations in addition to ESAT portfolio optimization. In the case of Davis-Monthan AFB, the analysis effort included detailed assessment of thermal coatings and micro turbine installations, which is the reason for the substantially large analysis effort. Another point to note is that for the AFCEC and ECIP demonstrations, the individual project assessments have already been done, so the benefits are relative to what would have been achieved using their legacy rank-order approach.

In addition to the quantitative measures recorded at the demonstration sites, we interviewed decision makers at the Energy Conservation Investment Program to gather feedback derived from their experience using ESAT, through multiple decision cycles, compared to the previously used rank order approach. The following feedback items are direct decision maker quotes which characterize their experience on how using ESAT successfully supported their decision cycle schedule:

- With the legacy approach, a lot of time is spent with the mechanics of manipulating the analysis spreadsheet – that is, a lot of time is spent *creating* the results vs. *analyzing* the results. With the ESAT approach, more data is produced for consideration, and it is more meaningful qualitatively. The time available to analyze for decision making is an order of magnitude more.
- The actual labor time spent “touching” the model was much less (approximately 25% as much) than the legacy approach, since the ESAT team did most of the modeling and analysis tasks. Therefore, “installation” labor was focused more on analyzing and refining the investigation route instead of analysis tool development activities.
- A quantitative measure of how many hours was required for the above criteria was not recorded during the legacy or new approach analysis; however, the ESAT approach demands far fewer hours of OSD personnel to conduct analysis and select the ECIP portfolio which best meets the DoD’s strategic goals. The legacy approach which utilized Microsoft Excel would be, at a minimum, 4-5 times more time intensive than the ESAT approach.

6.6.2 Net Present Value

This objective measures the net present value (NPV) improvement of the project portfolio recommendations from the ESAT approach relative to current practice. We set the success threshold value at a 5% or better improvement in NPV compared to current practice. We successfully met this metric. When using ESAT, the NPV improvement can be typically expected to be in the range of 10-20%, but vary due to several factors. Across the demonstration sites, sample NPV improvement results include:

- **AFCEC FY15 decision cycle**: 25% improvement
- **ECIP FY16 decision cycle**: 18% improvement
- **ECIP FY17 decision cycle**: 8% improvement

The improvements obtained for any of the multiple objectives (NPV, energy savings, cost savings, renewable fraction, GHG savings, and energy surety) depend on the decision maker's subjective preferences between objectives and the constraints imposed on the portfolio.

Decision maker's preference between objectives vary from decision cycle to decision cycle. For example, in one decision cycle, the pursuit of cost savings may be most important. In another decision cycle (for example, during ECIP FY17 cycle), energy resilience may be the most important objective to address. This necessarily limits the NPV improvement relative to current practice, though in all cases, ESAT approach has shown more than the minimum 5% improvement target.

Decision makers often impose complex constraints on the desired portfolios. Some of these constraints such as the desired percentage of the portfolio allocated to energy savings, renewable energy, and energy resilience can easily be addressed by the rank order approach. However, when such constraints are combined with other constraints such as the desire to have an equitable distribution of funding between different major services, it becomes tedious, if at all feasible, in the rank order approach to come up with a portfolio that satisfies these multiple constraints. For this reason, these constraints are often ignored in the rank order approach; we have ignored these constraints in modeling the rank order approach. For this reason, the results shown here for ESAT may underestimate the improvement relative to the rank order approach, when additional complex constraints are involved, for example as in FY15 to FY17 ECIP decision cycles.

6.6.3 Energy Savings

This objective measures the energy savings over the study period for the purpose of monitoring progress towards and meeting energy savings mandates. The success criteria is based on the ability of ESAT analysis support to meeting mandated energy savings goals with either improved NPV or reduced investment level by 5% over current practice. We successfully met this metric.

For the same two ECIP decision cycles cited above in the Net Present Value section, a significant energy savings was realized.

- **ECIP FY16 decision cycle**: 623,531 MMBTU Energy Savings improvement (with 18% NPV improvement)
- **ECIP FY17 decision cycle**: 340,567 MMBTU Energy Savings improvement (with 8% NPV improvement)

6.6.4 Cost Savings

This measures projected cost savings due to reduced energy usage. Success is based on ESAT analysis providing at least a 5% improvement in annual savings when compared to current practice. We successfully met this metric.

This metric is directly related to the NPV metric – the percentage NPV savings is equal to percentage annual cost savings for equal project durations. This metric was established in the project proposal, expecting that it would be of routine interest to decision makers. Its value is always produced and reported in each of the ESAT model analyses. Its usefulness in decision making varied among decision makers and degree of focus.

As cost savings improvement is in direct proportion to measured NPV improvement, in all demonstration analyses, this was greater than 5%, as previously reported in the NPV section.

6.6.5 Renewable Fraction

This objective measures the fraction of energy produced from renewable energy sources. Improvement in renewable fraction with the ESAT approach, relative to current practice, is the success criteria. We successfully met this metric.

This was used primarily as a secondary criteria in the analysis that were performed at ECIP, and not used to drive portfolio decisions at other installations. Therefore, the success criteria was the ability to meet the imposed constraints, when feasible. For all the ECIP decision cycles, the criteria for the renewable energy savings was successfully met for all portfolios that were presented to the decision maker. The final renewable energy savings during ECIP FY17 decision cycle is shown below:

- **ECIP FY17 decision cycle**: 36,338 MMBTU Renewable Energy increase (with 8% NPV improvement)

6.6.6 GHG Savings

This objective measures the reduction in greenhouse gas emissions. The success criterion for this objective is to improve the GHG emissions reduction by 5% relative to current practice. We successfully met this metric.

Greenhouse gas savings is dependent on the following factors (and to the extent that the composition of projects in the selected portfolio embody these):

- Energy saved
- Renewable energy substituted for non-renewable energy sources
- The energy production mix, and its associated emission profile, of the local grid utility which serves the installation.

Each ESAT analysis provides results which includes energy saved and renewable energy generated values. Though theoretically possible to calculate GHGs using the energy production mix of the installation’s local utility, project submissions didn’t include this data to make this calculation. In addition, decision makers generally placed comparatively higher priority on NPV, energy saved, renewable energy generated, and energy resilience than GHG savings. Nevertheless, reasonable approximations of GHG savings can be made using available data and sensible assumptions.

During the ECIP FY17 decision cycle, using baseline energy production mix of approximately 65% (35% natural gas, 30% coal) non-renewable energy generation sources (from US Energy Information Administration), GHG emissions savings include can be calculated from the following identified energy savings and renewable energy increase:

- 340,567 MMBTU Energy Savings improvement
- 36,338 MMBTU Renewable Energy increase

The GHG savings calculations are shown below.

GHG savings = (Energy Savings + Renewable Energy)*(0.35*$CO_{2 Natural\ gas}$-lb/MMBTU + 0.3*$CO_{2 Coal}$-lb/MMBTU)

Energy Savings + Renewable Energy = (340,567 + 36,338 MMBTU) = 376,905 MMBTU

GHG savings = 376,905 MMBTU*(0.35*117 lb./MMBTU + 0.30*206 lb./MMBTU) – conversion factors from US Energy Information Administration

GHG savings = 38,726,989 lb. or 17,603,177 kg.

This represents a significant GHG emissions improvement. The percentage improvement over legacy approach has not been tracked because this criteria was not used during the decision cycles, and never tracked during the legacy approach.

6.6.7 Energy Surety

This measures the ability to sustain critical installation capabilities when grid power is lost. The success criterion is the quantification of the tradeoff between islanding times and costs associated with an optimal selection of energy surety alternatives. This metric was partially met.

Though our team was prepared to respond with a pilot energy surety model to address these tradeoff challenges, the opportunity to exercise it was limited. Energy surety analysis was considered as optional "Special Studies" in the original proposal plan and was subsequently eliminated from the statement of work for both Luke and Davis-Monthan AFB when adding AFCEC as a demonstration site in the April 2014 contract addendum. Also, until the FY18 ECIP analysis was conducted, there wasn't an explicit investment requirement for energy surety projects.

Then, in the ECIP FY18 analysis decision cycle, energy resilience became an important consideration. Relevant project attribute values were assigned (not related to islanding time) and considered when selecting projects for the investment portfolio. Tradeoff studies were conducted with new visualizations and metrics created for this purpose, as described fully in Section 6.5.8. This new energy resilience analysis played a central role in project selection for investment, for example, determining how inclusion of energy resilience projects impacted the overall portfolio SIR.

6.6.8 Analysis Schedule

This objective measures the calendar time needed to provide optimized energy portfolio decision support. We successfully met this metric. Over the course of the demonstration period, we learned that exact calendar day durations to complete analysis was not as an important comparison measure than was efficiency, breadth, and quality of results. ESAT was superior to the legacy approach in all these measures.

We interviewed decision makers at the Energy Conservation Investment Program to gather feedback derived from their experience using ESAT, through multiple decision cycles, versus the previously used rank order approach. The following feedback items are direct quotes which characterize their experience on how using ESAT successfully supported their decision cycle schedule:

- The decision-making process is a six-week cycle, and ESAT successfully supported this timeline and met the required milestones. The ESAT model building and analysis process easily fit within the budgetary timeframe, allowing multiple iterations and analyses to discover the most suitable portfolio recommendation.
- Legacy and ESAT approach dates were not recorded; however, the ESAT approach is by far more accelerated. The FY17 ECIP portfolio selection was completed in less than two weeks which could not have been accomplished utilizing the legacy method. ESAT enabled almost real-time sensitive analysis which allowed for a review of multiple optimized ECIP portfolios to ensure the best portfolio was selected that maximized SIR and maximized contribution to DoD strategic goals

See Appendix F and Appendix G (Performance Objectives Feedback) for full details regarding benefits of using ESAT analysis vs. the legacy approach.

6.6.9 Insight Gained

This objective measures the degree of understanding provided to the decision maker about the tradeoffs between multiple, competing objectives. We successfully met this metric.

We interviewed decision makers at the Energy Conservation Investment Program to gather feedback derived from their experience using ESAT, through multiple decision cycles, versus the previously used rank order approach. The following feedback items are direct quotes which characterize their experience on how using ESAT impacted their decision making:

- Quantity of Portfolios Analyzed: The legacy approach provides for analyzing three to five project portfolios. For comparison, using the ESAT approach, hundreds of portfolios are examined for the equivalent analysis iterations.
- Decision makers have more information upon which to make their decisions, “less of a shot in the dark”.

- Analysis results are provided to make an informed decision. Legacy approach: here's the result, meaning one portfolio is offered with little substantiation or flexibility to search for alternatives. ESAT offers more flexibility and improved guidance for smart portfolio selection.
- The legacy approach doesn't provide a lot of feedback on whether or not the chosen criteria and weighting was appropriately applied. ESAT facilitated many iterations and provided more optimal portfolios, for consideration and analysis, to ensure that the selected portfolio actually addressed the needs, requirements and goals of ECIP. It facilitated meaningful iteration by repeatedly refining the criteria and constraints through sensitivity studies, informing the analysis evolution. ESAT is a focused approach vs. a "blind" or wandering approach. Each iteration precipitates the questions that need to be asked to further refine the analysis process.
- ESAT offers a drill down capability to verify the accuracy of results and provides understanding as to how the constituent projects interplay to comprise the portfolios. ESAT surfaces unexpected results and provides a mechanism to trace and identify their causes and effects.
- ESAT provides flexibility to add constraints or criteria "on the fly". Parameters that you didn't know were important until after you saw some initial results can be, subsequently, easily integrated.
- The ESAT approach provided better insight on balancing service project priorities, funds distribution by service, qualitative scoring, SIR, payback, and portfolio net present value. Insights were clearly evident through easy to understand visualizations of data analysis that could not have been accomplished without the ESAT tool and team.

See Appendix F and Appendix G (Performance Objectives Feedback) for full details regarding benefits of using ESAT analysis vs. the legacy approach.

6.6.10 Budget Justification

This objective measures the utility of this approach in providing justification to funding authorities for projects selected by the installation management. We successfully met this metric.

We interviewed decision makers at the Energy Conservation Investment Program to gather feedback derived from their experience using ESAT, through multiple decision cycles, versus the previously used rank order approach. The following feedback items are direct quotes which characterize their experience on how using ESAT assisted with their budget justification:

- Robust data and deep analysis is provided by ESAT so that the selected project portfolio is more easily explained for approval
- ESAT provides the right tools and analysis to show the benefit of the program to outside decision makers.
- ESAT provides visualizations that the legacy process doesn't, increasing the robustness of the analysis. Key visualizations include: geographic breakdown analysis, investment allocation, tree maps and heat maps.

- The ESAT tool was utilized to present a budget submission to OSD leadership and Congress. The ESAT tool enabled best possible budget submission to be made.

See Appendix F and Appendix G (Performance Objectives Feedback) for full details regarding benefits of using ESAT analysis vs. the legacy approach.

7.0 COST ASSESSMENT

The project cost, energy and savings data, used as inputs for the portfolio optimization analysis are generally BLCCA compliant. This is because the data sources are typically generated from (1) the BLCC software itself, which automates BLCCA; (2) the site's REM or energy team, which are familiar with BLCCA guidelines; (3) an audit from an energy/engineering consulting firm or national lab, who are also familiar with the guidelines; (4) from FEDS, which was developed by PNNL for DOE-FEMP. The cost-benefit analysis which ESAT performs is consistent with the BLCCA standard that NIST developed for Federal Energy Management Program (FEMP).

This section discusses the results of a cost benefit analysis focused on determining the value added, by our optimization technology, to the site's decision making. This project had a primary objective of refining the estimates of required effort and cost of gathering data, adapting models, and performing analysis in support of energy investment decisions.

The value of an ESAT analysis is based on the comparison of the net present value of the selected ESAT optimized portfolios of energy projects versus portfolios defined using the current approach to project selection, which is typically a simple rank ordering of the projects by their individual net-present values or another composite metric. This comparison can be carried out for a range of total annual investment levels.

These savings are compared to the cost associated with conducting an ESAT analysis over simple rank-order. The labor required to develop the estimated energy savings and capital cost for each project are the same for the two different portfolio selection methods. The additional cost of doing an ESAT analysis is associated with the labor required to format the data for the ESAT tool and run the analysis. In addition, there is some additional labor required to develop the analysis material to present ESAT optimized results and communicate these results to the decision makers at each site.

Finally, it must be re-emphasized that ESAT is a multi-objective decision support tool and capability. Complex decisions simultaneously consider cost as well as many other performance parameters and objectives. While the cost and performance evaluation of ESAT is discussed separately within this report by necessity, both sections should be considered together to give the best characterization of the capability. ESAT's ability to support the demonstration site's decision makers is detailed in Sections 6.2-6.5. The capability of ESAT in meeting the many established performance objectives is extensively covered in the preceding Section 6.6. The cost of the effort and realized benefits at each demonstration site is presented next.

7.1 LUKE AFB

7.1.1 Effort Required

Ten Luke AFB buildings were modeled in the FEDS tool. The time required for data collection & preparation, model building, analysis, and report writing was 255 hours. A breakout summary of this is shown in Table 9.

Table 9. Luke AFB Analysis Activity Labor Hours Required

Personnel	Data Collection & Preparation	Model Building	Analysis	Report	Total
Boeing	113	103	16	13	245
Luke AFB	10	0	0	0	10
Total	123	103	16	13	255

7.1.2 Cost Benefit Evaluation

The analysis project effort required was 255 hours. Dividing the NPV savings resulting from this effort by the cost results in a benefit ratio of 3.4. Therefore, there is a benefit to do this analysis. However, the suggested projects output by the FEDS models should be reviewed for practicality, applicability, etc.

7.2 DAVIS-MONTHAN AFB

7.2.1 Effort Required

Eleven Davis-Monthan AFB buildings were modeled in the FEDS tool. The FEDS output projects were combined with energy team provided projects and then optimized and the results reviewed with the energy team. The time required for data collection & preparation, model building, analysis, and report writing was 1245 hours. A breakout summary of this is shown in Table 10.

Table 10. Davis-Monthan Analysis Activity Labor Hours Required

Personnel	Data Collection & Preparation	FEDS Model Building	Optimization Analysis	Results Review	Report	Total
Boeing	609	73	61	452	30	1225
Davis-Monthan AFB	10	0	0	10	0	20
Total	619	73	61	462	30	1245

7.2.2 Cost Benefit Evaluation

The analysis project effort required was 1245 hours. Dividing the NPV savings resulting from this effort by the cost results in a benefit ratio is 9.9. Therefore, there is a benefit to do this analysis. However, the suggested projects output by the FEDS models should be reviewed for practicality, applicability, etc. Also, the added benefit of individual project analysis might not outweigh the added amount of collaboration with the energy teams and extra analysis time. A cost ratio was not completed on that specific portion of analysis because it was not in the contract scope for Davis-Monthan.

7.3 AFCEC

7.3.1 Effort Required

The total time required for data collection & preparation, model building, analysis, and report writing was 598 hours. A breakout summary of this is shown in Table 11.

Table 11. AFCEC Analysis Activity Labor Hours Required

Personnel	Data Collection / Preparation	Model Building	Analysis	Review & Report	Total
Boeing FY15	98	115	75	113	401
Boeing FY16	45	26	96	30	197
Total	143	141	171	143	598

7.3.2 Cost/Benefit Evaluation

The analysis project effort required was 598 hours. Dividing the NPV savings resulting from this effort by the cost results in a benefit ratio is 67.7. Therefore, there is a benefit to doing this analysis.

7.4 ECIP

7.4.1 Effort Required

Table 12. ECIP Analysis Activity Labor Hours Required

Personnel	Data Collection & Preparation	Optimization Analysis	Results Review	Report	Total
Boeing FY16	726	142	77	8	953
Boeing FY17	530	311	59	8	908
Total	1256	453	136	16	1861

7.4.2 Cost/Benefit Evaluation

The above analysis effort over the two-year period resulted in significant multiple benefits, as detailed in the following lists.

Improvement results from FY16 analysis:

- $30M (18%) NPV improvement
- 623,531 MMBTU Energy Savings improvement
- Saving to investment ratio improvement
- Simple payback improvement
- Service priority rank improvement

Improvement results from FY17 analysis:

- $12M (8%) NPV improvement
- 340,567 MMBTU Energy Savings improvement
- 36,338 MMBTU Renewable Energy increase
- 33 MGal Water Conservation Savings increase
- Simple payback improvement
- Service priority rank improvement

7.5 COST BENEFIT FOR FUTURE APPLICATION

The cost-benefit figures in Sections 7.1-7.4 are based on the labor cost during the demonstration program. For ESAT application in the future, however, it is appropriate to use the price planned to be charged for ESAT service. For information about service delivery options and associated pricing information, please contact the principal investigator at The Boeing Company (at the contact information listed in Appendix A.)

8.0 IMPLEMENTATION ISSUES

This section discusses technology transition issues, with focus on the mechanisms for applying ESAT technology across Department of Defense installations and program offices. This section also addresses all issues raised at the Interim Progress Reviews (IPRs).

8.1 APPLYING ESAT TECHNOLOGY TO NON-ENERGY PROJECTS

During the ESTCP Interim Progress Review (IPR) meeting in February 2016, the Air Force representative on the Technical Committee commented that, in the current funding environment, energy projects compete for funding with all sustainment and maintenance projects. It was pointed out that it would add more value if ESAT could address (optimize) the full combined list of energy and non-energy projects together. There is interest in understanding whether ESAT could be operated to include non-energy projects to support Air Force investment decision making. This section addresses this interest.

The underlying technology supporting ESAT is a general purpose, multi-objective optimization modeling framework and environment called "Design Sheet" (see Section 9.0 for more information). Because it is general purpose, the models built within the environment can be customized for solving a variety of complex problems. While ESAT, in its current state, is focused on solving the complex energy project investment challenge, multiple derivative applications with different aims is not only possible, but is regularly applied within Boeing business units for broad purposes (e.g. conceptual design, sustainment analysis, etc.). Therefore, it is possible to both respond to the need for optimizing the investment of non-energy projects independently as well as optimizing a collection of energy and non-energy projects simultaneously. In each case, some development work would be required.

In order to apply ESAT methodology to optimize investment for a portfolio of non-energy projects, a set of objective criteria for these non-energy projects need to be identified. Financial data and metrics, such as Investment, NPV, SRI, and AIRR will be the same between energy and non-energy projects. However, non-financial metrics and objectives will be different. For example, for Facilities, Sustainment, Restoration and Modernization (FSRM) projects, key attributes might be one or more of Building Condition Index, Functionality Index, and Remaining Service Life. The main effort in extending ESAT to such projects will be in defining these metrics, and more importantly which of these metrics can be combined into a single overall metric, and which others should be treated as one of the multiple objectives that needed to be traded off. More importantly, new portfolio level metrics based on these project-level metrics need to be developed. An example of a portfolio level metric that has been developed during the course of this demonstration is the Service Priority Rank, which compares two portfolios relative to how well they meet the priorities set by the Services.

Once these metrics are developed, the optimization model needs to be updated to reflect these new project and portfolio attributes. Some additional effort is required to develop or update visualization dashboards to reflect these new objectives/metrics. Before extending ESAT to non-energy projects, we need to conduct an interview process with the relevant decision makers/subject matter experts to understand their unique constraints and portfolio preferences.

Efforts were made to introduce ESAT capability to the AFCEC FSRM organization in March 2016, via two AFCEC points of contact (Steve McClellan, Paula Shaw). Neither pursuit was successful in generating further interest to demonstrate ESAT capability application to the AFCEC combined FSRM and energy project investment process. However, we are confident that if an opportunity presents itself for such a decision support scenario, ESAT could be extended within a time frame of 2-3 months to update the model and the visualizations.

8.2 INTEGRATING ESAT WITH OTHER TOOLS TO STREAMLINE DATA ENTRY

In the original proposal and demonstration plan for this ESTCP project, the FEDS and HOMER tools were highlighted as input data feeding tools to the ESAT optimization engine. These tools were regularly used at demonstration sites prior to beginning of this project and were anticipated to be used regularly again during this project. This assumption was true in the case of FEDS, but not true for HOMER. HOMER is more appropriate for use when planning to construct a micro grid with its associated multiple energy generation sources, loads, and related equipment. Our experience was that most projects submitted for funding consideration by installations/agencies are not that extensive in nature. Therefore, we don't anticipate frequently using HOMER in conjunction with ESAT in the future.

Although we have leveraged the energy project output reports of FEDS extensively during this project, it is not expected to be a core capability offering of ESAT in the future either. The FEDS tool was useful in assisting demonstration site staff with energy saving project idea generation and supplementing existing projects originated by the staff. However, the best alignment of ESAT's capability is with organizations with multi-site considerations, such as ECIP, AFCEC, USACE, etc. Although ESAT can be beneficially used on individual sites, the benefit is magnified when used with these larger organizations with their associated larger investment requirements and decision complexity. In the case of the larger organizations, project development and analysis has already been completed by the project submitter, typically with the BLCC tool or equivalent. Because of this, the FEDS tool would be rendered redundant or better used as an alternative by the project submitters themselves (vs. the ESAT team employing it), upstream of the ESAT optimization model.

BUILDER, the facility condition database, is another tool that we were asked to look into for integration. Such an integration will be useful if ESAT is extended to non-energy projects (FSRM projects) or if ESAT is used with FEDS for generating project candidates. In the latter case, building characteristics (dimensions, window locations, etc.), HVAC equipment characteristics, etc., could be extracted from BUILDER through custom queries for feeding into FEDS directly. However, we have been made aware of the fact that the BUILDER database is often not complete, and the extracted data needs to be augmented with manual entries, as the focus is on building and related systems maintenance, not on energy savings related projects. This opinion is based on publicly available information only, as we do not have access to the tool itself to do a more direct or extensive evaluation.

Other tools are not presently being considered for inclusion in the ESAT architecture. However, this does not preclude the possibility of incorporating them in the future should there be a benefit to do so. And if we do include additional tools, streamlining data entry will be possible. As most tools ordinarily produce a variety of output report formats, it would be relatively straightforward to collect the necessary inputs from these tools for ESAT, first in a semi-automated way, then eventually in a more automated way depending on how frequently the tool will be used or how much output data formatting is required to use the data. Other interface options are available as well.

For example, the tool's API could be used to directly interface with ESAT, or we could replicate the needed capability from the tool directly within ESAT.

8.3 TECHNOLOGY TRANSITION / FUTURE ESAT BUSINESS PLAN

As part of our efforts to promote the use of ESAT technology across DoD, we have attended several energy industry related conferences. We attended Energy Exchange 2015 in Phoenix, AZ, Energy Exchange 2016 in Providence, RI, and Energy Exchange 2017 in Tampa Bay, FL to network with and educate potential users of our capability. There, we established several new relationships with interested individuals (from USACE and CNO) and followed up with them afterward.

We attended and were speakers at the 39th World Energy Engineering Congress, held in Washington DC, September 2016, as part of the DoD Critical Issues Forum. This enabled another opportunity for awareness building of ESAT analytic capability. We presented an overview of ESAT, as well as, analysis results derived from working with our demonstration sites. A representative from CNIC showed interest in using ESAT for decision support, and we subsequently presented an ESAT overview at Washington Navy Yard November 9, 2017.

We attended the ESTCP Symposium during November 28-30, 2017, during which we presented information about ESAT via a poster session. Many interested individuals stopped by to learn more about our capability. Informational materials and business cards were exchanged.

We have developed informational presentations and videos to share with prospective customers. Multiple versions of these presentations and videos were made to appeal to a wide audience. From overview to detail, executives and analysts alike can be informed about ESAT's capability, to the depth of their interest. These videos have been made available to the ESTCP program office, and will be available to anyone upon request.

Consulting Service: Our primary vehicle for providing ESAT capability to customers after completion of the ESTCP project, at least initially, will be through a conventional service contract. This is a well-established channel which both the Boeing and DoD organizations are familiar with. Single and multi-year contracts are possible.

If significant new model development and analysis capability is required, initiating a technology development contract with Boeing Research & Technology (BR&T) is appropriate. If, instead, routine analysis support only is required, a contract with Boeing Technology Services (BTS) is recommended. Through BTS, potential customers can make requests through the Boeing website: www.boeing.com/bts, and can take advantage of government or commercial contract terms. BTS can advertise our capability on its website and represent ESAT at trade shows, if requested.

Other contract options we have considered and investigated include:

IDIQ contract – BR&T currently holds several DoD IDIQ research contracts. These contracts were examined for applicability and duration, for consideration of potentially using these as vehicles for ESAT analysis support. None were judged as being realistically applicable by description and generally had short life in their remaining duration.

GSA Schedule – Boeing Global Services organization is especially equipped and prepared to efficiently respond to any potential ESAT user that wishes to use this vehicle. The information below describes the current GSA contracts that would apply to ESAT analysis work.

GSA Professional Services Schedule (PSS), Boeing contract # GS-23F-0183K:

- This is a long-standing vehicle that offers streamlined ordering procedures, and pre-negotiated terms, conditions, labor categories and rates, which make it a popular choice of Contracting Officers
- Supplemental information about GSA Schedules is available at www.gsa.gov/schedules

GSA OASIS, Boeing contract # GS00Q14OADU107:

- This is a newer GSA professional services contracting vehicle that is becoming very popular.
- The OASIS website provides details at www.gsa.gov/oasis

DLA EMALL – this funding option is used for COTS items, such as tents, and is not applicable for procuring our analysis services.

Licensed software: There is no plan to offer the tool directly to the market via a license purchase. Boeing has evaluated this delivery option and determined that is not an attractive business model or focus area for the company.

Web-based subscription service: In addition to the consulting service option, we have explored the option to provide ESAT as an online web subscription service in partnership with our internal IT organization. This approach is intended to scale and provide efficiencies of ESAT use for both existing and new customers.

In this proposed form, users would establish an account, upload their input data, run analyses, and generate desired reports independent of the ESAT analysts being available or directly assisting. Whether this approach is appropriate depends on several factors:

- An important factor is whether a self-service option provides results of sufficient quality. As the portfolio decisions are guided by both objective and subjective criteria, and the subjective criteria may be different between installations or programs, there needs to be some customization that is needed for each new customer. Example customizations include new metrics and dashboards. Based on our experience with ECIP over multiple decision cycles, there is always a need for some customization for each decision cycle.
- Though customization does not preclude a web-based subscription service, this has steered us towards a mixed approach, where some need for customization is built into our proposed subscription model.
- The number of customers requesting this analysis support option will dictate the eventual cost of this option. The fixed cost to implement the needed infrastructure, e.g. IT architecture with necessary security, account management, and user preference features, model accommodations for a broad scenario spectrum, etc. can only be justified if there are sufficient number of yearly customers. We currently estimate this to be 4-8 customers over 3-5 years.

Cost of service: For information about service delivery options and associated pricing information, please contact the principal investigator at The Boeing Company (at the contact information listed in Appendix A.)

9.0 REFERENCES

Boeing's Design Sheet technology is the underlying multi-objective optimization and modeling framework. Additionally, the proposed technology relies on HOMER and FEDS models. The following is a list of publications that describe these technologies and discuss some applications of these technologies to energy modeling and analysis; it is not meant to be an exhaustive list of relevant articles.

Design Sheet, Multi-Objective Optimization, and Energy Modeling

Cline, R. G., Reddy, S. Y., and Fertig, K. W., "Energy Reduction Opportunity-Cost Analysis & Optimization System," 79th MORS Symposium, Monterrey, CA, 20-23 June, 2011.

Reddy, S. Y., and Fertig, K. W., "FBCoE: Fully Burdened Cost of Electricity," Boeing Research & Technology Report, December 2010.

Reddy, S. Y., and Fertig, K. W., "Constraint Management-based Integrated Cost and Performance Analyses," 2010 DOE Cost Analyses and Training Symposium, Santa Clara, CA, 19-20 May 2010.

Reddy, S. Y., Fertig, K. W., and McCormick, D. J., "Constrained Exploration of Trade Spaces," Second IEEE International Conference on Space Mission Challenges for Information Technology, July 2006, Pasadena, CA.

Reddy, S. Y., Fertig, K. W., and Smith, D. E., "Constraint Management Methodology for Conceptual Design Tradeoff Studies," 96-DETC/DTM-1228, *The 1996 ASME Design Engineering Technical Conferences and Computers in Engineering Conference*, Irvine, CA.

HOMER, FEDS, and Energy Modeling

Booth, S., et al, "Targeting Net Zero Energy at Marine Corps Air Station Miramar: Assessment and Recommendations," NREL/TP-7A40-47991, December 2010.

Brigantic, R. T., Papatyi, A., and Perkins, C. J., "Comprehensive Energy Assessment: EE and RE Project Optimization Modeling for United States Pacific Command (USPACOM)," PNNL-19831, September 2010.

Chvála, Jr., W. D., Dixon, D. R., De La Rosa, M. I., Brown, D. R., "Building Energy Audit Report for Hickam AFB, HI", PNNL-19633, September 2010.

Chvála, Jr., W. D., Dixon, D. R., Solana, A. E., "Facility Energy Decision System (FEDS) Assessment Report for Fort Buchanan, Puerto Rico", PNNL-15053, February 2005.

Facility Energy Decision System User's Guide, PNNL-17848, September 2008.

Kora, A. R., Dixon, D. R., Brown, D. R., "Facility Energy Decision System (FEDS) Assessment Report for US Army Garrison, Japan-Honshu Installations", PNNL-19232, March 2010.

Lambert, T., Gilman, P., and Lilienthal, P., "Micropower System Modeling with HOMER," In *Integration of Alternative Sources of Energy*, by Felix A. Farret and M. Godoy Simoes, John Wiley & Sons, Inc., 2006.

Newell, Brandon H., "The Evaluation of HOMER as a Marine Corps Expeditionary Pre-Deployment Tool," M.S. Thesis, Naval Post Graduate School, Monterrey, CA, September 2010.

Underwood, D. M., et al, "Energy Optimization Assessment at U.S. Army Installations: Fort Bliss, TX," ERDC/CERL TR-08-15, September 2008.

Walker, A., "A Heuristic Approach to Renewable Energy Optimization," In *Proceedings of the ES2009 Energy Sustainability 2009*, July 19-23, 2009, San Francisco, CA.

Energy Surety Approach

Van Broekhoven, S.B., Judson, N., Nguyen, S.V.T., Ross, W.D., "Microgrid Study: Energy Security for DoD Installations", Lincoln Laboratory Massachusetts Institute of Technology, Lexington, Massachusetts, June 2012.

APPENDIX A POINTS OF CONTACT

Point of Contact Name	Organization Name	Phone Email	Role in Project
Dr. Sudhakar Reddy	Boeing	408-807-8732, Sudhakar.Y.Reddy@boeing.com	Principal Investigator
Ken Fertig	Boeing	714-896-1514, kenneth.w.fertig@boeing.com	Co-investigator
Jim Hendricks	Boeing	314-233-4345, james.r.hendricks@boeing.com	Co-investigator
Corey Clive	Venergy	561-676-8382, Corey@venergygroup.com	Davis-Monthan site metering
Lt. Col. Andrew Middione	Davis-Monthan AFB	520-228-8396, Andrew.Middione@dm.af.mil	Davis-Monthan AFB Point of Contact
Cris Brownlow	Luke AFB	623-856-3815, cris.brownlow@us.af.mil	Luke AFB Point of Contact
CDR Matthew McCann	OASD	571-372-6856, Matthew.McCann@osd.mil	OSD Point of Contact (until Nov 2015)
CDR Walter Ludwig	OASD	(571) 372-6859 walter.s.ludwig.mil@mail.mil	OSD Point of Contact (since Nov 2015)

In addition to the phone and e-mail information for the points of contact listed in the table above, the following is the list of detailed location and contact information for the three demonstration sites:

Site 1 – Luke AFB:

56th Fighter Wing Public Affairs
14185 West Falcon Street Rm 138 Luke AFB, Ariz. 85309
Comm: (623) 856-LUKE (5853) DSN: 896-5853
Fax: (653) 856-6013 DSN: 896-6013

Site 2 – Davis-Monthan AFB (AMARG):

309th Aerospace Maintenance and Regeneration Group
2600 S. Craycroft Rd. Tucson, AZ 85708, (520) 228-3378
Public Affairs: Bldg. 3200, Room 2054, ph. 520-228-3204

Enterprise Site – OSD ECIP:

Office of the Deputy Under Secretary of Defense (Installations & Environment)
3400 Defense Pentagon, Room 3B856A,
Washington, DC 20301-3400

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APPENDIX B ADVANCED METERING SYSTEM INSTALLATION FOR DAVIS-MONTHAN AFB

This is an excerpt from Venergy's proposed metering system installation, which is planned in the early phase of the Davis-Monthan AFB site project:

Venergy will furnish all engineering, design, and place into service an advanced electrical metering system with future capabilities to add water, natural gas, and steam metering system with future points to monitor and/or control lighting and HVAC. The equipment provided includes the AquiSuite Data Acquisition Servers and Modhopper wireless transceivers by Obvius, LLC to transmit the data by the specific meters chosen (Veris meters/Modbus RTU) to meet the scope of work. Obvius equipment uses BACnet protocols and can deliver data in various languages including ASCII, and CSV.

The approach will consist of a two-phase effort. Phase 1 consists of the site visit, survey, investigating any existing utility monitoring device, collecting drawings, interviewing facility engineers, and creating a site condition report or Technical Data Package (TDP). The TDP will form the foundation of the design package and technical solution for this metering task. Survey findings will be reviewed with the Facility Manager and the most appropriate option will be selected for TDP development.

A Metering Plan will be developed within thirty days of contract award and will require approval by the Air Force (AF) prior to meter installation. The Metering Plan will include the installation schedule, building number with number of meters, pulse kits, meter ID, meter manufacturer, existing or new, and date installed.

Phase 2 effort will consist of procurement and the installation of the data management system. Technical metering solutions will be provided to the individual facilities identified in the scope of work and verified in the Phase 1 survey and design.

The following Table describes the quantity and type of metering equipment to be campus wide. This total includes Housing Metering.

Quantity	Type of Equipment
19 or 20	Electrical Meter (Veris E50C2 meters with solid(Split Core) CT's)
2	AquiSuite Data Acquisition Servers
19 or 20	Modhopper wireless transceivers by Obvius, LLC
5	Flex 10 Module, User Selectable Inputs, 2x Digital Outputs
5	Fiberglass, Omni Base Station Antenna (includes mounting bracket), Weather Rated
5	LMRl95 Cable, RPSMA Plug La N-Male Connectors, zon. Weather Rated
1	Server and Work Station
	Contingency
19 or 20	Electrical Outlet - Ext Mount
1	Storage Container (20') Rental / month

Meters to be installed in the following Aerospace Maintenance and Regeneration Group (AMARG) Buildings at Davis-Monthan AFB:

1. Command Building #7514; 400 Amps (1 Meter)
2. Support Squadron Building #7513; 400 Amps (1 Meter)
3. Start Treaty / Engineering Building #7507; 400 Amp (1 Meter)
4. Welding Shop Building #7441 (400 Amp; 2 Meters) -
5. Avionics Shop Building #7439; 600Amp (1 Meter)
6. Reclamation / Packaging & Crating Building# 7391 (1200 Amp Main; 1 Meter), (800Amp; 1 Meter)
7. IT Office / Supply Warehouse Building #7328; 1200 Amp Main; (1 Meter)
8. Wood Mill Building#7431; 400 Amp; (1 Meter)
9. Aircraft Maintenance Sun Shelter East Building #7428E; 800Amp (2 Meters)
10. Aircraft Maintenance Sun Shelter West Building #7428W; 600Amp; (1 Meter)
11. North Hanger Building #7408; 600 Amp; (1 Meter)
12. South Hanger Building #7506; 800Amp; (1 Meter)
13. New Energy Hanger; (Hanger Bays, Admin Offices, HVAC, 1MW power; 4 or 5 meters)

APPENDIX C APRIL 2014 DEMONSTRATION PLAN ADDENDUM

Introduction

Boeing proposes to modify the project demonstration plan by adding the Air Force Civil Engineering Center (AFCEC)-Energy Directorate as a demonstration site. AFCEC/CND manages and recommends, on behalf of the US Air Force, the energy saving projects to be funded. Adding this site would complement our other existing demonstration sites, collectively providing the opportunity to prove benefit at all organizational levels: (1) individual site level (Luke & Davis-Monthan AFB), (2) service level (USAF-AFCEC), and (3) DoD level (OSD/ECIP).

Through contacts from Luke AFB, we were introduced to Steve McLellan at AFCEC. We had an initial discussion with Steve, giving him a summary introduction to both our technology and the ESTCP project. This led to a request to perform preliminary analysis on example AFCEC data. This analysis provided an initial comparison of ESAT technology energy project portfolio recommendation results with the organization's current decision process results. These results were presented to AFCEC, demonstrating an opportunity for improved portfolio NPV. Steve McClellan subsequently volunteered AFCEC as a participating demonstration site. There is interest in applying ESAT technology to AFCEC's upcoming energy project portfolio selection process, occurring during the May-July 2014 timeframe.

The proposed changes to the demonstration plan outlined below have been reviewed and approved by the POC of the affected demonstration sites: Cris Brownlow (Luke AFB), Lt. Col. Andrew Middione (Davis-Monthan AFB), Steve McLellan (AFCEC), and CDR Matthew McCann (OSD/ECIP).

Work Scope Add/Change

Luke AFB - The work scope to be performed at Luke AFB will be reduced. The amended plan is to conduct FEDS analysis on the base's top ten energy intensity usage facilities. The FEDS output reports will contain candidate facility energy efficiency improvement retrofit project recommendations, with expected energy, cost and GHG emission savings. These will serve as the primary input to the ESAT optimization tool. Only a single iteration of ESAT optimization analysis results will be demonstrated at Luke AFB. The originally planned second iteration of optimization analysis that includes the special analysis studies phase related to energy surety analysis will be eliminated.

Davis-Monthan AFB **-** The demonstration plan at Davis-Monthan AFB will remain substantially unchanged, though there will be small reduction in the scope of the second iteration of portfolio optimization involving energy surety analysis. Additionally, a two month delay is planned regarding the initial modeling and analysis milestone, to accommodate the added AFCEC demonstration and the immediate support which is required, and better align with the data meter sensor installation delay.

As per the original plan for Davis-Monthan, FEDS analysis will be performed, on the same AMARG buildings in which the data meters will be installed, to identify potential energy projects. After about three months of collecting meter data, we will work with AMARG to analyze this data to identify additional energy efficiency retrofit projects. The energy staff at Davis-Monthan AFB will provide the ESAT team with planned projects that will be analyzed and included in the optimization.

The FEDS output reports will serve as the supplemental project input to the ESAT optimization tool. Only a single iteration of ESAT optimization analysis results will be demonstrated at Davis-Monthan AFB after project analysis is completed. The originally planned second iteration of optimization analysis that includes the special analysis studies phase related to energy surety analysis will be eliminated.

OSD/ECIP **-** The work scope to be performed at OSD/ECIP will remain unchanged. However, a two month delay is planned regarding the initial data collection and modeling and milestone, to accommodate the added AFCEC demonstration and the immediate support which is required. This should not impact the rest of the milestones as the modeling effort required for AFCEC will be beneficial for OSD/ECIP demonstration as well.

Air Force Civil Engineering Center (AFCEC)-Energy Directorate **-** AFCEC Energy Directorate is being added as a demonstration site. Immediate support will be provided for the upcoming 2014 project and budget evaluation cycle, occurring May–July 2014. The first phase of the demonstration will cover this period with a milestone in August 2014. The second phase of the demonstration will include additional iterations and/or updates to the initial analysis.

The performance objectives for this demonstration will be the same ones that have been identified in the original demonstration plan for the other demonstration sites.

Statement of Work:

1. Understand AFCEC current energy project portfolio selection process in detail.
    a. Establish baseline parameters for energy usage, goals
    b. Understand decision cycle process
2. Collect current cycle candidate energy project data (BLCC ECIP reports).
3. Define analysis and recommendation output report requirements.
4. Modify ESAT model as necessary to accommodate required analysis and outputs.
5. Modify visualization tool as necessary to accommodate required analysis and outputs.
6. Perform optimization analysis.
7. Perform requested trade study analysis and additional optimization analysis iterations.
8. Create reports.
9. Present results.
10. Collect labor and calendar effort expended in performing the analysis for both the ESAT approach and the rank order approach that is currently used.
11. Repeat analysis and reporting tasks for three additional quarterly updates.

Travel: One trip to Tyndall AFB is planned to present initial optimization analysis and collect feedback and lessons learned on the collaboration process.

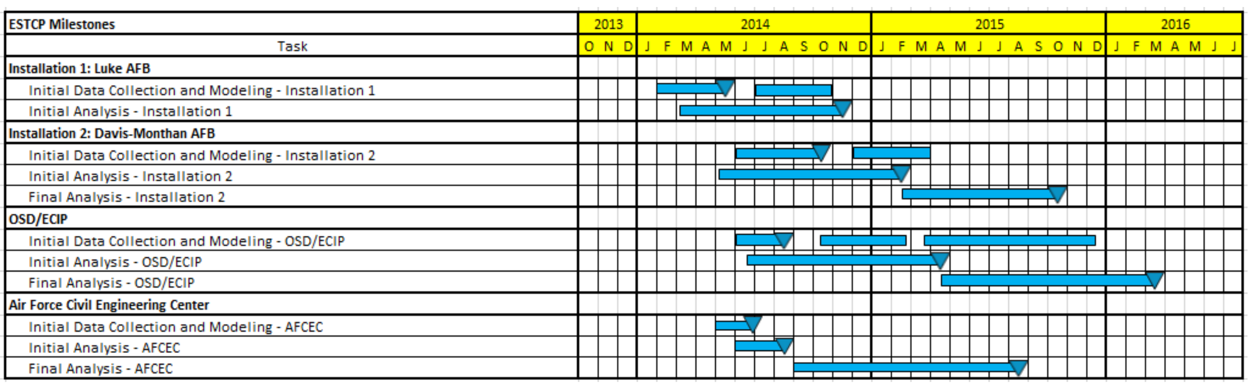
AFCEC POC information:

Steve McLellan
Energy Program Manager
Air Force Civil Engineer Center, AFCEC/CND
139 Barnes Drive, Suite 1
Tyndall Air Force Base, FL 32403
Comm 850-283-6453   DSN 523-6453

Schedule Change:

As a result of adding AFCEC as a demonstration site, there will be minor interim milestone changes to existing demonstrations site schedules, and added milestones for the added demonstration site. These schedule modifications are summarized in the table and Gantt chart below. However, the overall contract period of performance will remain unaffected.

Milestone	Luke AFB	Davis-Monthan	OSD/ECIP	AFCEC
Initial Data Collection and Modeling	No change	Delayed two months	Delayed two months	June 2014
Initial Analysis	No Change	No Change	No Change	August 2014
Final Analysis	Canceled	No Change	No Change	August 2015



SEMS will be updated to reflect the above milestone changes upon approval of this addendum.

Cost Impact:

No contract cost change modifications are required. The changes contained in this addendum are cost neutral to the project.

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APPENDIX D FEDS BLDG. CHARACTERISTIC DATA & NOTES, LUKE AFB, AUG. 2014

Bldg. 328 Petroleum Operations Building

- Used for training & support, fuels lab
- Schedule: 7:00 a.m. - 4:30 p.m. M-F; on Sat. /Sun. turn out the lights, and everything else is left as is.
- Temperature Set Point: heat = 76ºF, cool = 78ºF - this is the standard for the base, but not always followed or necessarily known by everyone. Lab kept at 68ºF.
- Lighting: 4', 2 tube T8; estimated quantity = 37. ~50% were not lit. Electronic ballast. 100% of building
- Cooling: Sgt. Dickson estimated A/C as 3.5 ton package, but use name plate data to verify. Small dedicated A/C unit to the lab, ~1-year-old, is a heat pump. West side is a packaged old looking A/C unit – 1994, not a heat pump.
- Hot water: electric, hot water heater, 100% of building
- Equipment in lab which use energy: fume hoods/exhaust fan on ½ hr. /day; flash tester (electric) 10 minutes/2x/week. Lab is used daily.
- Other miscellaneous items: propane tank for running equipment, diesel fuel tank and generator.

Image 1 - Bldg. 328 Petroleum Operations Building (South Wall)

Image 2 - Bldg. 328 Petroleum Operations Building (East Wall)

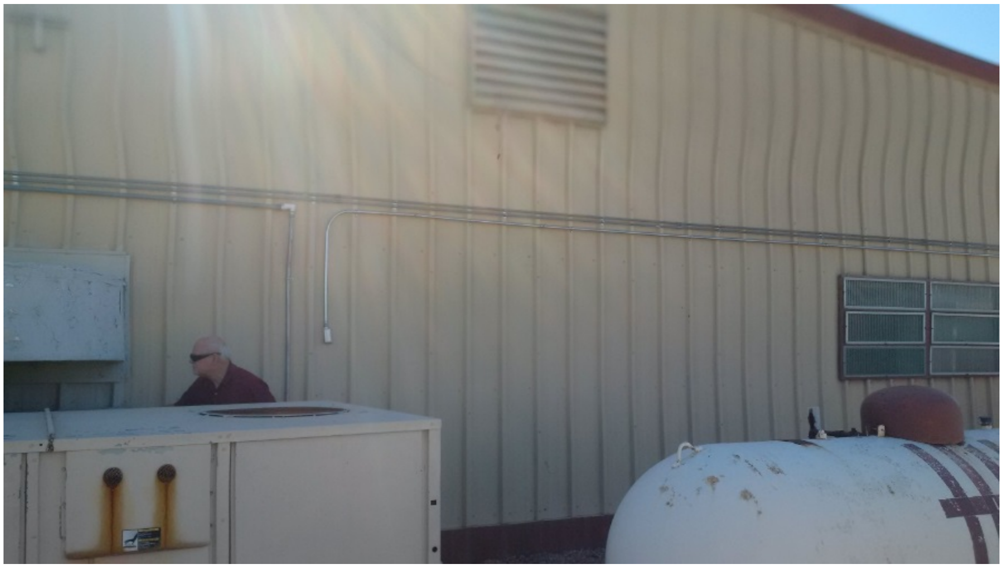

Image 3 - Bldg. 328 Petroleum Operations Building (West Wall)

Image 4 - Diesel Fuel Tank

Image 5 - Diesel Generator

Image 6 - Sample Office Lighting

Image 7 - Petroleum Lab Lighting

Image 8 - Small A/C unit dedicated to lab

<u>Bldg. 245 Visual Info (Public Affairs) Multimedia Center</u>

- Occupancy: No one in on the weekend, just shut the lights off. 7-9 people work in the building.
- Schedule: MWF 8:45 a.m. – 4:30 p.m.; Tuesday/Thursday 7:30 a.m. - 4:30 p.m. Bldg. manager said 8:00 a.m.-4:30 p.m.
- Temperature Set Point: 68^{o}F, said it needed to be cool so that expensive photo equipment (light, fuse, etc.) wouldn’t overheat.
- Lighting: 73 T8, 4’ fluorescent. 10 of these are off most of the time because they are in the studio where they are taking photos.
- Heating: Electric heat
- Cooling: Chilled water ducting from outside A/C. Note that none of the building visited are connected to the central A/C plant.
- Hot Water: Electric hot water, six gallon

Image 9 - Bldg. 245: Luke Multimedia Center

Image 10 - Bldg. HVAC

Image 11 - Bldg. 245 Office Lighting

Image 12 - Photo Lab

<u>Bldg. 547 Central Chiller Plant</u>

- Small Carrier A/C unit, 2011 mfg. date, cools the office area. Office area is about 18’ by 18’. Seven lights in the office.
- Building Construction Characteristics: Metal corrugated roof, no insulation, masonry walls, two small windows on front and side.
- Schedule: Mon.-Fri. 7:00 a.m. – 4:30 p.m.
- Heating: One small Reznor heater
- Cooling: Chillers are not dedicated to particular buildings. Received cooling GPM/tonnage load
- Hot water: natural gas, hot water heater
- Primary electric power likely for pumps and the chillers. See previous visit photos and notes for HVAC equipment details.
- Main bay where chillers are, 15 2x 4’ T8 Fluorescent lamps

Image 13 - Bldg. 547: Chiller Plant

Image 14 - Office Heater

<u>Bldg. 289 Vehicle Operations Admin</u>

- Operations in this building primarily admin, training, conferences, vehicle ops
- Schedule: Mon.-Fri. 5:00 a.m. – 6:00 p.m.; once per month reserve units use the facility on Sat. & Sun.; about 5-15 people work in the building
- Building heated/cooled 100%
- Cooling: Two split A/C units: 1 single compressor heat pump 2010, 1 dual compressor heat pump 2010
- Hot Water: Hot water serves 100% of building, fueled by natural gas
- In the annex, there is a supplemental window A/C unit. Annex size 22’ x 26’. Have dimensions for rest of the building from handout given to us.
- The recreational area has 7 lights, is about 30’x20’ in L-shape; about 40% of the building’s lights were unlit
- Exit signs are LED

Image 15 - Bldg. 289: Vehicle Management

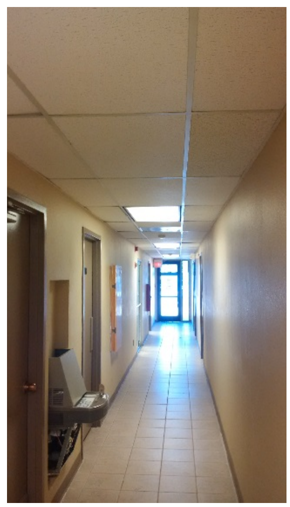

Image 16 - Office Lighting

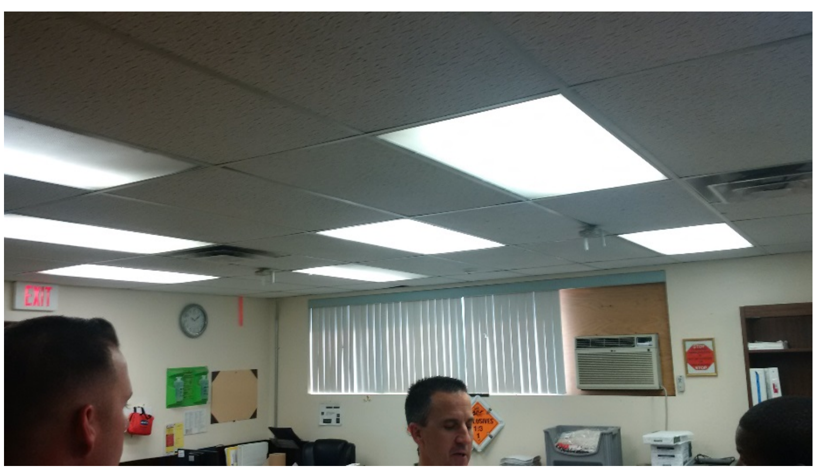

Image 17 - Office Lighting / Windows

Image 18 - LED Exit Lighting

Image 19 - HVAC

Bldg. 450 Fire Station

- Building Construction Characteristics: Masonry/plaster walls, consisting of an office area, truck bay, fitness center, a second small office area, small compressor charging area, 911 center/alarm room, kitchen area
- Schedule: open 24 hrs./day, 7 days/week
- Lighting: sky lights, and six rows of 2 tube T8 fluorescent 4' fixtures the length of the bay (120 ft.). Some halls lit, some unlit
- Heating: natural gas; in the bay, there is no heat;
- Cooling: two evaporative (swamp) coolers,
- Bay area is ~120'x120', fitness center is ~65'x40', has three medium size flat screen televisions, was 75^{o}F
- Alarm room has a split supplemental ceiling A/C unit; 25 computers, kept at 72^{o}F, has ceiling incandescent track lighting (6 flood lamps). Across the hall three server racks with another split supplemental ceiling unit.
- In the back, a cooling tower, two condensing units (from supplemental split A/C units)
- Natural gas powered hot water heater and boiler, with associated hot water storage tank
- Trane chiller not run in the winter, e.g. November-March. Instead a plate & frame heat exchanger is used which is more efficient.
- Kitchen area is about 20'x30'

Image 20 - Bldg. 450: Fire Station

Image 21 - Kitchen

Image 22 - Emergency Control Room

Image 23 - Truck Bay

Bldg. 959 Avionics Shop

- Occupancy: ~75 people work in the building; there are three building managers: one for QA, one for avionics, one for CMS staff (command staff/support staff). Small dark office unused except for communications server rack. (CMS)
- Schedule: 6 a.m.-midnight M-F,
- Temperature Set Point: 72°F
- Lighting: In large office area (QA) there were ~75 T8, 4’, two tube fluorescent lamps. A conference room had eight. Hallways under lit
- Heating: boiler
- Cooling: Two chillers, one cooling tower; one evaporative cooler to cool Mechanical Room (though I wonder if this is true, because the ducting didn’t seem to connect); one split supplemental A/C unit; plate & frame heat exchanger which serves in the November-March timeframe.
- Hot Water: 100% of building cooled/heated/served with hot water
- Air compressor
- Temperature was 78 °F (CMS)
- Avionics Bay: lighting: 96 4’, 4 tube T8 Fluorescent, side room with 24 4’ T8 fluorescent, plus three offices
- Avionics Bay: Fan coil McQuay 2’x5’ (no nameplate info)
- Avionics Bay: Two large AHUs which run 24x7.
- Avionics Bay: Test stations down run on weekends.

Image 24 - Bldg. 959: Avionics

Image 25 - Air Handler

Image 26 - Office Area

Bldg. 176 Communications Facility

- Occupancy: 15-20 people
- Schedule: M-F 7:00 a.m. – 5:00 p.m.
- Lighting: Standard office lighting (T8 two tube, 4' fluorescent), lights are turned off nights/weekend
- Temperature Set Points: Set points EMCS controlled
- Heating: Boiler (natural gas)
- Cooling: 1 dual fan A/C package unit mfr. in 2005, installed 2006; 1 supplemental fan coil dual fan A/C; 1 Carrier chiller A/C – three total units
- Hot Water: Hot water (natural gas)
- Communications room serves as the base central Comm. Center – kept a lot cooler

Image 27 - Bldg. 176: Communications Facility

Image 28 - Exterior View

Image 29 - Windows

Bldg. 968 Fuel System Maintenance Dock

- Building structured like:

- Bay dimension: ~160’x120’
- Occupancy: 40 people
- Schedule: Mon-Fri. 24 hrs./day; occasional weekend work
- Lighting: 67 pendant (mixed type, metal halide?) in the bay
- Heating: Four Reznor natural gas heaters on roof ducted into bay
- Cooling: Eight evaporative coolers in the roof ~4’ cube (18,000-20,000 CFM)
- Hot water: supplied to ~50% of facility
- Many skylights in roof
- Bay is both heated and cooled; office area is heated and cooled
- One office are has a common area, restrooms/showers
- The second office area has a break room (10’x20’, six light units), tool room (20’x20’, eight light units), both with T8 two tube 4’ fluorescent lighting, actual temperature = 74.5^{o}F, thermostat is set at 72^{o}F
- Above the second office area there is one package A/C unit (no plate info) and four evaporative coolers
- Also near the office area is a 30’x30’ maintenance area with 20 pendant lamps (likely 70w metal halide – according to TSgt Sheperd; however, they seemed way brighter than 70w). Another gas water heater is here
- If working with fuel, electric exhaust vents and trench run the entire time
- Outside the bay, there are six high pressure sodium lights illuminating the taxi-way
- On the weekend, all lights are turned off except one row for safety, PCs turned off, evaporative coolers turned off. There is no change to the thermostat.
- Over the first office area, called the main office, there are two package A/C units, one evaporative cooler. This office area has three offices

Image 30 - Bldg. 968: Fuel System Management Dock

Image 31 - Evaporative Condenser plus Heater

Image 32 - Shop Lighting

Bldg. 961 Weapon System Maintenance Mgt.

- Schedule: Entire building unoccupied now. However, lights are on and A/C runs as if it is fully occupied.
- Number of Stories: One story building
- Lighting: Long straight building with fluorescent lighting lining the corner join between ceiling and wall for entire length of building. Two tubes repeated for length on each side.
- Cooling: 1 medium size split A/C; 1 small size split A/C; 1 medium size split A/C; 1 large size split A/C; 4 total A/C units

Image 33 - Bldg. 961: Weapon System Maint. Mgt.

Image 34 - Interior Lighting

<u>Bldg. 913 Small Aircraft Maintenance Dock</u>

- Building shaped like this

- Bay accounts for ~70% of building area, each of the office areas ~15% each
- Associated with the <u>South Office Area</u>, is a conference room, three offices, harness braiding operations (small room), slab battery room, liquid O_2 maintenance
- Occupancy: ~5 people
- Number of Stories: South office is one story
- Schedule: Mon. 6:00 a.m.-Friday midnight, 24 hrs. Cooling is maintained 24/7. Lights are turned off on the weekend.
- Temperature set points: 68^{o}F winter and 78^{o}F summer
- Lighting: In the <u>Main Bay</u>, lighting consists of seven rows by ten columns of six tube 4' fluorescent T8 lamps
- Heating: No boiler in this area
- Cooling: 1 dual fan medium size A/C package chiller; 1 medium size single fan package A/C; 1 rooftop small A/C package; 3 total A/C units

- Hot water: Heater is in the slab battery room (for F-16)
- No cooling or heating in the main boiler and hot water heater, external generator for A/C (not sure if someone told me this and I recorded it…not recalling seeing this)
- Associated with the North Side office area, it is one story, but half of the floor area is two stories high
- About 10% hot water supplied, a small hot water heater in the mop room, which supplies restrooms
- Cooling on roof: 1 package A/C unit; 1 medium A/C package/chiller?; 1 medium A/C package/chiller?; five window/wall A/C units which supply cooling to the second story offices
- In the PC lab area (racks of laptops), doors are automatically opened and closed, and sometimes get stuck open, causing A/C to be continuously running
- Occupancy: 150-200 over three shifts
- Schedule: 24 hrs./day Mon.-Fri.; work one shift Saturday and Sunday one time per month

Image 35 - Bldg. 913: Aircraft Maint. Dock

Image 36 - Battery Lab

Image 37 - Hangar Lighting

Image 38 - Hangar

Image 39 - Office Window AC Units

APPENDIX E FEDS BLDG. CHARACTERISTIC DATA & NOTES, DAVIS-MONTHAN AFB, OCT. 2014

Bldg. 7514 AMARG Command Building

- Square Footage: 6,000 ft^2
- Building Construction Characteristics: commercial windows, metal walls, metal roof, with interior roof insulation, concrete floor with carpeting
- Number of Stories: 1
- Occupancy: ~15 people
- Schedule: 0600-1700 Monday-Friday
- Temperature set points: 72^{o}F year round
- Lighting: Recessed fluorescent lighting, 50% are de-lamped
- Heating: 2009, natural gas, boiler
- Cooling: 2005, electric, packaged unit
- Hot Water: Natural gas, hot water heater

Image 40 - Bldg. 7514 Command Building

Image 41 - Packaged unit

Image 42 - Hot Water heater

<u>Bldg. 7513 Support Squadron Offices with Transformation Conf. Room</u>

- Square Footage: 6,000 ft^2
- Building Construction Characteristics: residential windows, metal walls, metal roof, with interior roof insulation, concrete floor with carpeting
- Number of Stories: 1
- Occupancy: ~11 people
- Schedule: 0600-1800 Monday-Friday
- Temperature set points: 75^{o}F year round
- Lighting: Flush mount fluorescent lighting, 50% are de-lamped
- Heating: year unknown, natural gas, boiler
- Cooling: 2007, electric, chiller
- Hot Water: Natural gas, hot water heater
- Miscellaneous Characteristics: 40'x50' conference room used routinely

Image 43 – Bldg. 7513 Support Squadron Offices

Image 44 - Exit lighting

Image 45 – Office Lighting

Bldg. 7507: AMARG Engineering Offices and Start Treaty Conf. Center

- Square Footage: 6,000 ft^2
- Building Construction Characteristics: residential windows, metal walls, metal roof, with interior roof insulation, concrete floor with carpeting
- Number of Stories: 1
- Occupancy: ~10 people
- Schedule: 0600-1700 Monday-Friday
- Temperature set points: 75°F year round
- Lighting: Some flush mount and some recessed fluorescent lighting, about 15 flush mount T-8
- Heating: 2002, electric, heat pump; 2008, natural gas heat, packaged unit; 1997, natural gas heat, packaged unit

- Cooling: 2002, electric, heat pump; 2013, electric, packaged unit; 2002, electric, packaged unit; 2008, electric, packaged unit; 1997, electric, packaged unit
- Hot Water: Natural gas, hot water heater
- Miscellaneous Characteristics: 6 rooms 15’x25’

Image 46 - Bldg. 7507: AMARG Engineering Offices

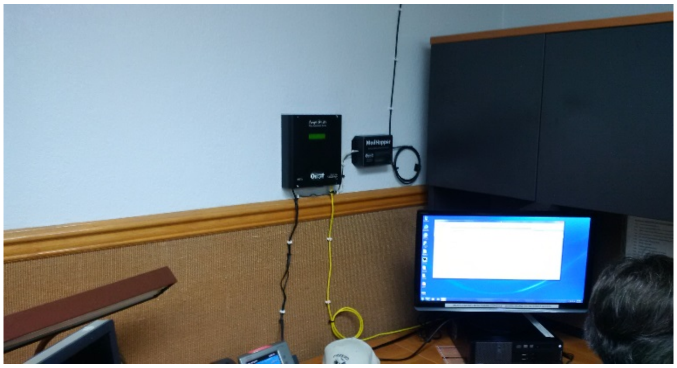

Image 47 - Wireless Meter Computer

Image 48 - Wireless Energy Meter

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Image 49 - Packaged Unit

<u>Bldg. 7328: Finance & IT Offices, AMARG Server room/Supply Warehouse</u>

- Square Footage: Warehouse: 29,000 ft2; Office: 20,500 ft^2
- Building Construction Characteristics: Warehouse: no windows, concrete block walls, metal roof, with interior roof insulation, concrete floor; Office: commercial windows, built up walls, and roof insulation, concrete floor
- Number of Stories: 1
- Occupancy: Warehouse: ~12-14 people; Office: ~60
- Schedule: 0600-1530 Monday-Friday same operating hours for the warehouse and office; half people, half days on Saturdays
- Temperature set points: Warehouse: 72^{o}F; Office: 70^{o}F
- Lighting: Warehouse: 40 Metal halide pendent lights; Office: some flush mount and some recessed fluorescent lighting
- Heating: Warehouse: natural gas, space heaters; Office: 2009, natural gas, boiler; 2000, electric, heat pump
- Cooling: Warehouse: one evaporative cooler; Office: 1998, electric, chiller; 1996, electric, packaged unit; 2000, electric, heat pump; 2005, electric, chiller. There is combined cooling between equipment.
- Hot Water: warehouse and Office: Natural gas, hot water heater
- Miscellaneous Characteristics: Two linked buildings: Warehouse and Office

Image 50 - Bldg. 7328: Finance & IT Offices

Image 51 - Boiler and Pump Area

Image 52 - Warehouse Lighting

<u>Bldg. 7391: Aircraft Parts Reclamation Processing Facility and Admin Offices</u>

- Square Footage: Warehouse: 40,000 ft2; Office: 4,000 ft^2
- Building Construction Characteristics: Warehouse: Commercial windows, concrete block walls, metal roof, with no interior roof insulation, concrete floor; Office: commercial windows, built up walls, and roof insulation, concrete floor
- Number of Stories: 1
- Occupancy: Warehouse: ~20 people; Office: ~ 20
- Schedule: 0600-1700 Monday-Friday same operating hours for the warehouse and office
- Temperature set points: Warehouse and Office: 72^{o}F
- Lighting: Warehouse: 84 Metal halide pendent lights; Office: flush mount fluorescent lighting
- Heating: Warehouse: natural gas, space heaters; Office: 2003, natural gas, boiler; 2002, electric, heat pump
- Cooling: Warehouse: seven evaporative coolers; Office: 2003, electric, chiller; 2003, electric, packaged unit; 2002, electric, heat pump; 2002, electric, packaged unit; 2003, electric, window unit. There is combined cooling between equipment.
- Hot Water: warehouse and Office: Natural gas, hot water heater
- Miscellaneous Characteristics: Two linked buildings: Warehouse and Office

Image 53 – Bldg. 7391: Aircraft Parts Reclamation Processing Facility and Admin Offices

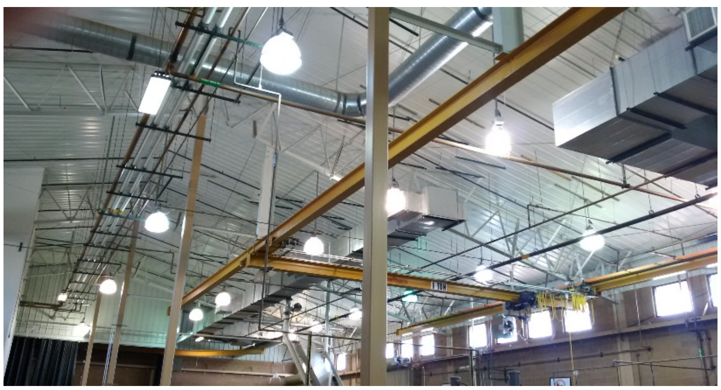

Image 54 – Production Facility Lighting

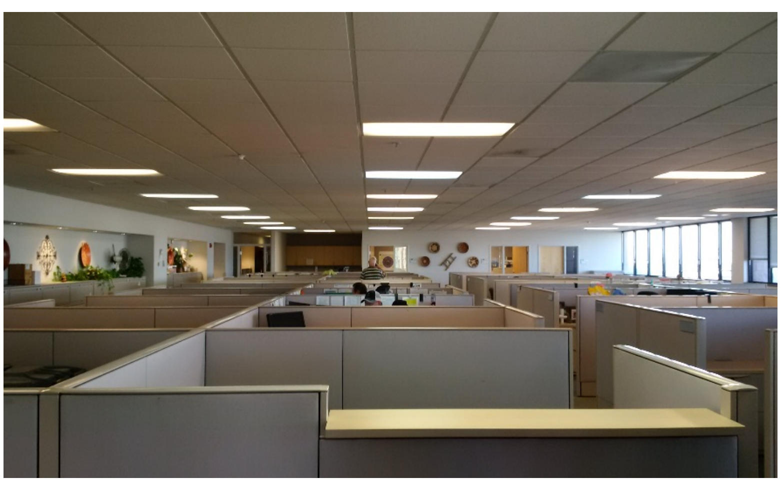

Image 55 – Admin Office Lighting

Bldg. 7439: Avionics, Radio & Electric Shop

- Square Footage: 11,200 ft^2
- Building Construction Characteristics: Shop: Commercial windows, Metal walls, metal roof, with interior roof insulation, concrete floor; Office: commercial windows, built up walls, and no roof, concrete floor
- Number of Stories: 1
- Occupancy: ~19-24 people
- Schedule: 0600-1700 Monday-Friday
- Temperature set points: 72^{o}F year round
- Lighting: Some flush mount and some recessed fluorescent lighting, 50% de-lamped, two external floodlights
- Heating: natural gas, space heaters; 1995, natural gas heat, packaged unit
- Cooling: 1995, electric, packaged unit
- Hot Water: Natural gas, hot water heater
- Miscellaneous Characteristics: small offices inside of the shop

Image 56 - Bldg. 7439: Avionics, Radio & Electric Shop

Image 57 - Shop Office without a Roof

Image 58 - Evaporative Cooler and a Packaged Unit

Bldg. 7431: AMARG Wood Mill

- Square Footage: Warehouse: 15,520 ft2; Office: 480 ft^2

- Building Construction Characteristics: Warehouse: Commercial windows, metal walls, metal roof, with no interior roof insulation, concrete floor; Office: commercial windows, built up walls, and roof insulation, concrete floor
- Number of Stories: 1
- Occupancy: Warehouse and Office: ~28 people
- Schedule: 0600-1600 Monday-Friday same operating hours for the warehouse and office
- Temperature set points: Warehouse and Office: 72^{o}F
- Lighting: Warehouse: 42 Metal halide pendent lights; Office: flush mount fluorescent lighting
- Heating: Warehouse: No heating Office: 2005, natural gas, boiler; 1995, electric, heat pump
- Cooling: Warehouse: six evaporative coolers; Office: 1995, electric, heat pump; 2003, electric, window unit. There is combined cooling between equipment.
- Hot Water: warehouse and Office: Natural gas, hot water heater
- Miscellaneous Characteristics: Two linked buildings: Warehouse and Office

Image 59 - Bldg. 7431: AMARG Wood Mill

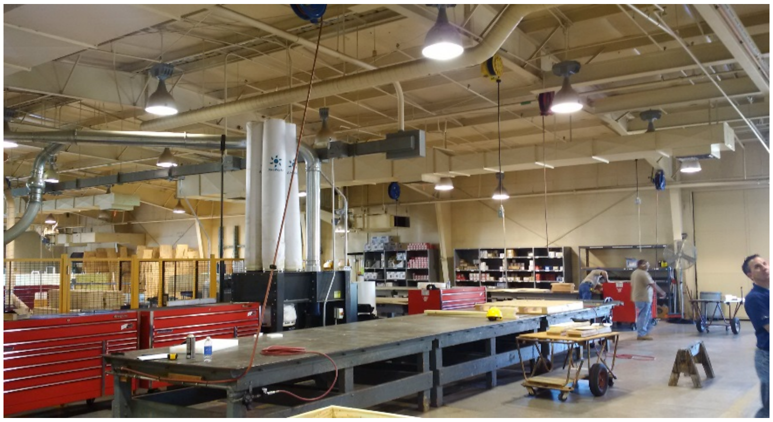

Image 60 - Wood Mill Shop lighting

Image 61 - Window AC Unit

<u>Bldg. 7441: Welding and Machine Shop</u>

- Square Footage: Warehouse: 6,000 ft2; Office: 400 ft^2
- Building Construction Characteristics: Warehouse: Commercial windows, metal walls, metal roof, with no interior roof insulation, concrete floor; Office: commercial windows, built up walls, and roof insulation, concrete floor
- Number of Stories: 1
- Occupancy: Warehouse and Office: ~15 people
- Schedule: 0600-1700 Monday-Friday same operating hours for the warehouse and office
- Temperature set points: Warehouse and Office: 72ºF
- Lighting: Warehouse: 45 Metal halide pendent lights; Office: flush mount fluorescent lighting
- Heating: Warehouse: Natural gas, space heaters; Office: 2000, electric, packaged unit
- Cooling: Warehouse: three evaporative coolers; Office: 2000, electric, packaged; two 2005, electric, window unit. There is combined cooling between equipment.
- Hot Water: warehouse and Office: Natural gas, hot water heater
- Miscellaneous Characteristics: Two linked buildings: Warehouse and Office

Image 62 - Bldg. 7441: Welding and Machine Shop

Image 63 - Shop Lighting

Image 64 – Window AC Inside of Office

<u>Bldg. 7428: Aircraft Sun Shelter</u>

- Square Footage: Warehouse: 161,000 ft2; Office: 1,400 ft^2; Portable Office: 1,600 ft^2
- Building Construction Characteristics: Warehouse: Metal roof, open air (no walls, no windows), with no interior roof insulation, concrete floor; Office: commercial windows, built up walls, and roof insulation, concrete floor; Portable Office: residential windows, built up wood walls, and roof insulation, concrete floor
- Number of Stories: 1
- Occupancy: Warehouse, Office, and Portable Office: ~15 people
- Schedule: 0600-2300 Monday-Friday same operating hours for the warehouse and office
- Temperature set points: Office, and Portable Office: 72^{o}F
- Lighting: Warehouse: 270 Metal halide pendent lights, 72 fluorescent; Office: T-8 flush mount fluorescent lighting; Portable Office: Flush mount fluorescent
- Heating: Warehouse: none; Office: 2011, electric, packaged unit; Portable Office: none

- Cooling: Warehouse: none; Office: 2011, electric, packaged; eight 2005, electric, window unit; Portable Office: three 2013, packaged units There is combined cooling between equipment.
- Hot Water: Office only: Natural gas, hot water heater
- Miscellaneous Characteristics: Three linked buildings: Warehouse, Office, and Portable Office

Image 65 - Bldg. 7428: Aircraft Sun Shelter

Image 66 - Packaged Units

Image 67 - Office Inside of Sun Shelter with Window AC Units

Image 68 - Portable Office Packaged Units

<u>Bldg. 7506: Small F-16 Hangar and Admin Offices</u>

- Square Footage: Warehouse: 8,241 ft2; Office: 4,059 ft^2
- Building Construction Characteristics: Warehouse: No windows, metal walls, metal roof, with interior roof insulation, concrete floor; Office: No windows, built up walls, and roof insulation, concrete floor

- Number of Stories: 1
- Occupancy: Warehouse and Office: ~10 people
- Schedule: 0600-2300 Monday-Friday same operating hours for the warehouse and office
- Temperature set points: Warehouse and Office: 72°F
- Lighting: Warehouse: 44 Metal halide pendent lights; Office: flush mount fluorescent lighting, ten external floodlights
- Heating: Warehouse: none; Office: 2004, natural gas, boiler
- Cooling: Warehouse: six evaporative coolers; Office: 2004, electric, packaged unit. There is combined cooling between equipment.
- Hot Water: warehouse and Office: Natural gas, hot water heater
- Miscellaneous Characteristics: Two linked buildings: Warehouse and Office

Image 69 - Bldg. 7506: Small F-16 Hangar and Admin Offices

Image 70 - Hanger Lighting

Bldg. 7408: Medium F-16 Hangar and Admin Offices

- Square Footage: Warehouse: 18,400 ft2; Office: 4,600 ft^2
- Building Construction Characteristics: Warehouse: Commercial windows, concrete block walls, metal roof, with interior roof insulation, concrete floor; Office: no windows, built up walls, and roof insulation, concrete floor
- Number of Stories: 1
- Occupancy: Warehouse and Office: ~30
- Schedule: 0600-2300 Monday-Friday same operating hours for the warehouse and office
- Temperature set points: Warehouse and Office: 72^{o}F
- Lighting: Warehouse: 66 Metal halide pendent lights; Office: flush mount fluorescent lighting, 12 1000W floodlights
- Heating: Warehouse: natural gas, space heaters; Office: 2002, natural gas heat, packaged unit; 2008, natural gas heat, packaged unit
- Cooling: Warehouse: six evaporative coolers; Office: 2008, electric, packaged unit; 2002, electric, packaged unit; two 2005, electric, packaged unit. There is combined cooling between equipment.
- Hot Water: warehouse and Office: Natural gas, hot water heater
- Miscellaneous Characteristics: Two linked buildings: Warehouse and Office

Image 71 - Bldg. 7408: Medium F-16 Hangar and Admin Offices

Image 72 - Hanger Lighting and Heater

APPENDIX F ECIP FY16 PERFORMANCE OBJECTIVES FEEDBACK

The following are the full comment set provided by CDR Matthew McCann, after completing FY16 decision cycle using ESAT.

1) Analysis Cycle Labor Effort Required

With the legacy approach, a lot of time is spent with the mechanics of manipulating the analysis spreadsheet – that is, a lot of time is spent *creating* the results vs. *analyzing* the results. With the ESAT approach, more data is produced for consideration, and it is more meaningful qualitatively. The time available to analyze for decision making is an order of magnitude more. The actual labor time spent "touching" the model was much less (approximately 25% as much) than the legacy approach, since the ESAT team did most of the modeling and analysis tasks. Therefore, "Installation" labor was focused more on analyzing and refining the investigation route instead of analysis tool development activities.

2) Analysis Cycle Duration Required

The decision making process is a six week cycle, and ESAT successfully supported this timeline and met the required milestones. The ESAT model building and analysis process easily fit within the budgetary timeframe, allowing multiple iterations and analyses to discover the most suitable portfolio recommendation.

3) Insight Gained

Quantity of Portfolios Analyzed: The legacy approach provides for analyzing three to five project portfolios. For comparison, using the ESAT approach, hundreds of portfolios are examined for the equivalent analysis iterations. Decision makers have more information upon which to make their decisions, "less of a shot in the dark". Analysis results are provided to make an informed decision. Legacy approach: here's the result, meaning one portfolio is offered with little substantiation or flexibility to search for alternatives. ESAT offers more flexibility and improved guidance for smart portfolio selection. The legacy approach doesn't provide a lot of feedback on whether or not the chosen criteria and weighting was appropriately applied. ESAT facilitated many iterations and provided more optimal portfolios, for consideration and analysis, to ensure that the selected portfolio actually addressed the needs, requirements and goals of ECIP. It facilitated meaningful iteration by repeatedly refining the criteria and constraints through sensitivity studies, informing the analysis evolution. ESAT is a focused approach vs. a "blind" or wandering approach. Each iteration precipitates the questions that need to be asked to further refine the analysis process. ESAT offers a drill down capability to verify the accuracy of results and provides understanding as to how the constituent projects interplay to comprise the portfolios. ESAT surfaces unexpected results and provides a mechanism to trace and identify their causes and effects. ESAT provides flexibility to add constraints or criteria "on the fly". Parameters that you didn't know were important until after you saw some initial results can be, subsequently, easily integrated.

4) Budget Justification

Robust data and deep analysis is provided by ESAT so that the selected project portfolio is more easily explained for approval. ESAT provides the right tools and analysis to show the benefit of the program to outside decision makers. ESAT provides visualizations that the legacy process doesn’t, increasing the robustness of the analysis. Key visualizations include: geographic breakdown analysis, investment allocation, tree maps and heat maps.

APPENDIX G ECIP FY17 PERFORMANCE OBJECTIVES FEEDBACK

The following are the full comment set provided by CDR Walter Ludwig, after completing FY17 decision cycle using ESAT.

1) Analysis Cycle Labor Effort Required

A quantitative measure of how many hours was required for the above criteria was not recorded during the legacy or new approach analysis, however the ESAT approach demands far less hours of OSD personnel to conduct analysis and select the ECIP portfolio which best meets the DoD's strategic goals. The legacy approach which utilized Microsoft Excel would be, at a minimum, 4-5 times more time intensive than the ESAT approach.

5) Analysis Cycle Duration Required

Similar to the previous answer, legacy and ESAT approach dates were not recorded, however the ESAT approach is by far more accelerated. The FY17 ECIP portfolio selection was completed in less than two weeks which could not have been accomplished utilizing the legacy method. ESAT enabled almost real-time sensitive analysis which allowed for a review of multiple optimized ECIP portfolios to ensure the best portfolio was selected that maximized SIR and maximized contribution to DoD strategic goals

6) Insight Gained

The ESAT approach provided better insight on balancing service project priorities, funds distribution by service, qualitative scoring, SIR, payback, and portfolio net present value. Insights were clearly evident through easy to understand visualizations of data analysis that could not have been accomplished without the ESAT tool and team.

7) Budget Justification

Although the multi-year demonstration is still underway, the ESAT tool was utilized to present a budget submission to OSD leadership and Congress. The ESAT tool enabled best possible budget submission to be made.