Appendix A. Measure Category Definitions

ESCOs applying for NAESCO accreditation are asked to indicate the measures installed in each project based on a list of over 100 specific measures organized by end use. These reported measures were aggregated into the categories presented in Table 5-4 and Table 6-4 to facilitate interpretation of the results. The specific measures included in each category are shown in **Table A-1**, below.

Table A-1. Measure Category Definitions

Measure Category	Measures Included in Category
Lighting	• controls/motion sensors • lighting retrofit • exit signs • ballasts • parking lot/outdoor lighting • lamps • reflectors • daylighting
Heating, Ventilation & Air Conditioning (HVAC):	
Boilers	• boilers
Chillers	• chillers
Other HVAC sources	• cooling towers • furnaces • heat pumps (air source)
Distribution/ventilation	• air handling units • ducts/fittings (also duct insulation) • heat exchangers • piping/steam distribution • pumps & priming systems • steam/heat traps • variable air volume • airflow control • dampers/blowers • exhaust/ fans • fume hoods
Controls	• energy management systems • thermostats
Other HVAC	• thermal storage • spot AC/window units
Packaged/roof-top/split systems	• air-cooled condensers • water-cooled condensers • economizers (air side and water side)
Air quality	• dessicants • filters • heat pipes • humidifiers

Measure Category	Measures Included in Category
Building envelope (e.g., insulation, windows, doors)	• doors • insulation • weather proofing • reflective roofs • windows
Geothermal heat pumps	• geothermal heat pumps
Motors/drives:	
High-efficiency motors	• engines • motor resizing • motor retrofit • new/replacement motors
Variable speed drives (VSD)	• variable speed drives
Water heaters	• demand/instantaneous water heaters • electric water heaters • gas-fired water heaters • oil-fired water heaters • solar water heaters • hot water piping/distribution • water heater heat exchangers • drain water heat recovery • water heater electronic ignition • water heater heat pumps • water heater heat traps • water heater insulation • water heater replacement/upgrade • water heater timers
Miscellaneous equipment/systems	• plug loads • office/computer equipment • vending machines • traffic signals • ovens/cooking equipment (food warming, infra-red heaters) • laundry equipment • pool systems • waste disposal equipment
Industrial process improvements	• compressed air • other industrial processes
Other measures/strategies	• staff training • equipment scheduling • fuel conversion • utility tariff analysis • peak shaving • commissioning • load management systems • metering/billing systems
Water conservation	• low-flow toilets/urinals • low-flow faucets • low-flow showers • water conservation

Measure Category	Measures Included in Category
Distributed generation:	
Renewables	• biomass digesters • hydro-electric generators • photovoltaics • wind turbines • land-fill gas generators
Cogeneration	• cogeneration
Other DG technologies	• fuel cells • gas-fired turbines • microturbines • natural gas engines • steam turbines
Backup/emergency generators	• diesel engines • natural gas engines (if known to be for emergency use)

Appendix B. Retrofit Strategy Definitions

This Appendix describes the classification of NAESCO/LBNL database projects into the retrofit strategies used throughout this report and how we mapped these strategies to strategies developed independently by PNNL for projects in FEMP's UESC database.

B.1. LBNL Retrofit Strategies

The goal of developing retrofit strategies was to define several common retrofits that would provide insights into project characteristics and trends. Because the majority of ESCO projects contain multiple measures and the set of possible combinations of measures is large, it was challenging to define mutually exclusive retrofit strategies that were common enough to provide meaningful project comparisons. Our strategies were coded based on what we determined, after considerable data exploration, to be the dominant measures in the project. For a description of the six strategies, see section 5.2.4.

The methodology for coding projects is outlined in the flowchart in **Figure B-1**. Lighting-only projects are defined by having installed various types of lighting efficiency measures (e.g., high-efficiency lamps, ballasts, controls) (step 1 in Figure B-1). Among multi-measure projects, we ranked key measures in importance based on their relative costs as well as customer motivation to install them. Distributed generation technologies were given highest priority – any project including DG is included in the DG strategy, regardless of the other measures in the project (step 2 in Figure B-1). This is because the cost of installing a DG system tends to outweigh the cost of other measures, and also because DG is installed primarily for reliability or cost-savings rather than energy savings.

Capital-intensive non-energy-saving measures were ranked second in importance, and any non-DG projects with these measures were included in the "non-energy" category (step 3 in Figure B-1). Our objective in this ranking was to separate projects with relatively poor economics due to the installation of high-cost, non-energy improvements that do not contribute directly to reducing energy usage at the customer's facility.

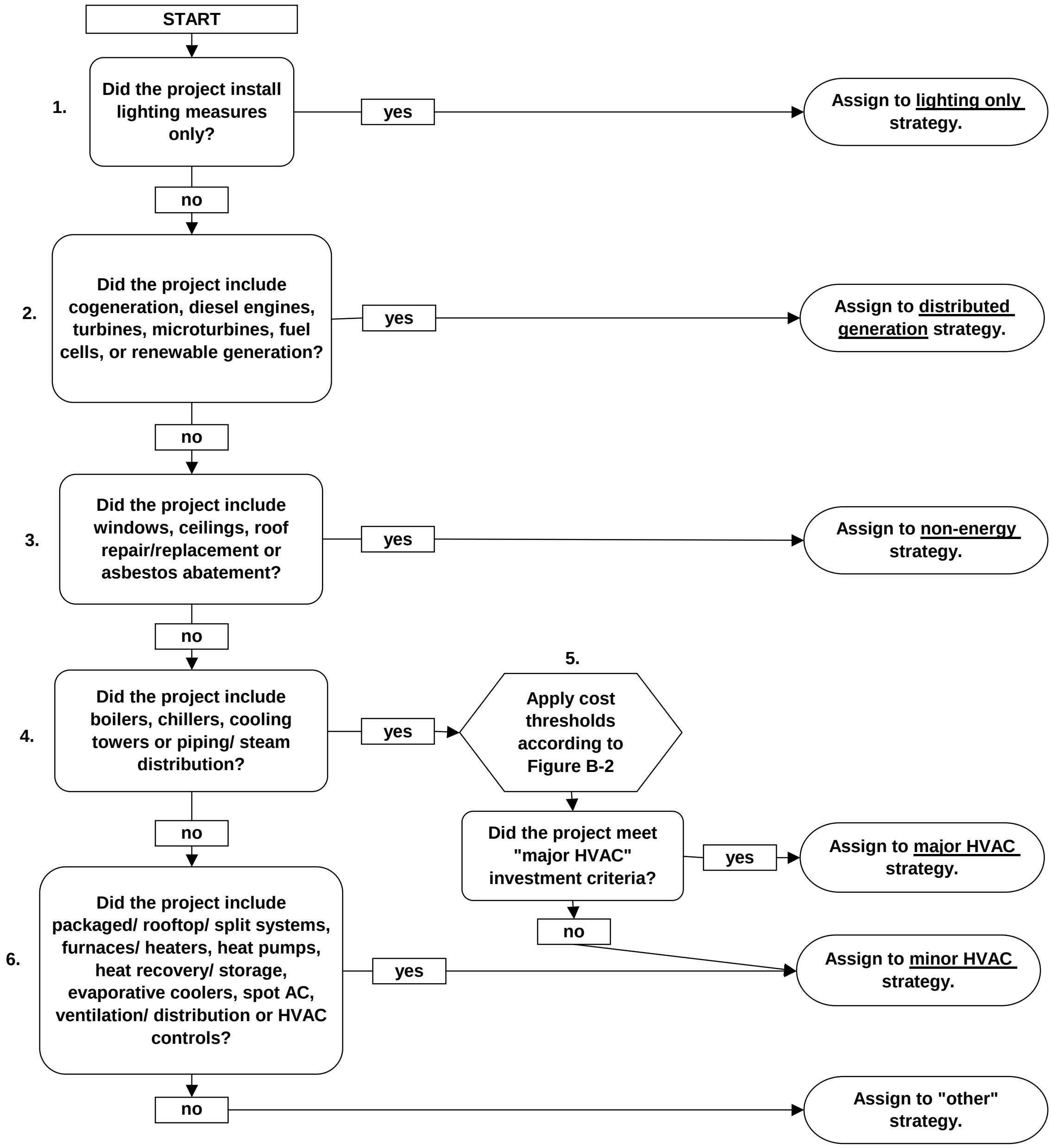

Figure B-1. Procedure for Coding NAESCO Database Projects by Retrofit Strategy

The remaining projects were classified according to their HVAC measures (or lack thereof). We separated HVAC projects into major and minor HVAC retrofits based in part on the measures installed (major HVAC projects installed at least one of boilers, chillers, cooling towers or piping/steam distribution; see step 4 in Figure B-1), and according to investment thresholds (see step 5 and section B.1.1 below). Projects without HVAC measures were classified in the "other" strategy (step 6).

B.1.1 Classification of Major and Minor HVAC Projects

In defining "major" and "minor" HVAC projects, our goal was to separate capital intensive retrofits, where the entire heating or cooling or distribution system was replaced, from relatively minor HVAC improvements. For projects that reported measures that we deemed could be capital intensive – boilers, chillers, cooling towers and piping/steam distribution – we did not have enough information to know if a major HVAC system replacement was undertaken, or whether a single boiler at a large campus-type facility was replaced or existing HVAC equipment was simply retrofitted. The solution that we arrived at, given the data available to us, is outlined in the flowchart in **Figure B-2**. Projects that installed at least one of boilers, chillers, cooling towers or piping/steam distribution (and that had not been classified as DG or non-energy in Figure B-1) were evaluated based on their project investment per square foot relative to established investment intensities for these technologies.

To complete this evaluation, projects had to have cost data (step 1 in Figure B-2); 18% of the projects subjected to this process did not. The majority of such projects included other (minor) HVAC measures, so we simply assigned them to the minor HVAC retrofit strategy (see step 2 in Figure B-2). Ten projects did not have other HVAC measures; we decided to exclude them due to lack of information, leaving these projects unclassified.

The other key data required to code major HVAC projects is floor space. For the 25% of projects missing this information, the median project floor area for the project's market segment was assigned to the project using the data in Table 5-1 (steps 3 and 4 in Figure B-2). Project investment intensity per square foot was then calculated from cost and floor space data (step 5).

Before comparing project investment to typical costs for the capital-intensive measures (boilers, chillers, etc.), we attempted to back out the cost of other measures included in the project. We developed estimates of typical investment for as many measures as possible, using measure-specific data available in the 129 federal Super ESPC project Delivery Orders, calculating the median cost per square foot for each measure that had a sufficient number of data points.[1] We then subtracted the cost per square foot for each of these measures that were installed in the project from the project's total cost per square foot (step 6 in Figure B-2). The resulting "net" project cost was assumed to represent the cost of the capital-intensive HVAC measures (boilers, chillers, etc.), net of other measures in the project.[2]

The next step in this process was to develop investment thresholds for the four capital-intensive HVAC technologies that we wished to compare against: boilers, chillers,

[1] Measure-specific costs and savings were not provided for other database projects – only project-level information was reported.
[2] This assumption is not perfect: projects may have included other measures that we did not have cost data for and therefore could not subtract, and projects may have spent more or less on measures than the median costs that we used. Nonetheless, it was the best possible solution given the data available to us.

cooling towers and piping/steam distribution (see section B.1.2, below, for details). For each project under evaluation, we developed a "cost cutoff" by adding the investment thresholds for each of the capital-intensive HVAC measures installed in the project (e.g., if a project installed both chiller and cooling tower measures, we added the cost thresholds for chillers and cooling towers to come up with a project-specific cutoff criteria; step 7 in Figure B-2).

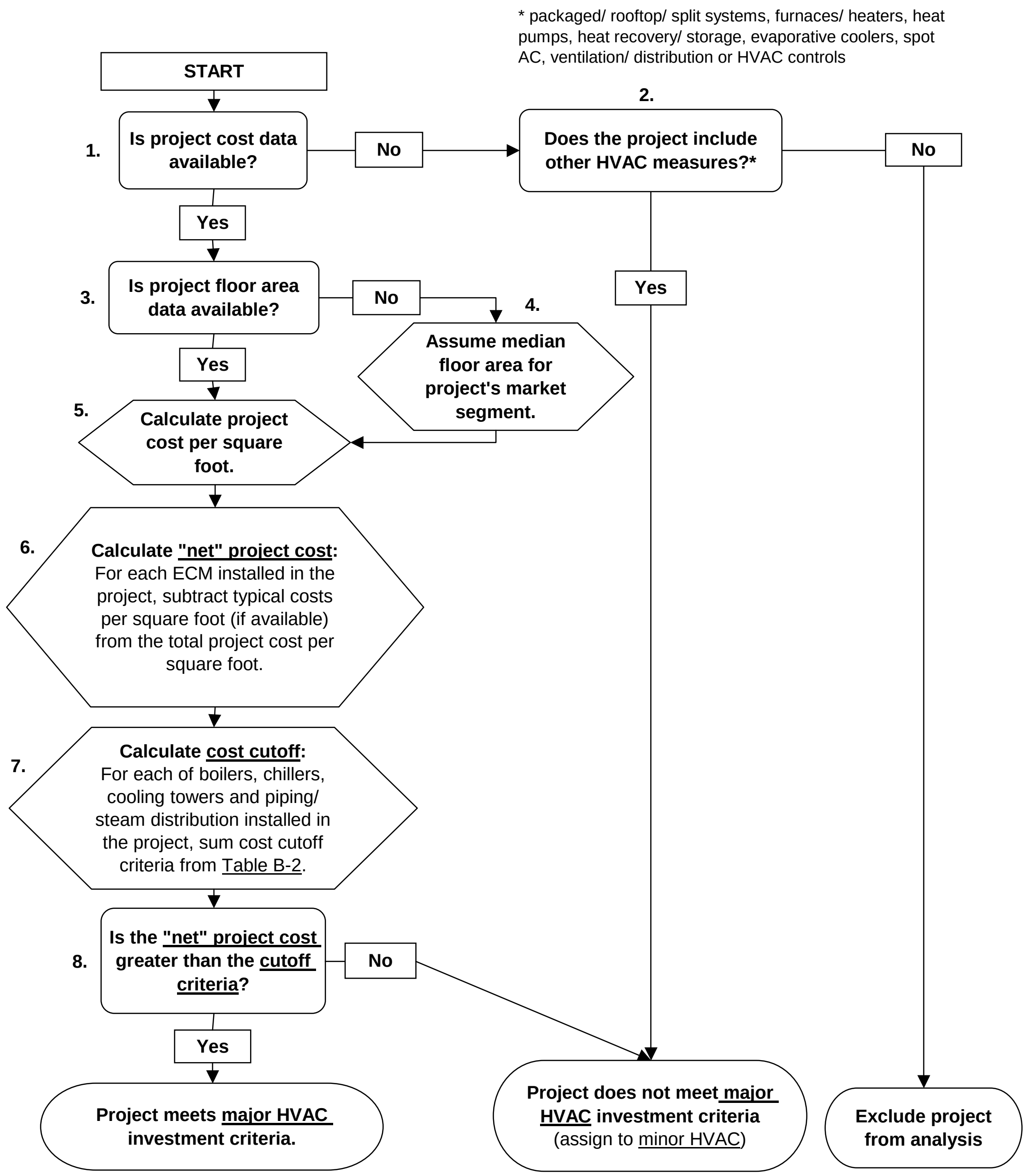

Figure B-2. Procedure for Identifying Capital-Intensive Major HVAC Projects

Finally, the estimated ("net") project cost (per square foot) for HVAC-related equipment measures was compared to the cost cutoff for each project (step 8 in Figure B-2). Projects that had estimated HVAC-related equipment costs greater than the cutoff were deemed to have met the major HVAC criteria and were classified in this category. Those that didn't were classified in the minor HVAC category.

B.1.2 Determining Cost Cutoff Criteria for Major HVAC Technologies

Establishing investment intensities of major HVAC technologies – boilers, chillers, cooling towers and piping/steam distribution – that could be used as criteria for evaluating projects with minimal bias was challenging. Each ESCO project is unique; facility characteristics, energy savings opportunities, customer needs and project design elements, for example, vary considerably and may impact investment intensity, even for specific technologies. We attempted to reduce the bias inherent in assigning cutoffs based on "typical" projects to such a wide variety of situations by exploring the range of costs that could be expected in different building types and locations.

Based on the median building size in each market sector (see Table 5-1), we defined four typical building types to which we assigned projects from each market segment: 1) high rise office buildings, found in the civilian federal government sector, 2) hospitals, 3) low rise office buildings, found in local government, K-12 schools, and university market segments, and 4) campuses served by district heating and cooling found in military federal government and university sectors. For each building type, we estimated a heating and cooling load based on sizing guidelines in *Means Mechanical Cost Data* (Means 2003). These values were checked against heating and cooling capacities calculated by DOE-2, a detailed building energy simulation software tool, for prototypical commercial buildings (Huang and Franconi 1999, Huang et al. 1990), and it was found that the cooling loads in *Means* were oversized.[3] To address this, we substituted the cooling load per square foot from the DOE-2 calculations for the *Means* cooling guidelines for each building type. Labor and equipment costs from *Means* for boilers, chillers and cooling towers sized to meet each building load were used to determine a cost per square foot by technology for each type of building. For military and university campuses, the project floor area was used to size the load since it was assumed that the campus used a central plant to provide heating and cooling. For comparison, we also calculated median costs per square foot for boilers, chillers and piping/steam distribution from the Super ESPC projects in our dataset that installed these technologies.[4]

Having assembled these estimates, we decided to choose a single cost cutoff for each technology, regardless of building type, because the range of estimates across building types was within our margin of error. For boilers, chillers and cooling towers, we chose values slightly lower than the average of highest two building type estimates calculated from *Means* and DOE-2 data.[5] For piping/steam distribution, we used the median cost for

[3] Cooling equipment is commonly oversized to avoid user complaints due to underperformance on extremely hot days that exceed the design temperature of the cooling equipment. Thus, the prediction that the *Means* cooling equipment was oversized was not unexpected.

[4] An insufficient number of Super ESPC projects had installed cooling towers to do a similar calculation for this technology.

[5] The cost criteria for major HVAC equipment were deliberately set high because, for many projects, the estimated HVAC-related equipment measure costs per square foot ("net" cost) still included the costs of

this measure from Super ESPC projects, because it was the only estimate available. These final cost cutoff criteria are shown in **Table B-1**.

Table B-1. Investment Intensity of Capital-intensive HVAC Measures

Measure	Cost Cutoff Criteria ($/ft^2)
Boilers	0.22
Chillers	0.88
Cooling towers	0.16
Piping/steam distribution	0.33

The cutoff criteria were then slightly adjusted for each project based on regional labor cost adjustments published in *Means* (2003). The states with the highest labor costs were Hawaii and Alaska (23% and 27% higher than average), and the states with the lowest labor costs were Missouri, North Carolina and South Carolina (28-29% lower than average).

B.2 Aligning LBNL and PNNL Retrofit Strategies

As described in section 6.1, retrofit strategies were defined and projects were coded independently for the FEMP UESC database managed by PNNL. The UESC projects had been previously classified by an engineer who reviewed each project individually and made a judgement about the predominant retrofit for the project based on the measures installed, costs and savings. In this way, each project was assigned to one of 11 retrofit strategies.

To make comparisons between projects in the two datasets, it was necessary to map PNNL's 11 retrofit strategies to the 6 LBNL strategies used in this report. **Table B-2** shows how this was accomplished.[6]

other individual measures in the project that we were not able to remove due to lack of cost information (see section B.1).

[6] Two of the UESC strategies – renewables and insulation/envelope – did not match the LBNL strategies exactly. These projects were assigned based on the particular technologies involved, as shown in Table B-2.

Table B-2. Mapping of LBNL and PNNL Retrofit Strategies

LBNL Retrofit Strategy	**PNNL Retrofit Strategies**
Lighting Only	• Lighting
Distributed Generation	• Distributed Energy • Renewables (not including GHP projects)
Major HVAC	• Central Plant
Minor HVAC	• Boiler/chiller (partial system upgrades) • Controls/Upgrades/Repairs • HVAC/Motors/Pumps • Lighting and Mechanical Systems • Renewables (GHP projects only)
Non-energy	• Insulation/envelope – windows projects only
Other	• Insulation/Envelope (not including projects with windows) • Water • Other

Appendix C. Economic Analysis

In this appendix, we describe the economic indicators used in our analysis, as well as the approach, assumptions and data sources used to develop the key inputs to our economic analysis.

<u>Economic Indicators</u>

We calculated the following economic indicators from project data:

(1) Simple Payback Time = C/S, where:

C = turnkey project costs
S = annual savings

(2) Benefit-Cost Ratio = $[\Sigma \{B_n / (1+r)^n\}] / C$ where:

B_n = project benefits in year n
r = discount rate
C = turnkey project costs

(3) Net Benefits (section 5.5.4*) = $[\Sigma \{B_n / (1+r)^n\}] - C$, where:
B_n = project benefits in year n
r = discount rate
C = turnkey project costs

* project costs assumed paid at time of project completion

(4) Net Benefits (section 5.5.4.1 "financed" scenario) =

$$[\Sigma \{B_n / (1+r)^n\}] - C_a - [\Sigma \{(C_n + C_{m\&v}) / (1+r)^n\}]$$, where:

B_n = project benefits in year n
r = discount rate
C_a = appropriated funds applied to the project upon completion (e.g., portion of the project that was not financed)
C_n = debt service in year n (capital repayment plus interest)
$C_{m\&v}$ = M&V costs in year n

(5) Net Benefits ("Appropriations" scenarios in section 5.5.4.1**) =

$$[\Sigma \{B_n / (1+r)^n\}] - [\Sigma \{C_{delay} / (1+r)^n\}] - [C / (1+r)^n]$$, where:

B_n = project benefits in year n
r = discount rate
C_{delay} = opportunity cost of delay
C = turnkey costs

** project costs are paid up front, but may be discounted depending on the project delay scenario

All indicators were calculated in nominal dollars. Net benefits results for each project were converted into 2003 dollars before adding project results together.

Discount Rates

We used nominal discount rates of 5%, 7% and 10% in our calculations. Our rates are nominal for consistency with the other inputs into our calculations, which were all nominal. See section 5.5 for a discussion of our rationale for choosing these discount rates.

Project Costs

Turnkey project costs, reported by ESCOs, include all design, construction management, installation, construction period financing and any costs to arrange long term financing that occur before project completion and acceptance. Long-term financing costs are not included in turnkey costs; neither are ongoing O&M, M&V, or other service-phase costs (e.g., administrative fees, insurance, etc.).

REEP incentives are subtracted from turnkey costs, assuming that the entire incentive was received at the time the project was installed. For rebates, 100% of the incentive is subtracted. For standard performance contract and DSM bidding program incentives, only 50% of the incentive is subtracted to account for (1) the possibility that the ESCO did not share some or all of the incentive with the customer and (2) the fact that such incentives are generally paid out over several years.[7]

In the "financed" scenario in section 5.5.4.1, interest costs are added to turnkey costs, which together are discounted over the life of the financing term. M&V costs are also included in this scenario over the life of the contract.

M&V, O&M and other service phase costs are not included in the base-case economic analysis or the "appropriations" scenarios in section 5.5.4.1.

Project Benefits

Project benefits included in this analysis derive from energy savings (electricity, natural gas, fuel oil, other fuels), water savings, O&M savings and other non-energy benefits (such as tariff changes resulting from fuel switching). Indirect benefits (such as improved comfort or productivity) are not included in our economic analysis due to lack of information.

For the NAESCO/LBNL database projects, we calculated initial-year project benefits by multiplying electricity, fuel and water savings by historic prices published by the Energy Information Administration (EIA) for the year, sector (e.g., commercial, industrial) and state in which each project was completed.[8] Where possible, we used average actual (realized) annual savings; when not available, we used predicted annual savings instead.[9] By matching fuel prices with the year of project completion, we ensure that project costs and savings are in a consistent year's dollars. These resource savings were then added to any O&M or other non-energy savings reported for the project. If actual energy savings were not available, we used the dollar value of savings as reported by the ESCO.

For benefit-cost and net benefits calculations, we calculated the project's benefits over its estimated economic lifetime by inflating the initial year's benefits according to projected energy escalation rates published in EIA's *Annual Energy Outlook* for the year the project was completed.[10]

For the projects in FEMP's UESC database, dollar savings were taken as reported by utilities and federal agencies because insufficient project information was available to calculate savings from energy units.

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[7] We do not discount these incentives because we do not have information about the number of years the incentives were received or the annual amounts received; we only know the total incentive amount.
[8] See Goldman et al. (2002) for a detailed list of energy price data sources; we have added recent years' data from the same sources for this analysis.
[9] These savings estimates reflect any baseline adjustments made by the ESCO as part of the contractual agreement.
[10] Energy escalation rates are reported by EIA in real terms. We converted them to nominal dollars using the OMB's Nominal Treasury Interest Rates. See Goldman et al. (2002) for a detailed list of data sources; we have added recent years' escalation factors from the same sources for this analysis.

Project benefits are treated identically in our base case economic analysis and the "appropriated" and "financed" scenarios in section 5.5.4.1.

Lifetime of Savings

For benefit-cost and net benefits calculations, we assumed that the energy and non-energy benefits of each project would be sustained over the economic lifetime of the installed measures. We determined the economic lifetime of savings to be the maximum of the project contract term or the established lifetime of the longest-lived measure installed in the project. The measure lifetime data used are reported in Goldman et al. (2002).