Deploying New Technologies
to Increase Energy Savings in the Federal Sector

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Alliance to Save Energy

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ALLIANCE TO
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Creating an Energy-Efficient World

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Executive Summary

The federal government is the single largest energy consumer not only in the United States but in the world. It is also the single largest deployment ground for energy-consuming equipment. Consequently, the federal government has the responsibility to manage its energy consumption through improved efficiency and use of renewable energy sources, both to save tax dollars and to limit its environmental impact. At the same time, the government's market influence gives it the opportunity to help advance the commercialization of advanced energy-saving technologies by creating an entry market for promising new technologies, measuring and documenting their performance, and – by example to other buyers and reduced market risk to suppliers – encouraging broader market acceptance of these new technologies. In this report, we give an overview of near-term opportunities for such a technology path through federal action and provide additional recommendations for federal leadership through interagency cooperation.

It takes more than a one-time effort to effectively deploy new energy-saving technologies across the federal sector. It takes coordination among agencies and expert staff within agencies with the designated task of assuring the effective deployment of promising technologies. These efforts require commitment of time and funds but can dramatically increase the likelihood that technology development translates into real energy savings. The promise is increased long-term energy and cost savings for federal agencies, improved opportunities for new technology market entry and market acceptance, as well as a higher rate of return from federal investments in R&D.

Federal leadership and clear market signals through demand and support for innovative energy-saving technologies can help achieve energy conservation goals both within and outside the federal sector. As summed up in Chapter 1 of this report, federal energy saving goals are becoming more ambitious, requiring solutions that go beyond business as usual. Adoption of innovative technological solutions within the federal sector can also lead to their wider use across the US economy as a whole, where interest in accelerated energy efficiency is on the rise – due to rising prices in oil, natural gas, and electricity, and to an intensified concern for reducing energy-related greenhouse gas emissions. To provide such a leadership role, the federal sector needs to proactively assess new technology opportunities and establish a broad interagency network of cooperation to ensure that the most promising options are given sufficient support.

To identify a range of technologies that are new or presently underutilized but could yield substantial energy savings if deployed at a larger-scale, the Alliance to Save Energy screened many new and emerging technologies. This screening, though by no means exhaustive, covered a wide range of energy-efficiency and renewable energy technologies with good energy-savings potential that might not be realized without federal support. Chapter 2 gives an overview of our technology screening, with assessments of specific technologies following in Chapter 3.

In Chapter 4, we recommend policies and specific actions to support the assessment and early adoption of new energy-saving technologies in the federal sector. These include the following:

- Establish agency-level teams to lead technology validation and implementation;

- Establish an interagency coordinating team to provide consistency to federal efforts;
- Disseminate project results within the federal sector;
- Leverage funding and financing mechanisms; and
- Involve non-federal stakeholders in implementation strategies in order to send strong market signals.

1. Overview of the Policy Background

The need for new and emerging energy-saving technologies to help agencies achieve deeper energy savings derives from two important policy goals for federal energy management:

1) Achieving aggressive energy savings goals over the next decade and beyond.
2) Providing market leadership in energy efficiency.

Energy savings goals – The Energy Policy Act of 2005 directs federal agencies to reduce energy intensity in their facilities by 2 percent per year from 2006 through 2015. In early 2007, Executive Order 13423 on "Strengthening Federal Environmental, Energy, and Transportation Management" increased this goal to 3 percent annually or by 30 percent by the end of 2015 relative to the 2003 baseline. This new goal, more recently codified into law in the Energy Independence and Security Act of 2007 (P.L. 110-140), represents an acceleration of the historical progress in energy efficiency, and thus the need to consider new approaches such as a federal role in early adoption of energy-saving emerging technologies. Other statutory requirements for new and renovated federal buildings to achieve energy performance levels well above prevailing codes, and to move toward zero fossil fuel use for federal construction starting in 2030, further underscores the need for federal agencies to make full use of advanced energy-saving technologies.

Renewable energy goals – The Energy Policy Act of 2005 also directs federal agencies to increase the share of renewable electricity consumption to at least 3 percent in fiscal years 2007 to 2009, followed by at least 5 percent in fiscal years 2010 to 2012, and at least 7.5 percent in 2013 and beyond. Executive Order 13423 added the requirement that at least half of this renewable energy must come from new renewable sources put in service after January 1, 1999.

Market leadership – FEMP and other federal agencies have long maintained that the federal government can be a national model of energy efficiency for other levels of government, as well as for businesses and individual consumers. The Energy Policy Act of 1992 called on federal agencies to use their buying power to help accelerate the commercial introduction of new energy-saving technologies. DOE itself is a natural candidate to model these initiatives and set an example for other federal agencies.

Implementation mechanisms for energy-efficient technologies in the federal sector include third-party financing through energy saving performance contracts (ESPCs) and utility energy service contracts (UESCs). Other mechanisms are lease agreements, technology procurement with energy efficiency specifications, utility rebates, voluntary programs, and codes and standards.

1.1 ESPCs, UESCs, and New Energy Efficient Technologies

An ESPC is a contracting vehicle that allows agencies to accomplish energy projects for their facilities without up-front capital costs. An ESPC project is a partnership between the federal customer and an energy services company (ESCO). The ESCO undertakes energy efficiency improvements after guaranteeing that these will generate energy cost savings sufficient to pay for the project over the term of the contract. The ESCO designs and constructs energy efficiency improvements in consultation with the agency customer to meet the agency's needs. The ESCO also arranges financing to pay the initial cost for these measures and in many cases for associated operation and maintenance (O&M) services, training of on-site staff, and appropriate measurement and verification of energy performance (M&V).

Original ESPC legislation was passed by Congress in 1992 and implementation began in 1995. More than half of all ESPC projects are implemented by the Department of Defense (DoD). Technology-specific Super ESPCs have been established by DOE to streamline the process for ESPC projects that involve specific technologies and are carried out by selected ESCOs with a good track record. Super ESPCs allow agencies to implement projects in shorter time. The emphasized technology must be the center of technology-specific ESPC projects, but inclusion of other technologies into these projects is also encouraged. Presently, there are four kinds of technology-specific Super ESPCs:

- Geothermal heat pumps
- Photovoltaics
- Biomass and alternative methane fuels
- Solar thermal

Utility UESCs are similar financing mechanisms that may be offered by a utility as part of an area-wide agreement to serve its federal customers. Once again, the initial capital cost of energy-saving measures are repaid by the agency over a period of years, based on anticipated energy cost savings, but unlike an ESCO-funded project there is no guarantee of savings nor any statutory requirements for performance measurement and verification. Agency requests to include new and advanced technologies are likely to be eligible for UESC financing, as long as the agency is willing to assume the performance risk and to repay the utility investment.

1.2 Other Implementation Mechanisms

- **Lease agreements – equipment leasing and building leases**
  The deployment of new energy-efficient technologies could be included as a condition in federal lease agreements. In new building leases or lease renewals, the federal lessee could require that some of the equipment in the leased buildings be specified as advanced technologies. Federal agencies could also lease advanced technologies directly.

- **Technology procurement**
  FEMP issues guidelines for energy-efficient federal procurement. In some cases, it can be viable for federal procurement to specifically aim for new technologies instead of more common options. The potential for advanced technology

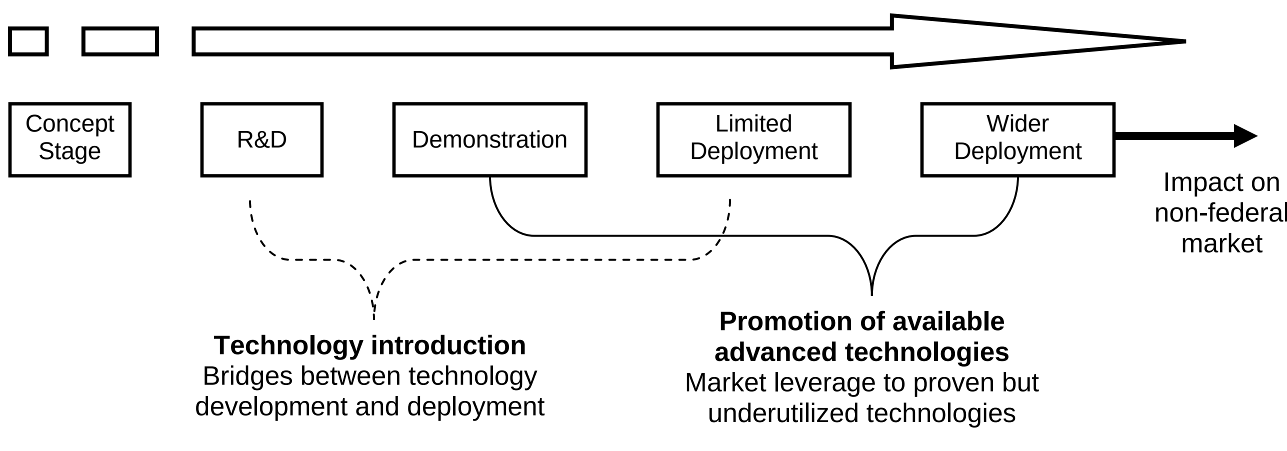
procurement depends strongly on both the technology and the identified agency needs.

- **Utility rebates**
  Deployment of advanced technologies could be supported by utilities, especially those subject to regulatory requirements to support new and emerging technologies. These utilities could have an interest in offering rebates, technical assistance, or UESC financing to federal agencies to procure new technologies that meet the criteria of the utility and its regulatory agency. An interactive map of states showing which utilities offer rebate programs is shown on the FEMP utility management website.

- **Voluntary Programs, Codes and Standards**
  Larger-scale deployment of advanced technologies in the federal sector helps to increase the experience with these technologies and supports their wider market penetration. As technologies become more prominent, their inclusion in the ENERGY STAR program may be a valuable next step, with the eventual possibility of their inclusion in energy codes and standards.

2. Overview of Technology Screening

The Alliance to Save Energy screened a wide range of new and emerging technologies, most of which have been developed, demonstrated, or supported by DOE, other federal agencies, state programs, or utility companies. Due to the immediate need for promoting available advanced technologies that can provide near-term savings, only technologies that are commercially available and proven, though underutilized, were considered for closer evaluation. As the schematic diagram below shows, the considered technologies were in the demonstration or deployment stages, where immediate market leverage can be applied. On the other hand, technologies that were just in the process of being introduced from the research and development (R&D) stage into demonstration and deployment were not the focus of this screening.



Based on this initial screening, we developed a document, *Emerging Technologies for Energy Savings Performance Contracting in the Federal Sector* (November 2007). In this paper, we identified an initial group of new and advanced energy-saving technologies recommended for use in federal facilities, with an emphasis on technologies suitable for retrofit applications financed through ESPCs and UESCs. The report was supplemented with a matrix including the recommended technologies, important information on these, and links to references, contact persons and technology description documents, some of which were developed for this task by Lawrence Berkeley National Laboratory (LBNL) in cooperation with the Alliance.

2.1 Information Sources

The research conducted by the Alliance was based on a review of previous work by FEMP, the Pacific Northwest National Laboratory (PNNL), the New Technology Installation Program (NTDP), and non-DOE agencies (e.g. EPA, DoD). In addition, we consulted very valuable technology screenings by non-federal sector organizations such as the American Council for an Energy Efficient Economy (ACEEE), the California's Public Interest Energy Research program (PIER) and Emerging Technologies Coordinating Council, as well as technology evaluation programs by Bonneville Power Administration and the New York State Energy Research and Development Authority (NYSERDA). The main sources are listed below:

- Federal Energy Management Program – New Technologies
- Lawrence Berkeley National Laboratory – Energy Efficient Technologies
- National Renewable Energy Laboratory – Technology Research
- Oak Ridge National Laboratory – Engineering Science & Technology Division
- Pacific Northwest National Laboratory - Emerging Technologies Project
- American Council for an Energy Efficient Economy – www.aceee.org
- Emerging Technologies Coordinating Council – www.etcc-ca.com
- Bonneville Power Administration – Energy Efficiency Technology Roadmap
- NY State Energy Research and Development Authority – Research and Development
- US Environmental Protection Agency – Environmental Technology Verification Program

2.2 Criteria for Evaluating New and Emerging Technologies

Including emerging technologies in federal sector ESPC projects will help support promising yet underutilized energy efficient technologies, provide valuable energy improvements to federal facilities, and create replicable technological success stories. With these goals in mind, we recommend the following five criteria as a general guideline for evaluating energy-efficient and renewable energy technologies for the federal sector. Additional or revised criteria may be established in the future, for instance by an interagency coordination team (see recommendations in Chapter 4).

1. **Federal market leverage**

   Can federal promotion help overcome barriers to wider use of the technology (e.g., lack of familiarity, performance risk, supply chain limitations, maintenance and support, first-cost)?

   The following questions can help determine the potential federal market leverage:

   - Is the technology at a critical juncture in its market development?

- To what extend does the technology need support in getting past this juncture?
- How big a difference could the federal government make by providing support?

2. **Federal sector savings potential**

How does the technology promise to meet the needs of federal facilities?

Technologies should support the federal government's goal of achieve a 30 percent reduction in energy intensity by 2015. The savings potential by 2015 is therefore an initial focus, although the technology's potential beyond that year must be taken into account as well.

3. **U.S. economy savings potential**

Can promotion of the technology in the federal sector be expected to lead to widespread application in the U.S. economy as a whole? What savings potential can be expected outside the federal sector?

When considering a technology's non-federal savings potential, a potential time lag for adoption beyond the federal sector should be taken into account.

4. **Cost-effectiveness**

What is the technologies cost-effectiveness taking into account both its present and expected future cost and performance?

The ACEEE study *Emerging Energy-Saving Technologies and Practices for the Buildings Sector as of 2004* (Sachs et al. 2004) provides very useful estimates of new technologies' cost-effectiveness over their expected useful life.

Technologies with low cost-effectiveness may still be worth pursuing for federal projects and federal procurement, if their cost-effectiveness can be expected to increase with product and manufacturing refinements, production and marketing volume, and market supply-chain experience – or if they bring provide substantial non-energy benefits in specific applications. Some advanced technologies (such as solar photovoltaics and fuel cells) may also be very appropriate for special situations such as remote sites with high fuel and power costs, or communication and data centers requiring very high reliability.

5. **Retrofit applicability**

Can the technology be implemented as near-term application in existing facilities (i.e. for retrofits or equipment replacement) or is its promotion better aimed at new construction?

The retrofit applicability of the technology is an important factor since existing buildings offer the greatest opportunities for near-term energy savings. Retrofit applicability also determines how well a technology is suited for third-party financed energy performance improvements.

In addition to any technologies that might be favored according to these criteria, **any list of recommended new technologies should provide the opportunity for project managers to add their own site- or agency-specific technology options.** These would be based on special opportunities identified for that site.

The Department of the Navy's Technology Validation Program (Techval) has set specific criteria for its technology selection mechanism (see appendix). These can serve as an example for criteria that meet a specific department's needs but may easily be adopted in a modified form by other departments and agencies.

2.3 High Potential Technologies Identified in Screening

The following is a list of commercially available technologies that the Alliance has screened and identified as offering a high potential in at least one of the above-mentioned criteria – federal sector savings potential, cost-effectiveness, and retrofit applicability. In addition, all of these technologies types are presently underutilized and could benefit from federal market leverage. These technologies are briefly described in the next section, and in more detail in the technology assessment fact sheets referenced in our November report.[1]

A Lighting

- A1 Spectrally enhanced lighting
- A2 Addressable dimming fluorescent ballasts
- A3 Daylighting systems and integrated daylighting controls
- A4 CFL adaptor for recessed downlights
- A5 LED lighting for niche applications
- A6 High-output T5 high bay lighting

B HVAC

- B1 Aerosol-based duct sealing for commercial buildings
- B2 Advanced rooftop air conditioning
- B3 High-efficiency heat pump systems
- B4 Demand-controlled ventilation with advanced controls
- B5 Air conditioning for climates with high or low sensible heat ratios
- B6 Thermal destratifiers
- B7 Condensing fuel-fired hydronic boilers

C Water Heating

- C1 Heat pump water heaters
- C2 Solar water heaters
- C3 Condensing fuel-fired water heaters

D Building Envelope

- D1 Highly insulating windows
- D2 Passive solar ventilation preheating
- D3 Cool roofs

E Power Generation

- E1 Combined heat and power
- E2 Biomass

[1] See the Appendix for a list of these fact sheets, with their urls, many of which are on-line at the FEMP new technologies website: http://www1.eere.energy.gov/femp/new_technology/.

E3 Fuel Cells
E4 Distributed Wind Power
E5 Photovoltaic systems

F Sanitation

F1 Low-flush (pressure-assisted) toilets

G Special

G1 Advanced metering

3. Evaluated Technologies

This chapter provides short descriptions of the high-potential technologies identified in our screening and summary assessments of these technologies based on our technology evaluation criteria. Regarding a technology's federal market leverage, federal sector savings potential and retrofit applicability, we consulted publications and other sources where available but had to rely to a lrge degree on our own judgment. Our assessments of U.S. economy savings potential and cost-effectiveness drew greatly from the American Council for an Energy Efficient Economy's study *Emerging Energy-Saving Technologies and Practices for the Buildings Sector as of 2004* (Sachs et al. 2004).

We should once again emphasize that this is not intended as an exhaustive list of promising new technologies for federal adoption, but instead represent a snapshot as of mid-2007 of some technologies that in our view met a specific need (near-term deployment through federal ESPC and UESC contracts). The process of identifying and assessing new technologies needs to be ongoing, as we recommend below, and one that addresses both broadly applicable technologies and those that may be tailored to specific types of facilities and applications in the highly diverse federal stock.

3.1 Lighting

3.1.1 Spectrally Enhanced Lighting

Spectrally enhanced (or scotopic) lighting takes advantage of the fact that for most people, vision is improved by illumination with high correlated color temperature (CCT), even if lighting levels are reduced. Spectrally enhanced lighting (in the blue-green part of the spectrum) stimulates the "rod" photoreceptors in the eye, causing the pupil to contract and thus improving visual acuity for tasks such as reading printed text. Spectrally enhanced sources thus allow for installation of lamps with lower light output and lower power, while providing the same level of visual performance. Fluorescent and HID lamps with a CCT of more than 5,000° Kelvin have been determined to provide the clearest vision.

- **Federal market leverage:** High. If wide adoption by the federal government helped the technology achieve recognition by the Illuminating Engineering Society, wide acceptance in the mainstream market could follow.
- **Federal sector savings potential:** Medium-high. As a practice ideal for existing commercial buildings, scotopic lighting has a particularly high potential in the federal sector.
- **U.S. Economy savings potential:** Medium.
- **Cost-effectiveness:** High. No cost premium over traditional lighting.
- **Retrofit applicability:** High. However, it is recommended to switch all lighting in a facility to scotopic at the same time, so that the stock of replacement lights can be completely scotopic and confusion with traditional lights is avoided.

3.1.2 Addressable Dimming Fluorescent Ballasts

Individually addressable dimming ballasts combined with Digital Addressable Lighting Interface (DALI) controls allow for occupant-preferred lighting levels, reduced electricity use for lighting, and more effective peak-shaving and demand-response, also depending on occupant preferences and the amount of light provided through daylighting.

- **Federal market leverage:** High. Federal support could help give the technology the extra push needed to advance to become standard practice in the market.
- **Federal sector savings potential:** High. Savings can be maximized with the integration of load management, demand-response, daylighting, and occupancy sensor controls, as well as reductions in initial overlighting that many designers use to compensate for lamp lumen depreciation.
- **U.S. Economy savings potential:** Medium.
- **Cost-effectiveness:** Medium.
- **Retrofit applicability:** High. Wireless ballast communications may be more practical in many cases than providing Ethernet or similar wiring to each fixture.

3.1.3 Daylighting Systems and Integrated Daylighting Controls

Daylight collection devices (tubular skylights, hybrid solar lighting, etc.) can be effectively combined with daylighting controls. Lighting levels are controlled through photo sensors and/or occupants via wired or wireless controls.

- **Federal market leverage:** High. Federal promotion of daylighting systems and controls can significantly increase the experience with available technologies, stimulate innovation, and help the market introduction of recently developed technologies.
- **Federal sector savings potential:** High. Low-rise commercial buildings with good savings potential from daylighting constitute a large share of the federal building stock.
- **U.S. Economy savings potential:** High.
- **Cost-effectiveness:** Medium.
- **Retrofit applicability:** Medium. Effective daylighting systems are easier to achieve in new construction than in existing buildings that are not designed for daylighting.

3.1.4 CFL Adaptor for Recessed Downlights

Retrofit adaptor kits can convert 75-200 W incandescent downlights to allow for the use of CFLs. One design has the lamp ballast housed in the trim ring of the fixture, allowing better heat dissipation and improving ballast lifetime and efficiency. Another option is complete replacement of the downlight fixture with a pin-based (“dedicated”) CFL fixture.

- **Federal market leverage:** Medium. Through large scale purchases, the federal government can significantly stimulate the market for the technology.
- **Federal sector savings potential:** Medium. A large number of incandescent downlights are in homes and the potential for federal applications is mainly in non-residential buildings.
- **U.S. Economy savings potential:** High.
- **Cost-effectiveness:** High.
- **Retrofit applicability:** High.

3.1.5 LED Lighting for Niche Applications

Current LED products still produce fewer lumens per watt than most CFLs, but can be effective for niche applications where highly directional lighting, extended lifetimes or high reliability under varying temperatures are important features. Examples include task lights, street lighting, signage, parking and other high-bay lighting, refrigerator lighting, or airport runway lighting.

- **Federal market leverage:** High. The federal government's continuous support for the development and early application of LED technologies is crucial for the technology's progress.
- **Federal sector savings potential:** Low. The technology will be confined to niche applications in the near term.
- **U.S. Economy savings potential:** Medium. Starting around 2020, the savings potential is expected to grow more rapidly as the technology matures.
- **Cost-effectiveness:** Medium. Assuming a significant cost reduction in the near term.
- **Retrofit applicability:** High.

3.1.6 High-output T5 High-bay lighting

T5 lamps are tubular fluorescent lamps with 5/8" diameter. The small diameter provides for improved efficacy compared to thicker T8 (or T12) lamps, as well as good optical control that enables use in applications traditionally reserved for HID systems.

- **Federal market leverage:** Low. Even without federal promotion, demand for the technology is increasing.
- **Federal sector savings potential:** Medium. The savings potential is high in any high-bay space, such as maintenance workshops, warehouses, and large retail buildings.
- **U.S. Economy savings potential:** Medium.
- **Cost-effectiveness:** High.
- **Retrofit applicability:** High.

3.2 HVAC

3.2.1 Aerosol-based Duct Sealing for Commercial Buildings

Aerosol duct sealing technology involves blowing tiny sealant particles through a pressurized duct system to seal leaks from the inside. This process can reach inaccessible leaks and save considerable time and cost compared with manual duct sealing. Aerosol-duct sealing has be used in the residential sector for years and is now also available for application in commercial buildings.

- **Federal market leverage:** Medium. Increased use of the technology in larger federal buildings would have the benefits of potentially large energy savings and more demonstrations of actual costs and savings.
- **Federal sector savings potential:** High. After very successful demonstrations, ESCOs are becoming familiar with the technology
- **U.S. Economy savings potential:** High.
- **Cost-effectiveness:** High.
- **Retrofit applicability:** High. The technology is most useful in the existing building stock.

3.2.2 Advanced Rooftop Air Conditioning

Automated fault detection and diagnosis (FDD) for rooftop unitary air conditioners can monitor conditions at various points in cooling system and communicate diagnostic information to the facility manager or a remote monitoring site. In addition, low-efficiency equipment should be replaced with high-efficiency rooftop AC units that meet or exceed the highest tier set by the Consortium for Energy Efficiency (EERs/IPLVs of 12.0/12.4 for unit capacities of 65-240 MBtu/h).

- **Federal market leverage:** Medium.
- **Federal sector savings potential:** High. Due to the large percentage of federal buildings with rooftop AC,[2] the savings potential can be expected to be relatively large. Even without replacing existing rooftop units, immediate savings will accrue from the installation of automated fault detection and diagnosis devices at existing rooftop units.
- **U.S. Economy savings potential:** Medium.
- **Cost-effectiveness:** High.
- **Retrofit applicability:** High. Rooftop air conditioning units require relatively frequent replacement. FDD systems can also be applied as a retrofit to existing rooftop air conditioners.

3.2.3 High-efficiency Heat Pump Systems

Geothermal, hybrid-geothermal, or low temperature heat pumps. Geothermal heat pumps can provide heating, cooling, and hot water. Low temperature heat pumps are designed to function efficiently without resistance heat backup at below 40° F outdoor temperature.

- **Federal market leverage:** High. Low-temperature heat pumps have just recently become commercially available and currently rely on government and utility support to overcome initial market hurdles and technical uncertainties.
- **Federal sector savings potential:** Medium. Geothermal and hybrid-geothermal heat pumps[3] offer tremendous savings potential - 15-25 percent of total building energy use in nonresidential buildings (FEMP 2002). However, geologically favorable locations are limited. Low-temperature heat pumps, on the other hand, will not be large-scale in the near future.
- **U.S. Economy savings potential:** Medium.
- **Cost-effectiveness:** Medium. The cost-effectiveness of geothermal heat pumps depends strongly on the site. Low-temperature heat pumps are still expensive and best suited to cooler climates.
- **Retrofit applicability:** Medium. Geothermal heat pumps are often retrofitted, but ideally they are installed during initial construction, since digging a well or trench for the ground-source loop may be difficult in some retrofit situations.

3.2.4 Demand-controlled Ventilation with Advanced Controls

Demand-controlled ventilation using carbon dioxide (CO_2) sensors is a combination of two technologies: CO_2 sensors that monitor CO_2 levels in the air inside a building, and a

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[2] Around 50% of floorspace, based on FEMP estimates using the CBECS national survey.

[3] A hybrid geothermal heat pump uses a design that includes an auxiliary air source exchanger (during cooling mode) to reduce the size and cost of the ground source heat exchanger.

variable air volume air-handling system that uses data from the sensors to regulate the amount of ventilation air admitted.

- **Federal market leverage:** Medium. The technology has been widely available for years and has a proven track record of performance. Further case studies and promotion to increase awareness and familiarity with the technology among designers, architects and building owners could increase its use substantially.
- **Federal sector savings potential:** Medium. The technology offers the highest potential if applied in high-occupancy buildings such as office buildings, auditoriums, schools, and sports centers.
- **U.S. Economy savings potential:** Medium.
- **Cost-effectiveness:** High.
- **Retrofit applicability:** Medium. Industry literature states that the technology works best with constant volume or variable air volume systems.

3.2.5 Air Conditioning for Climates with High or Low Sensible Heat Ratios

In hot and dry climates, two-stage (both direct and indirect) evaporative cooling provides better performance than vapor compression cooling. In hot and humid climates, cooling systems that combine desiccant-based dehumidification with vapor-compression cooling systems are more efficient than conventional cooling.

- **Federal market leverage:** Medium. Application of these technologies is climate specific and some of these technologies are for the residential and small commercial sector only.
- **Federal sector savings potential:** Low. Applicability in the federal sector is moderate due to the climate-specific nature and the limited applicability of evaporative cooling in larger non-residential buildings.
- **U.S. Economy savings potential:** Medium. Regional savings in small commercial and residential buildings can be substantial.
- **Cost-effectiveness:** High.
- **Retrofit applicability:** Medium. Adjustments in the building's HVAC system will be necessary if dehumidification technologies or evaporative cooling have not previously been used.

3.2.6 Thermal Destratifiers

Thermal destratifiers are powerful fans that circulate warm air away from the ceiling in high bay buildings to reduce thermal stratification and thus improve thermal comfort at floor level while reducing the need for heating. Buildings with high ceilings and well-sealed building envelopes in climates with long heating seasons offer good opportunities for energy savings through thermal destratification.

- **Federal market leverage:** High. The commercialization of the technology is dependent on initial federal promotion to attain more demonstration results and familiarity with the technology.
- **Federal sector savings potential:** Medium. In high-ceiling buildings such as airport hangars and other DoD facilities, savings can be up to 40 percent of heating and cooling energy.
- **U.S. Economy savings potential:** Low. Considering the technology's limited applicability, economy-wide savings are assumed to be relatively low, although considerable potential exists in cold-climate high-bay buildings.

- **Cost-effectiveness:** Medium. Cost-effectiveness is assumed to grow as experience with the technology grows and if applied in worthwhile locations.
- **Retrofit applicability:** High.

3.2.7 Condensing Fuel-fired Hydronic Boilers

Condensing fuel-fired hydronic boilers are designed to recover the latent heat of water produced in the combustion process. This allows for much higher utilization of the heat content in the fuel, compared with the best available non-condensing boilers.

- **Federal market leverage:** Medium. Use of condensing boilers at a larger scale could help reduce the technology's initial cost, which is its main market barrier.
- **Federal sector savings potential:** Medium. The energy savings potential from installing condensing boilers in the federal sector is a large portion of the economy-wide savings potential due to the high demand for large boilers in the federal sector (Consortium for Energy Efficiency 2001).
- **U.S. Economy savings potential:** Low. Outside the federal sector, there are only a moderate number of potential applications, but schools and apartment buildings offer themselves as opportunities for savings with condensing boilers.
- **Cost-effectiveness:** High.
- **Retrofit applicability:** Medium. Careful system design including effective controls is required if conventional boilers are replaced with condensing boilers, to assure that the return-water temperature is low enough to achieve condensing performance.

3.3 Water Heating

3.3.1 Heat Pump Water Heaters

Heat pump water heaters are at least twice as efficient as electric resistance water heaters. Products have been offered in both the residential and commercial sector for many years but low demand due to high initial cost, along with performance and reliability problems with early models have prevented significant market development. New, more advanced models have recently been developed with support from Oak Ridge National Laboratory. Heat pump water heaters are somewhat more common in European and some Asian markets.

- **Federal market leverage:** High. Only a handful of U.S. manufacturers have offered heat pump water heaters (Harris and Neme 2005), and none to date have been marketed at a large scale or for a number of years. A stable, if small, federal market (military family housing and other smaller buildings) could provide manufacturers with the certainty needed to scale up manufacturing and increase installers' familiarity with the product.
- **Federal sector savings potential:**Medium-Low. Applicability in the Federal sector is limited to smaller buildings with electric water heating.
- **U.S. Economy savings potential:** Medium.
- **Cost-effectiveness:** High.
- **Retrofit applicability:** High. Heat pump water heaters can replace existing electric storage water heaters provided that new designs are reliable and take up no more space than a conventional water heater, and that the water heater location has an adequate ambient heat source (i.e., is not installed in a closet).

3.3.2 Solar Water Heaters

Solar water heaters utilize thermal solar energy for water heating to supplement or replace fuel-fired or electric water heaters. Solar heat is absorbed by a rooftop solar collector and transferred to the potable water either directly or via a heat transfer fluid and a heat exchanger.

- **Federal market leverage:** Medium. The federal government and some state governments already promote solar water heaters through tax incentives, which stimulate the market.
- **Federal sector savings potential:** Medium. In all climates, solar water heating is viable for replacing at least part of conventional energy consumption for water heating, especially in buildings with substantial hot water consumption such as military barracks, schools, prisons, hospitals, and other facilities with commercial kitchens or laundries.
- **U.S. Economy savings potential:** Medium. Unless energy prices increase significantly, competition from gas and electric water heaters is likely to remain strong.
- **Cost-effectiveness:** Medium. Solar water heaters are often cost-effective compared with electric resistance storage water heaters and along with tax incentives can sometimes compete with conventional fuel-fired water heaters.
- **Retrofit applicability:** High.

3.3.3 Condensing Fuel-fired Water Heaters

Condensing fuel-fired water heaters recover latent heat from the water produced in the combustion process. This way, the heat content of the fuel is utilized more efficiently than with conventional water heaters, providing efficiency increases by more than 20 percent to a potential efficiency of more than 90 percent.

- **Federal market leverage:** Medium. Promotion through the federal government would increase customer awareness even in the absence of an ENERGY STAR water heating program.
- **Federal sector savings potential:** Medium. Federal prisons, hospitals, and barracks are examples of facilities where the technology can provide substantial savings.
- **U.S. Economy savings potential:** High. Large potentials in the residential and commercial sectors exist.
- **Cost-effectiveness:** Medium.
- **Retrofit applicability:** High.

3.4 Building Envelope

3.4.1 Highly-insulating Windows

Windows with the combined performance of three glazing layers, low-E coatings, gas fills, well-insulated frames, and low-conductance spacers provide substantially better insulating performance (i.e. lower U-factor) than commonly available products. Such products achieve whole-window U-factors of 0.25 or lower, and potentially as low as 0.15.

- **Federal market leverage:** High. Federal procurement could provide manufacturers with a significant incentive to add production capacity for highly-insulating windows.
- **Federal sector savings potential:** Medium-low. Highly-insulating windows are most applicable to new construction or major renovation of buildings with punched window openings such as DoD barracks, medical facilities, or school buildings.
- **U.S. Economy savings potential:** Medium.
- **Cost-effectiveness:** Medium.
- **Retrofit applicability:** Medium. If the existing windows do not need replacement, it is usually not cost-effective to install new windows.

3.4.2 Passive Solar Ventilation Preheating

Passive solar ventilation preheating collects solar heat at south-facing walls to preheat ventilation air before it enters the building. Solar heat is collected either through transpired air collectors in a perforated façade or through a glazed solar collection wall. An added fan or the building's existing ventilation system draws the pre-heated air from the air space between the collector and the wall into the building.

- **Federal market leverage:** Medium.
- **Federal sector savings potential:** Medium-Low. Building walls without windows, such as aircraft hangars or warehouses, are good opportunities for application of the technology. The technology is limited to climates with heating demands.
- **U.S. Economy savings potential:** Medium-Low. Most of this potential lies in the industrial sector (manufacturing facilities and warehouses), where aesthetic concerns are less important and window areas are limited.
- **Cost-effectiveness:** High. Transpired air collectors are more efficient than glazed solar walls due to higher absorptance and lower reflectance of solar heat.
- **Retrofit applicability:** Medium. The technology can be applied to existing buildings but might require adjustments in the HVAC control system.

3.4.3 Cool Roofs

Cool roofs use materials with high reflectance of solar infrared radiation. Different colored materials can reach reflectance of up to 0.60, while white roofs have even higher reflectance.

- **Federal market leverage:** Medium. Cool roofs are increasingly common within and outside the federal sector, but the potential for more widespread applications in cooling-dominated and transition climates is still enormous. Colored cool roofs are yet relatively new and subject to further research and development.
- **Federal sector savings potential:** Medium. Cool roofs provide great savings potential for flat roofed buildings, which are common in the federal building stock. However, savings are moderated by the fact that cool roof installation makes sense mainly at time of re-roofing, or for new construction.
- **U.S. Economy savings potential:** High. The highest potential is in the commercial sector with its high cooling demand.
- **Cost-effectiveness:** High. The cost-effectiveness is highest for flat (low-slope) roofs, since the incremental cost of choosing a highly reflective surface in these

cases is very small and perhaps zero, as part of a new installation or re-roofing project.

- **Retrofit applicability:** Medium-low. Cool roofs are most economical if installed at times of a planned re-roofing.

3.5 Power Generation and Renewable Fuels

3.5.1 Combined Heat and Power

Combined heat and power (CHP) is achieved with reciprocating gas-fired engines, microturbines, or fuel cells (see below) that generate electricity while using the waste heat for space heating, water heating, or for space cooling with absorption refrigeration or desiccant cooling. CHP systems minimize transmission losses by providing electricity on site. Networks of integrated CHP can increase system reliability and power security. CHP can also supply space conditioning and power to facilities that are not connected to the grid.

- **Federal market leverage:** High. Dedicated federal promotion can potentially achieve a breakthrough for the technology.
- **Federal sector savings potential:** High. DoD, Veterans Affairs, and DOE are agencies with the highest potential for CHP. The most potential by building type is in hospitals, industrial, and laboratory facilities. Performance is best where both electric and space conditioning needs are large, relatively predictable, and occur at the same time.
- **U.S. Economy savings potential:** High. Larger-scale CHP can be applied to larger commercial buildings and at a campus level, smaller-scale CHP can have high potential for multifamily and other residential buildings.
- **Cost-effectiveness:** Medium. Presently, microturbines have not yet achieved a high level of cost-effectiveness, but the cost-effectiveness of larger reciprocating engines is more favorable.
- **Retrofit applicability:** Medium. Utilization of the technology’s potential requires integration into the facility’s heating and cooling system.

3.5.2 Biomass

Biomass refers to the fuel from plants and plant-derived materials, including wood, food crops, grassy and woody plants, residues from agriculture or forestry, the organic component of municipal and industrial wastes and even the methane produced from landfills. Biomass is often used to co-fire boilers otherwise fired with coal.

- **Federal market leverage:** Medium. FEMP is offering a Technology-Specific Super ESPC for Biomass and Alternative Methane Fuels.
- **Federal sector savings potential:** Medium. Biomass can be applied for co-firing coal-fired boilers at federal facilities. The relatively small size of typical coal-fired boilers in federal facilities makes it easier to cover a substantial part of fuel needs with biomass.
- **U.S. Economy savings potential:** Medium. For utility-scale power generation projects, acquiring steady, year-round supplies of large quantities of low-cost biomass can be difficult.

- **Cost-effectiveness:** Medium. Sites where waste wood supplies are readily available and conventional fuels are expensive offer good potential for cost-effective use of biomass.
- **Retrofit applicability:** Medium. Biomass can be used for co-firing with existing coal-fired boilers. Modifications to existing emissions permits may be required for co-firing projects.

3.5.3 Fuel Cells

A fuel cell is an electrochemical device that combines hydrogen and oxygen to produce electricity, with water and heat as its by-product. Proton exchange membrane fuel cells are currently the most advanced type, although other types such as solid oxide fuel cells, molten carbonate fuel cells, direct methanol fuel cells, and phosphoric acid fuel cells have been developed. An on-site reformer to convert natural gas (methane) to hydrogen is often installed as part of the fuel cell system.

- **Federal market leverage:** High. First-cost and commercial availability remain the major constraints. More pilot applications that demonstrate the performance of this new technology can be of value in advancing the market.
- **Federal sector savings potential:** Medium. Fuel cells can be used for electricity generation – or better for combined heat and power production – in a wide range of federal facilities. Facilities with limited or no access to external energy supplies would benefit most from the technology. In addition, fuel cells can provide crucial back-up power – or potentially a highly reliable primary power source – for facilities that rely on uninterrupted power supply (e.g., federal datacenters, communications, or air traffic control facilities).
- **U.S. Economy savings potential:** Medium. The theoretical savings potential from widespread application of fuel cells is enormous. However, the economics of the technology at present limit the likely scope of application.
- **Cost-effectiveness:** Low. As a very recent technology, fuel cells are very expensive. For maximum efficiency, the waste heat from fuel cell's chemical reactions should be captured for space or water heating purposes, or for space cooling through thermally activated technologies such as desiccant or absorption cooling.
- **Retrofit applicability:** Medium. Utilization of the technology's CHP-potential requires integration into the facility's heating and cooling system. Applications where fuel cells are economically feasible without CHP are limited to remote locations or others with special power supply needs (e.g., very high reliability).

3.5.4 Distributed Wind Power

Small, modular wind-power-generating technologies can be located at or near the location where the energy is used. Small, distributed wind turbines can be used to power ranches, farms, homes, and businesses.

- **Federal market leverage:** Medium.
- **Federal sector savings potential:** Medium. Remote federal facilities, particularly DoD facilities, may be able to meet part of their power supply from distributed wind power generation. Distributed wind applications require adequate open space with good wind conditions and low potential for interfering with on-site operations.

- **U.S. Economy savings potential:** Medium-small. Although vast potentials for wind power exist in the West and the North, this potential is often best harvested though larger wind turbines instead of distributed wind power. In rural areas, where the potential for smaller wind power is great, electricity demand is limited.
- **Cost-effectiveness:** Medium. Depending on the location, wind turbines can be very cost-effective, especially if providing electricity at remote sites in combination with other distributed energy sources (FEMP 1998b).
- **Retrofit applicability:** Medium. Wind power can be added to existing power supply. A suitable site must be found for the generation and transmission system.

3.5.5 Photovoltaic Systems

Seventeen out of 24 federal agencies are using photovoltaic systems for power generation. Photovoltaics are made of semiconducting materials that directly convert sunlight into electricity for on- or off-grid applications. The size of systems used in the federal sector range from several watts to 1.1 megawatts (MW). A typical photovoltaic cell converts approximately 10 percent of the energy striking its surface into usable electricity.

- **Federal market leverage:** Medium. Various supporting programs exist, but any additional supporting activities that help grow market volume will help make the technology more competitive.
- **Federal sector savings potential:** High. The Energy Policy Act of 2005 directs the federal government to increase its renewable energy use to 3 percent or more in fiscal years 2007 through 2009 and to 5 percent in fiscal years 2010 through 2012. Photovoltaic systems are a major contributor to the federal government's renewable energy portfolio.
- **U.S. Economy savings potential:** Medium. The savings potential from solar power across the U.S. is vast. Nonetheless, solar competes not only with conventional power generation but with renewable sources such as wind power, which is more competitive in many areas.
- **Cost-effectiveness:** Low. The main strength of photovoltaic systems lies in the reduction of electricity demand during times of peak cooling demand. Distributed systems also eliminate transmission and distribution losses, but in turn require power conversion unless end-use such as lighting and electronic equipment are configured to use DC power directly from the PV installation. A few systems now integrate photovoltaic panels into building components, such as roofing tiles or glazing, thus saving the cost of installing those components separately. From the perspective of overall energy savings, present PV technologies have not yet reached high cost-effectiveness.
- **Retrofit applicability:** Medium. PV panels can be applied on top of existing roofs. Photovoltaic shingles have been developed that can be installed as roof retrofits.

3.6 Sanitation

3.6.1 Low-flush (Pressure-assisted) Toilets

Highly efficient low-flush toilets may only require 1.0 gallons of water per flush (the EPAct 1992 requirement is 1.6 gpf). The best flushing efficiency is provided by pressure-assisted toilets, which contain a chamber inside the toilet tank that traps air, which for operation is compressed and pushed out, propelling a small amount of water at a very high velocity to provide a powerful flush.

- **Federal market leverage:** Medium. Increased federal demand for pressure-assisted toilets can certainly increase the supply of different options in the market. Yet further initiatives will be needed to translate federal demand into adoption by the private sector.
- **Federal sector savings potential:** High. Toilets contribute about 21 percent of water use in the federal sector (McMordie Stoughton et al. 2005). A large part of these toilets consume 3.5 gallons per flush. Pressure-assisted toilets can cut this consumption dramatically.
- **U.S. Economy savings potential:** Medium. Because they create a louder flush than traditional tank toilets, pressure-assisted toilets are not very popular in residential settings. In commercial buildings, however, they can be acceptable and very cost-effective due to frequent use.
- **Cost-effectiveness:** High. The technology is very cost-effective in high-use applications such as in public or commercial buildings.
- **Retrofit applicability:** Medium. Where toilets are replaced, these can easily be replaced with low-flush toilets.

3.7 Special

3.7.1 Advanced Metering

Advanced metering includes remotely read interval electricity meters or submetering of large equipment or systems. The Energy Policy Act of 2005 (EPAct 2005), Sec.103 requires installation of meters and advanced electric meters on all federal buildings by the year 2012, and the ASHRAE advanced guidelines and proposed Standard 189 call for additional submetering of major equipment and end-uses.

- **Federal market leverage:** High. Implementation of advanced metering throughout the federal sector will serve as an important example to be followed by utility companies and the private sector where not yet adopted.
- **Federal sector savings potential:** High. If implemented throughout the federal sector and followed up by consistent commissioning, the savings potential is very high.
- **U.S. Economy savings potential:** Medium. Savings potential varies greatly depending on existing metering practices and potential for commissioning.
- **Cost-effectiveness:** Medium. Varies with application; FEMP guidelines suggest rules of thumb for advanced metering applications.[4]
- **Retrofit applicability:** High.

3.7.2 Best-in-class Efficient Equipment

Federal agencies are already required by law to purchase ENERGY STAR or FEMP-designated efficient products, for many categories of energy-using equipment. These specifications are typically set at a level representing the top 25% of efficient models on

[4] FEMP. 2006. *Guidance for Electric Metering in Federal Buildings*. http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf.

the market. For new or replacement equipment in a category covered by ENERGY STAR or FEMP specifications, agencies or ESCOs could go further in the context of advancing new technologies, by selecting a product from the *top 1-5% most efficient models* available at any one time.

- **Federal market leverage:** High. By promoting the most efficient available products, the federal government could pave the way for new FEMP and ENERGY STAR specifications.
- **Federal sector savings potential:** High. The most energy-efficient equipment identified by ENERGY STAR or FEMP typically consumes significantly less energy than equipment with the minimum required efficiency for federal purchase; incremental energy savings from upgrading to the best-available model range from 10% to several hundred percent.
- **U.S. Economy savings potential:** High.
- **Cost-effectiveness:** Medium. Cost-effectiveness of top-of-the-line equipment varies by category.
- **Retrofit applicability:** Medium. In most cases, a best-available model can be installed as readily as the required ENERGY STAR or FEMP-designated model, where an equipment replacement, retrofit, or new installation is already planned.

4. Policy Recommendations

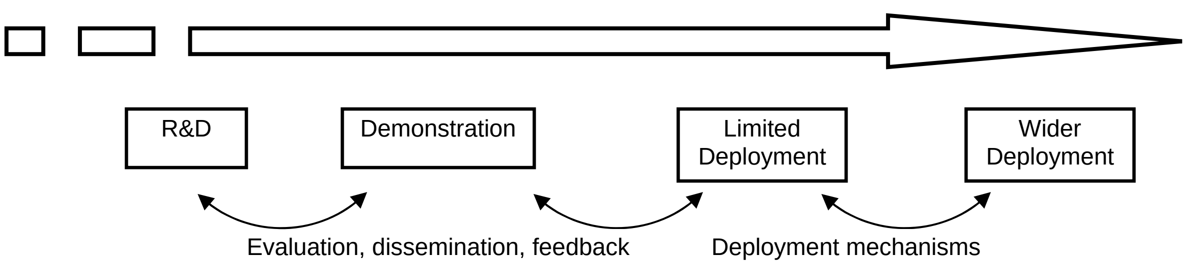
In this chapter, we recommend policies to support the implementation of new energy-saving technologies in the federal sector. These include the following:

- Establish agency-level teams to lead technology validation and implementation;
- Establish an interagency coordinating team to provide consistency to federal efforts;
- Disseminate project results within the federal sector;
- Leverage funding and financing mechanisms; and
- Involve non-federal stakeholders in implementation strategies in order to send strong market signals.

The following sections discuss the objective of these recommendations and the ideas behind them.

4.1 Objective

The policies recommended here are designed to help technologies bridge the steps between development of a new technology and its full deployment in the federal sector. As shown in the graphic below (a variant of the figure shown earlier), these stages beyond R&D often start with demonstration, then limited deployment, to wider deployment. In reality, it can take a long time for newly-developed technologies to be fully demonstrated and widely deployed, and even some promising technologies never reach this last stage. The goal of bridging the implementation stages is to ensure that the benefits of technologies are proven and brought to bear in large-scale deployment – both within the federal sector and, through federal leadership, in the broader commercial market. This requires deliberate efforts to create bridges between the implementation stages, coordination among stakeholders, and new federal mechanisms and resources for technology deployment.



Bridges between implementation stages

Stages of technology implementation can be bridged by disseminating the demonstration results to potential users of the technology and by inviting feedback from these users so that their experiences with specific technologies can inform the evaluation of new technologies.

Bridging the implementation stages involves:

- Evaluating the performance, costs, and benefits of a new technology;
- Disseminating results to implementers; and

- Providing feedback mechanisms.

Coordination among stakeholders
Effective bridges between the technology implementation stages rely on coordination among stakeholders, including:
- Direct specifiers and users of technologies, such as facility managers, building designers, and ESCOs;
- Coordinators of energy management and technology evaluation within agencies;
- Coordinators of activities throughout the federal sector, such as FEMP; and
- Initiatives outside the federal sector, such as state and utility programs as well as private sector activities.

Coordination among stakeholders can help them anticipate and overcome resistance to new technologies, share experiences for more effective energy management, and avoid duplication of efforts.

Mechanisms for technology deployment
Even with effective coordination among stakeholders and links between the implementation stages, technologies often need effective deployment and financing mechanisms to be adopted at a larger scale. In addition to direct agency appropriations, the most prominent implementation mechanisms for energy-saving technologies in federal facilities are:
- Energy Saving Performance Contracts
- Utility Energy Service Contracts
- Technology procurement
- Lease agreements

In the following paragraphs, we summarize comments from a series of interviews with federal agency personnel, suppliers of advanced energy-saving technologies, and ESCOs (see Appendix). Based on their comments and our review of other published and on-line resources, we suggest policies and actions to help link the stages of technology implementation, coordinate the efforts of stakeholders, and enhance implementation mechanisms.

4.2 Energy technology teams

Each federal agency with major responsibility for facilities construction or operation should establish a team to initiate, coordinate, and oversee the validation and implementation of energy-efficiency and renewable energy technologies.

Interview Findings

We asked our interviewees for recommendations on how to improve the adoption of new and advanced energy-saving technologies by agencies and facilities.

- A utility program provider stated that although energy managers are often willing to explore new energy-saving options, facility decision makers need to approach new technologies with caution.

- A facility manager agreed that it is difficult for facilities to contemplate long-term technology goals when decisions are based on short-term funding. It appears that the willingness to explore new technologies depends on support from champions for energy-saving technologies, at the agency and facility level, who are dedicated to evaluation, communication, and implementation of new technology options.
- This was also the opinion of a facility manager and a technology evaluator, both of whom described the Department of the Navy as having taken a promising approach toward innovative technologies, largely through the leadership of its Technology Validation Program (Techval – see https://navyenergy.navfac.navy.mil/projects/Techval.html).
- A representative of this program described Techval as a team focusing on transitioning energy-efficiency technologies from the demonstration stage into agency-wide application. Techval was started five years ago because the Navy saw a need for accelerating technology adoption to meet their energy saving goals. Techval's mission is to identify potential technologies for energy savings within the Navy, work with facilities on validating their performance, and promote the wider application of those technologies with proven performance and potential. The Techval staff invite technology recommendations from vendors and expert advisors outside the Navy, send email blasts to all Navy energy managers to enlist interested participants for demonstration projects, brief Navy facility managers at training sessions at least once a year, and take other actions as needed to facilitate the acceptance of new technologies.
- Notably, Techval does not select project demonstration sites based on payback, to avoid having these demonstrations concentrated only in regions with the highest energy prices. Techval employs four or five project engineers at a time, in addition to contractors. Its budget is between $1.8 million and $4.8 million.
- Based on the experience with Techval, the person we interviewed mentioned that a key factor for the program's success is support from agency upper management and their endorsement of the criteria used to select the technologies to be demonstrated. - as well as to resist in some cases including technologies proposed by manufacturers, vendors, or other advocates.
- Another supporting element is the involvement of key personnel throughout the Navy, to ensure that a broad group of people have a stake in the program's success. Techval also invites facility managers' interest in specific solutions by allowing them to propose technologies via the Techval website. Even facility personnel not involved in energy issues can contribute to Techval, for instance by providing feedback about the usefulness and maintenance requirements of new technologies. To alleviate concerns of any health, safety or other risk associated with technologies installed through Techval projects, Techval signs agreements with facilities about their responsibilities, including an offer to repair or remove any failing technologies.

Recommendations

Having in place a team of skilled, experienced agency personnel to provide leadership in technology assessment and deployment may be the single most important step to assure the implementation of advanced energy-saving technologies. Each federal agency with major responsibilities for facility design, construction, or operation should have a permanent team taking this role, identifying high-potential technologies, demonstrating and documenting their performance, and advocating for the deployment of promising new technologies.

Federal agencies would benefit from replicating the model of the Navy's Techval program for energy-saving technology assessment and implementation, and adapting this model to their own circumstances. Executive Order 13423, reinforced by the energy saving goals set by Congress in the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007, all underscore the need for each agency to find ways to use advanced technologies to help deliver cost-effective energy savings and renewable energy. This mission would be the main focus of agency-level energy technology teams. Depending on demand and resources, the scope of the teams' work could also include related aspects such as sustainability and perhaps non-energy technology performance issues.

The Navy's Techval provides a promising, replicable model for agency energy technology teams. Such a team would be tasked with the following:

- *Assess technology opportunities* and potential application in federal facilities;
- Organize and conduct *field tests* to measure and evaluate a technology's overall performance, energy savings, and cost-effectiveness;
- *Document results* of field tests and demonstrations, in the context of other information available about the technology and any alternatives;
- Assess the *potential savings and feasibility* of broader (agency-wide, federal sector, or economy-wide) implementation of the energy saving technology;
- Once technologies have been proven to reliably save energy, facilitate their *transition to widespread use* within the agency and where appropriate, to other federal agencies;
- Identify technologies that do not provide reliable and potentially cost-effective energy savings, are applicable only under specific conditions, are inferior to other alternatives, or need further development – in order to *prevent agencies from wasting their time and money*.

Combined, these tasks will help establish bridges between the implementation stages for new technologies by ensuring that technologies with proven benefits are more likely to be identified and adopted. The agency teams would also provide stakeholder coordination among technology providers, third party financers, and the end users at federal facilities.

An energy technology team's budget should provide for about three to eight permanent staff members per agency, contractors for specific technology applications, capital costs for demonstration projects, and resources to evaluate and disseminate results and then help "kick-start" the deployment of technologies after successful demonstration. The team would coordinate with facility managers to assess their needs, identify suitable sites for demonstration, and help cover the risk of technology failure. Team members would also serve as a point of contact for the exchange of documented results with other agencies and evaluate suggestions from technology providers. Excessive demands for technology evaluation on an individual agency's team can be avoided through coordination among the agencies, ideally led by an *interagency coordinating team* (see below).

The resources invested in the operation of such teams will greatly enhance the effectiveness of federal efforts to reduce energy use and help ensure that new energy-saving technologies developed and demonstrated with federal resources are actually deployed and save energy.

For coordination of efforts beyond individual agencies and across the federal government, we recommend establishing a permanent interagency coordinating team to create a network of agency-level technology teams, and also to reach out to those federal agencies that may not need their own team since they are primarily tenants rather than facility developers, owners, or operators.

4.3 Interagency coordinating team

The activities of individual agencies' energy technology teams should be coordinated by an interagency team with a permanent mandate of facilitating communication, common criteria and approaches for technology evaluation, and information-sharing across the federal government.

Interview Findings

We asked the individuals we about their experience with the coordination of technology implementation among agencies and about suggestions for improvement.

- One technology evaluator stated that interagency coordination is presently lacking. However, the potential for coordination exists: most of the technologies evaluated by the Navy, for example, could also be used in non-Navy buildings.
- A recent initiative is seeking to improve coordination: DOE and DoD recently established a joint technology validation working group with the initial purpose of improving communication so as to avoid overlapping activities. However, this effort remains informal and does not yet have a specific funding source.
- In addition to the need for interagency communication, technology implementation efforts also lack consistent criteria. Technology evaluators mentioned that demonstration projects are often done as a result of Congressional earmarks, and are often not overseen by permanent teams. As a result, there might not be a consistent long-term commitment to deployment, and many technologies do not make the transition from the demonstration to the deployment stage.
- Presented with the idea of an interagency coordination team, one interview respondent suggested that such a cross-cutting activity could have different sub-programs – e.g. energy efficiency, renewable energy, and environmental performance might be separate subject areas.

Recommendations

FEMP would be a natural candidate for establishing an interagency coordination team. FEMP does already fulfill such a role to some extent, but a dedicated team within FEMP with the mandate to actively coordinate agency efforts would provide substantial benefits beyond FEMP's present scope. It would respond to needs as they arise, track lessons learned, and disseminate results.

Part of an interagency coordinating team's role would be to continue the tasks of the New Technology Demonstration Program (NTDP), which was authorized by the Energy Policy Act of 1992 but has received little emphasis recently. The purpose of NTDP was to provide federal facility managers with information on new and underutilized technologies. NTDP not only released publications and responded to requests for information, it also identified and recommended technologies for demonstrations based on suggestions from federal agencies and laboratories. However, NTDP could not always provide consistent coordination of deployment efforts, since there was no network of permanent agency energy technology teams as we propose. The creation of such a network coordinated by a new interagency team could provide the needed consistency.

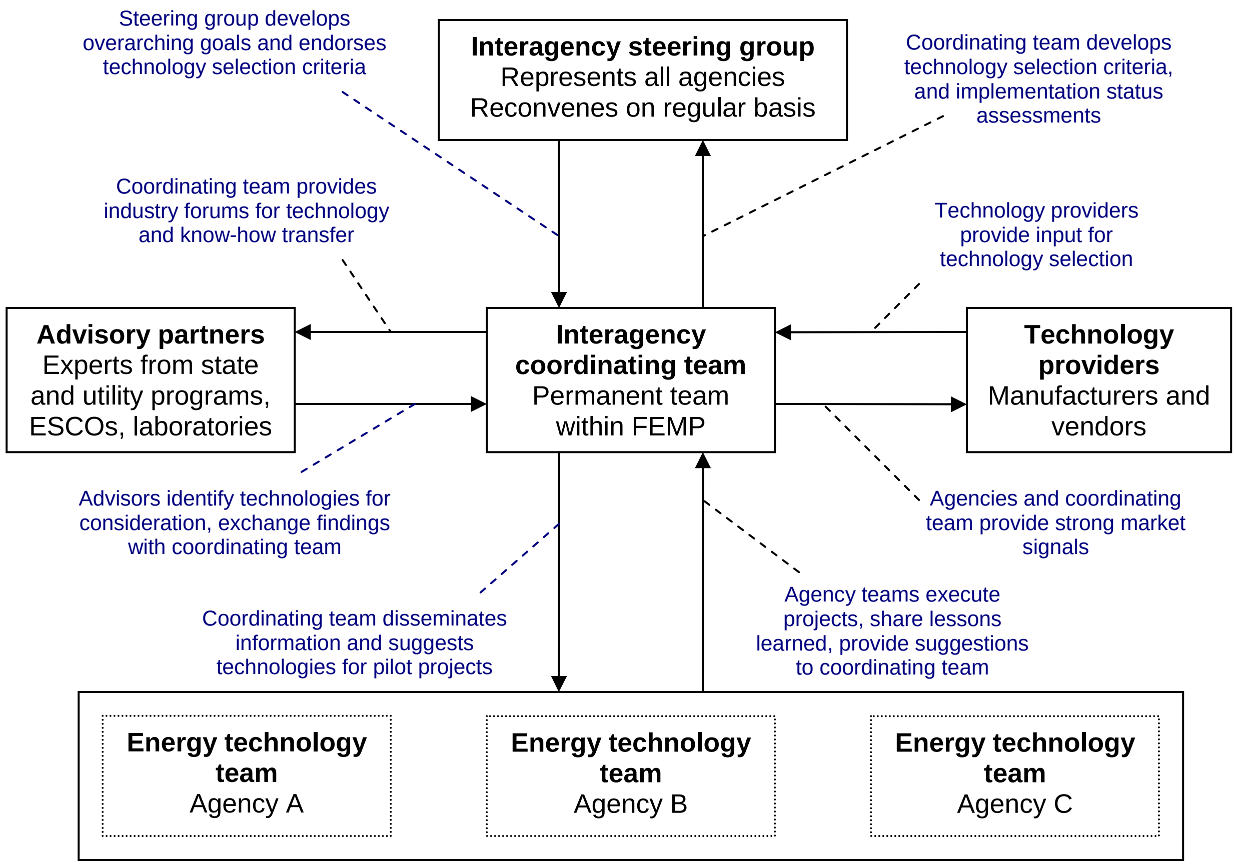
A recent step in the direction of coordinating agency efforts has been taken by DOE and DoD staff members who formed a Technology Validation (Techval) Working Group in December 2007.[5] The purpose of this working group is to:

1. Coordinate demonstrations within DoD and DOE to avoid overlap;
2. Provide a central repository for reports generated from these demonstrations;
3. Work to transition validated technologies.

A full-fledged coordination team would not only coordinate the efforts of different agencies, it would also evaluate technology recommendations from experts outside the federal government, periodically revise technology criteria, compile and disseminate information about progress made and new experience, and facilitate effective financing. The overarching goals for the coordinating team could be set by an interagency steering group consisting of experts from all involved agencies. A possible structure for the coordination of the different actors is presented in the graphic below, which is inspired by the organizational diagram for the Navy's Techval (see appendix).

Possible organizational diagram for interagency coordination

[5] This Technology Validation Working Group was formed at the request of Dr. Get Moy, former Director of Utilities & Energy, Office of the Deputy Undersecretary of Defense (Installations and Environment). It is co-chaired by Allan Hoffman, US DOE, and Paul Kistler, US Dept. of the Navy.



The interagency coordinating team would support the agency's technology demonstration and implementation activities with know-how gained from previous projects. If a common fund was established for reducing the risk associated with new technologies, this could also be administered by the interagency team to support selected projects by sharing financial risk.

4.4 Dissemination of results

A priority for an interagency coordinating team would be to disseminate project results within the federal sector and invite feedback from the implementers at federal facilities.

Interview Findings

Our interviewees were asked about recommendations on improving information exchange between federal stakeholders. Moreover, those interviewed were asked how agencies and other stakeholders acquire information on new technologies and what were the common channels for dissemination of such information.

Several interviewees called the present level of technology information exchange among federal agencies far from optimal. Although there are important efforts within agencies and FEMP to compile and disseminate information, a facility manager argued that many such efforts suffer from inefficiency due to their being based on short-term projects.

Steady if moderate funding for permanent technology teams is more likely to achieve effective dissemination of up-to-date information.

A technology evaluator emphasized the need for a central database that provides easily accessible information to implementers within the federal government. For this purpose, concise documents of 2-4 pages per technology are more crucial than detailed reports. Concise documents allow energy managers to access information quickly and can be easily updated once new information becomes available. According to a technology provider, wider adoption of new technologies would be enhanced if concise information is supplemented with guidelines for technology application and easily replicable program patterns.

A utility program provider emphasized that energy managers as well as third-party financiers need reliable information for the wider adoption of new technologies. One ESCO stated that direct interaction with manufacturers at energy conferences is presently the major means for ESCOs to gather information on new technologies.

Recommendations

Information dissemination can be provided through several channels. Of key importance is that a permanent team (ideally an interagency coordination team as discussed above) oversees the dissemination to ensure that information is up to date according to the latest findings from the different agency efforts. It would encourage agencies to demonstrate technologies and share lessons learned. Moreover, this team would not only reach out to partners but by also serve as a point of contact that can provide assistance when questions arise.

Specific outreach and assistance items could include the following:

- Workshops & training sessions – Set up by agency energy technology teams;
- Booths and presentations at GSA or energy conferences – Energy conferences are a vital source for ESCOs that are interested in information on new technologies;
- Share lessons learned with federal power authorities (BPA, TVA) and state technology research programs (e.g. by NYSERDA or the California Energy Commission);
- Unified Facility Guide Specifications (UFGS) for new or underutilized technologies – Adding specifications to the UFGS, to provide simple models for replicable implementation of new technologies, may be a particularly valuable tool.

The task of information dissemination has until recently been fulfilled by FEMP's New Technology Demonstration Program (NTDP). It has been a challenge is to provide up-to-date information on new technologies. Technology assessments can change frequently due to new findings and market developments. Therefore it is recommended that the interagency coordinating team create and manage a database of technology information that provides brief summaries of evaluations which can easily be modified by stakeholders once new findings are available. Developing such a database would be a near-term task that could also be completed even before a full-fledged network of agency technology teams is established. The appendix includes a suggested outline for an accessible energy technology database.

4.5 Deployment mechanisms

The federal government should provide funding support to kick-start the deployment of advanced energy-saving technologies. Barriers to third-party financing, such as risk and long payback, need to be addressed.

Interview Findings

Interviewees were asked about barriers to the implementation of technologies through third-party financing, and about possible means of surmounting these barriers.

Interviewed facility managers stated that limited funds make facilities reliant on third-party financing for energy-efficiency investment. However, higher risk and prolonged payback were pointed out as barriers to third-party financing of new technologies. Many ESCOs are risk-averse due to the required savings guarantees. Legally, they cannot quantify risk in dollars, so higher-risk technologies are usually only included as a small portion of larger contracts. A facility manager stated that it would not be viable to require ESCOs to use new technologies if higher risk is involved.

Facility managers described UESC financing as allowing more opportunities to choose new technologies since the risk is mainly borne by the customer. To keep the overall payback time of the project within acceptable limits, expensive and/or higher-risk new technologies are generally installed as demonstration projects alongside measures with lower risk and shorter payback.

According to technology evaluators and ESCOs, the barrier of higher risk to ESPCs can be reduced by:

- Thoroughly validating technology performance to enable reliable savings projections;
- Allowing ESCOs to use more favorable measurement and verification (M&V) options to shift risk from the ESCO to the agency.[6]

Interviewed ESCOs, facility mangers and utility program providers agreed that government cost sharing or incentives from state and utility sources can greatly expand the scope of new technologies within ESPC or UESC projects. This is the case with utility rebates and tax incentives for renewable energy, although possible delays due to bureaucracy may be a risk for ESCOs relying on utility and state incentives.

Some of those interviewed also mentioned other deployment mechanisms for advanced technologies:

- DoD’s Energy Conservation Investment Program (ECIP) is funding energy-efficiency and renewable energy projects. From 2009 onward ECIP will be restricted to renewable energy.
- States can partner with agencies and fund field demonstrations in federal facilities. One example is a current partnership between DOE and the California

[6] For a discussion of the most favorable M&V option from the ESCO perspective, Option A (verified potential to perform, stipulated performance), see: FEMP. 2002. *Detailed Guidelines for FEMP M&V Option A.*

Energy Commission to demonstrate advanced window daylighting and shading. Results of this study are disseminated through utility companies.[7]

- Case studies of high-potential technologies can sway utility companies to offer rebate programs. Case studies can be conveyed from agencies to utilities through the Consortium for Energy Efficiency on a national basis, as well as directly with their local utility at each facility.

Recommendations

Funding for new technology projects can greatly enhance deployment. Federal and non-federal cost-sharing can expand the potential of UESC and ESPC projects by addressing the barrier of longer payback for many new technologies. On the other hand, some facilities may employ such funding directly (outside of an ESPC or UESC) to leverage their experience with specific technologies, ensure efficient deployment, and achieve swift payback.

Longer payback for some new technologies is one barrier to third-party financing. If not addressed with cost-shared funding, UESC and ESPC projects can improve overall payback by bundling new technologies with conventional fast-payback technologies. Another barrier for ESPCs is risk, as ESCOs need to guarantee energy savings from implemented measures, which can be a challenge with contracts involving new technologies. In select cases, ESCO's concerns may be addressed by more favorable M&V options, but in the long run, increased adoption of any new technologies by ESCOs will reduce the perceived risk and thus remove a barrier to its wider deployment. Energy technology teams can support this process by:

- Maintaining a close working relationship with ESCOs;
- Providing reliable case study results;
- In select cases, offering funding assistance or insurance against particular risks;[8]
- Reminding ESCOs of the increasing need for deeper savings.

As discussed in Chapter 1, other deployment options can be used to implement new energy-saving technologies:

- Lease agreements – The deployment of new energy-efficient technologies could be included as a condition in lease agreements between federal agencies and private lessors.
- Technology procurement – In some cases, it can be viable for federal procurement to specifically aim for new technologies instead of more common energy-efficient options, especially where projects can aggregate buyer demand across federal agencies and perhaps with non-federal institutional, government, or corporate buyers.

[7] For more information on this project, contact Eleanor Lee, Building Technologies, LBNL at ESLee@lbl.gov.

[8] For instance, an interviewed ESCO mentioned projects including geothermal heat pumps as a example where ESCOs may need to do expensive site testing before the technology can be considered. Should the site be unsuitable, the ESCO thus bears a risk of not being able to recoup the initial investment. Energy technology teams can coordinate with ESCOs on sharing such risks.

- Utility rebates – Utilities could have an interest in offering rebates to federal procurement of technologies that fall under the regulation's definition of emerging technologies. By collaborating with individual utilities as well as working through the Consortium for Energy Efficiency (CEE), federal agencies can reach out to utility program providers across the country.
- Voluntary Programs, Codes and Standards – Energy technology teams can lend their expertise with technologies that are gaining in prominence to the ENERGY STAR program and to code- and standard-setting bodies. With the increasing interest in advanced energy codes, new technologies might be introduced through model building energy codes and advanced guidelines (including the federal UFGS, ASHRAE Advanced Guidelines, and Standard 189) may be substantially accelerated.

4.6 Involvement of non-federal stakeholders

Non-federal stakeholders should be involved in implementation strategies for new energy-saving technologies. Strong and consistent market signals are needed to reduce uncertainty about federal demand.

Interview Findings

We asked those interviewed about the involvement of non-federal stakeholders (state and utility programs, technology providers, third-party financers) in implementation strategies. They were also asked about their perception of the market signals coming from the federal agencies with respect to new energy-saving technologies.

Whereas the interviewed ESCOs stated that they were in constant interaction with federal agencies and facilities, two of the interviewed technology providers were very interested in closer communication with federal agencies. One technology provider stated that the range of technologies considered by FEMP was somewhat limited due to reliance on pre-screening by the national laboratories. The provider preferred a chance for direct contact with energy managers who could be interested in site-specific solutions.

On the other hand, a utility program provider and a technology evaluator mentioned that input from technology providers can easily be overwhelming due to concerns about technology reliability. One technology provider mentioned that concerns about product performance can be addressed by the company offering shared savings packages and energy savings guarantees.

One technology evaluator emphasized the importance of not only improving coordination among federal agencies but also between agencies and non-federal programs such as California's Public Interest Energy Research (PIER) program or the programs by the New York State Energy Research and Development Authority (NYSERDA). A technology provider also portrayed California's efforts as trailblazing due to high levels of funding for advanced technology work. Another manufacturer mentioned that municipalities or cities are sometimes at the forefront of deploying new technologies and can thus provide valuable lessons.

At present, the federal sector seems to issue ambiguous signals concerning the adoption of new and advanced technologies. On the one hand, interviewees perceived a strong interest in new technologies among energy managers in the federal sector. On the other hand, interviewees perceived other federal decision-makers as still cautious or, due to funding constraints, inconsistent in their pursuit of longer-term goals such as the deployment of new advanced technologies.

Recommendations

Important stakeholders outside the federal government should be involved in strategies for the implementation of advanced technologies, without compromising the focus and consistency of federal efforts.

Coordination with a wide group of non-federal stakeholders is certainly valuable. These include state and local governments, utilities, ESCOs, technology providers, and international partners. Single agencies may not be able to stay in touch with such a broad spectrum of potential advisors. An active interagency coordination team, on the other hand, can help to maintain close cooperation with diverse non-federal organizations and experts.

The Federal government can provide strong market signals by informing technology suppliers of the performance requirements sought in new energy-saving technologies. Where it is possible to estimate the potential federal demand for a new technology type, providers should be informed at federal energy events to improve the chances of timely and adequate supplies of products (and services).

Input from providers on their new technology options is certainly valuable, but needs to be evaluated as to its reliability and usefulness. An interagency coordinating team would improve this process by establishing criteria for technology consideration so that the choice of technologies to be considered can be narrowed down and closer interaction with providers is possible.

Agencies and the interagency coordinating team should definitely strengthen coordination with non-federal programs such as California's PIER program, NYSERDA's emerging technologies program and the Consortium for Energy Efficiency. DOE is already in constant contact with these programs, but FEMP has been less involved, and additional effort will be needed to establish joint projects for the government-wide implementation of new technologies in federal facilities.

Through ESPC and UESC projects, ESCOs and utility companies are involved in federal energy management strategies. Improving the implementation of new and advanced energy-saving technologies through these projects requires improved funding and financing mechanisms, as discussed in the previous section.

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Appendices

Appendix 1: Interviews with Technology Stakeholders

Stakeholder Type	Organization Name	Interviewee Name	Interviewee Position
ESCO	Ameresco	Brian Hashimoto	Senior Account Executive
Technology provider	American Solar, Inc.	John Archibald	President
Technology evaluator	California Energy Commission	Michael Seaman	Program Manager
Technology provider	CREE	Greg Merritt	Director, Corporate Marketing
Technology evaluator	EERE, U.S. Department of Energy	Allan Hoffman	Senior Analyst
Facility manager	Fort Huachuca	Bill Stein	Energy Coordinator and Utility Sales Officer
Facility manager	Fort Huachuca	Craig Hanson	Energy Technician
ESCO	Honeywell	Alicia Collier	Director, Energy Policy, National Energy Solutions
ESCO	Honeywell	Jeffrey Stringfield	Solutions Development Team Leader
Facility manager	Lawrence Berkeley National Laboratory	Geoffrey Bell	Senior Energy Management Engineer
Technology provider	Orion Energy Systems	Steve Heins	VP, Corporate Communications
Technology provider	Orion Energy Systems	Mike Potts	Executive Vice President
Facility manager	Port Hueneme Naval Base (Department of the Navy)	Tom Santoianni	Facilities/Energy Manager
Utility program provider	Sempra Energy	Gordon Maynard	Project Manager
Technology evaluator	Techval (Department of the Navy)	Paul Kistler	Team Leader
Technology evaluator	U.S. Army Corps of Engineers	Alexander Zhivov	Engineer, Research and Development

Appendix 2: Interviewees' Comments on Specific technologies

Lighting

Spectrally enhanced lighting (SEL)

- Utility program provider pointed out that when SEL light bulbs are replaced, facility managers need to ensure that they are also replaced with spectrally enhanced lights. This is only certain if all available replacement bulbs in a facility are SEL, which is best ensured if the switch to SEL is done for all of the facility's lighting at once.

Addressable dimming fluorescent ballasts

- One facility manager experienced problems with dimming ballasts that tended to burn out fast and rarely turn off completely. He suggested that a better system would have just 3 stages of lighting intensity: 100%, 50%, or 0%. Such a system has been developed by the California Lighting Technology Center.

Daylighting systems and integrated daylighting controls

- One technology provider stated that passive daylight harvesting with integrated lighting controls is very cost-effective and has been installed in Ellsworth air force base, SD.
- According to one ESCO's experiences, the difficulty with daylighting lies in getting tenants to use the technology right. Energy managers do not have the authority to direct tenant behavior, and tenants need to cease overriding the lighting controls for the daylighting to save energy. The ESCO also cautioned that active daylighting technologies are maintenance-intensive.

LED lighting for niche applications

- Among the current potential applications, a technology provider listed office buildings (task lighting, downlights), military installation, air force taxiways, and parking lots. According to the provider, adoption of LED lighting is more driven by states and municipalities than by the federal sector. Ann Arbor, MI, and Raleigh, NC are examples of cities replacing street lights with LED lights.
- A technology evaluator stated that DOE's solid state lighting program failed to partner with states, although CA and NY have done substantial research on the technology.
- A utility program provider stated a serious concern about LED lighting as long as there is no firm standard on light degradation.

High output T5 high-bay lighting

- One facility manager recommended T8 instead of T5 lighting due to slightly higher efficiency.

HVAC

Aerosol-based duct sealing for commercial buildings

- According to a facility manager, an ESCO is planning to try aerosol duct sealing for commercial buildings because LBNL is comfortable with demonstrated performance (has been tested for 5 years) and the manufacturer has a good track record with the residential technology.

Air conditioning for climates with high or low sensible heat ratios

- A technology evaluator stated that the Army is presently interested in dedicated outdoor air systems with dehumidification, particularly for sensible cooling.

Building Envelope

Passive solar ventilation preheating

- A technology provider gave Fort Huachuca, AZ as an example of a site where solar heat recovery is performed with piping, fans, controls and ducts added to conventional water-tight metal roofing and siding. The heat recovery equipment can be installed at low extra cost if roofs or siding are replaced for non-energy reasons. Facilities' roofing budgets can pay for the roofing retrofit. More efficient as siding

Power generation

Combined heat and power

- An ESCO mentioned Fort Bragg, NC as an example where 50 percent cost share from an EERE grant program allowed the ESCO to cost-effectively install CHP.

Photovoltaics

- A utility program provider mentioned Marine Corps Base Camp Pendleton, CA as a site where photovoltaic panel installations have been installed along with other capital-intensive measures through UESC financing.
- A technology provider stated that photovoltaics do not offer good economics, but that solar thermal measures implemented at the same time can make up for the poor payback of PV through their higher cost-effectiveness.

Additional technologies

Waterless urinals

- A facility manager mentioned growing experience with waterless urinals. These have been installed in larger numbers (more than 100) in Port Hueneme, CA (U.S. Navy). Maintenance is an issue, but low-maintenance options are under development and demonstration.

Low-volume fume hoods

- A facility manager mentioned low-volume fume hoods as an example of a technology developed by LBNL and licensed by an ESCO after thorough demonstration and validation in national laboratories.

Turbocor

- Several interviewees (facility manager, technology evaluator, utility program provider) gave Turbocor as an example of a successfully validated and implemented technology. This frictionless magnetic bearing compressor has been demonstrated and evaluated by Techval and can be used for chiller retrofits. Due to its proven benefits it has reached wide acceptance among facility managers throughout the Navy and is being adopted by ESCOs.

Data centers and hospitals

- Not as a technology solution but as a growing priority for energy saving measures, a facility pointed to data centers and hospitals as new focus areas for

ESPC projects. Reducing energy use in these facilities requires good, sound engineering more than radically new technologies.

Appendix 3: Recommended Technology Information Database Structure

We recommend that the interagency technology coordinating team administer a web-based database of on new energy-saving technologies. Developing such a database can be a near-term task that could also be completed before a real interagency coordinating team is established. The goal of the database is to provide a central point of access for all agencies to obtain up-to-date information on advanced technologies and to which agencies can give input based on their latest experiences.

The database structure should reflect the following priorities:

- Easily accessible information;
- Information on lessons learned, including success stories as well as problems;
- Options for frequent updates and input from users of technologies.

The information items provided for each technology type in the database should reflect these priorities. The database could contain the following elements:

Concise central document. Each technology should have a concise central document (1-4 pages), in which the technology is described and evaluated. The purpose of such a document is to provide energy managers an idea about the technology's merits without requiring time-consuming research in longer documents. Good examples for such documents are the introductory fact sheets that form the first couple of pages of the Federal Technology Alerts. However, it is also important that these documents are updated as new important findings are made. The interagency coordinating team should ensure that the central documents for the various technologies are consistent in their structure, so that direct comparisons between technologies can be made.

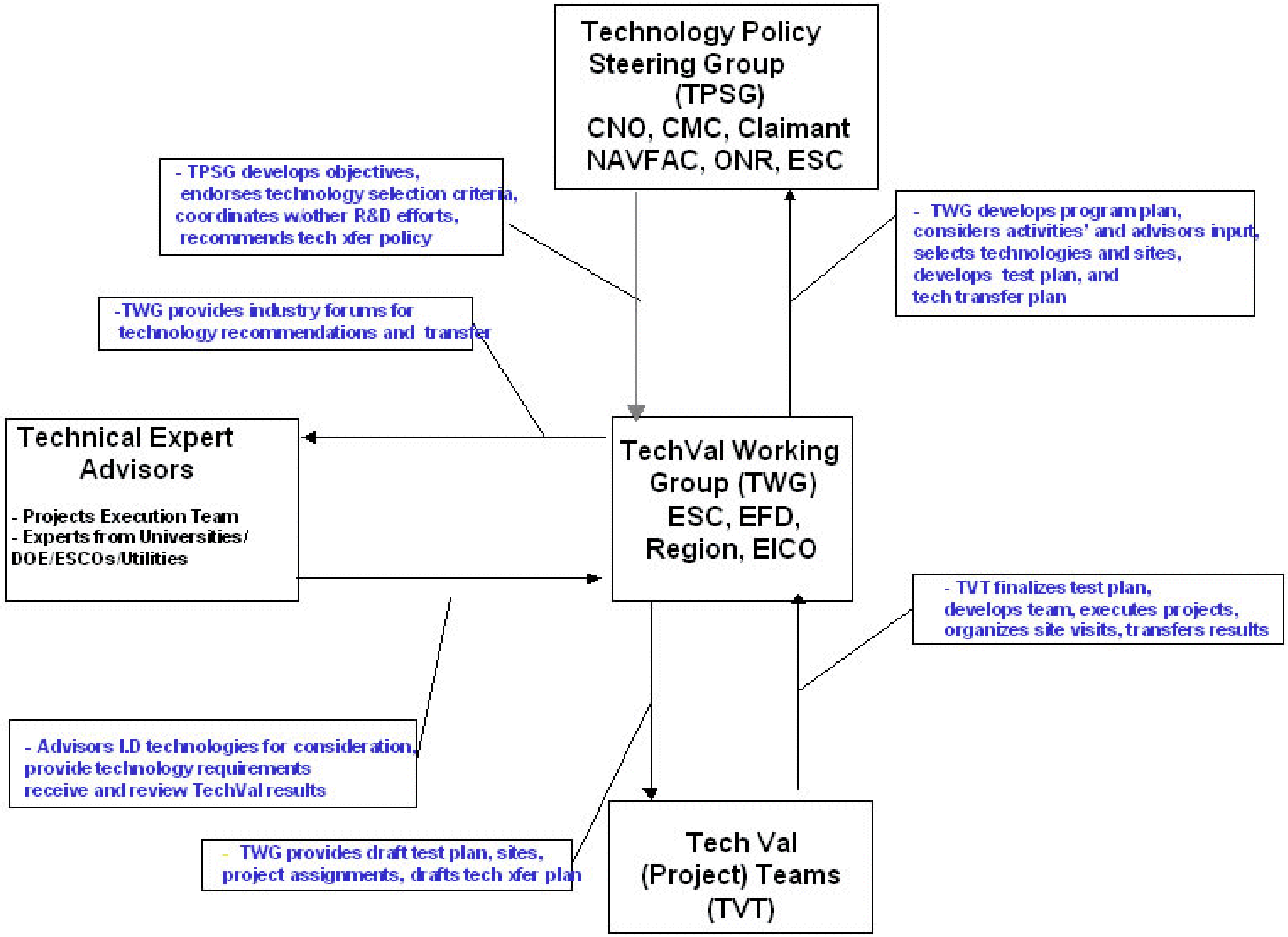
Supporting documents. Longer reports and studies can be added as supporting documents providing more detail than the concise central document. As opposed to the central documents for each technology, the supporting documents can vary in type between technologies. Reports from federal and non-federal sources already exist for many advanced technologies, and new documents can be added anytime.

Database of technology installations. A database of installations would list federal sites where a given technology has been implemented. This information would help energy managers find out about sites from which they can learn about concrete experiences. The database would list the installation site, the year of installation, optionally provide the contact information of the site's energy management as well as a short description and information about lessons learned (problems as well as successes). Facility managers should have online access to this database for content input and updates.

Supplier information. Links to technology supplier websites as well as supplier contact information will help energy managers inquire about product options.

The concise central documents would require an ongoing effort by a team dedicated to maintaining accuracy and consistency. The other information items can be added gradually from diverse sources and with input from energy managers and expert advisors.

Appendix 4: Techval Organizational Diagram



Source: https://navyenergy.navfac.navy.mil/projects/Techval.html

Appendix 5: Techval Selection Criteria

Source:
https://navyenergy.navfac.navy.mil/projects/Techval%20Selection%20Criteria.htm

Criteria	Raw Score (1-10)	Weight	Raw Score x Weight
Total MBtu energy or Kgal of water saved Navy/Marine wide		1.6	
Implementation cost, $/MBtu or $Kgal		1.4	
Probability of project success Can we test the technology? Will Navy adopt?		1.2	
Mission impact is neutral or improved		1.2	
Overall environmental impact is neutral or improved		1.2	
< 10 year simple payback		1.1	
Reliability		0.8	
Low maintenance		0.8	
Technology easy to remove or abandon if it does not work		0.6	
Sum Total			

All criteria shall be given a raw score from 1 to 10 and then multiplied by the weight. The criteria is weighted such that if all of the raw scores are given a value of 10, the Sum Total will equal 100. A raw score of 10 indicates a high probability of the following outcomes and 1 indicates a low probability of the following outcomes.

1) l Total MBtu or Kgal water saved Navy/Marine wide is defined as the probability that the technology if adopted to the maximum extent possible Navy/Marine wide will save the most number of total Mbtus Kgal water when compared to the other technologies being considered for demonstration and validation.

2) Implementation cost, $/MBtu or $/Kgal water is defined as the probability that the technology will have the lowest cost for each MBtu saved when compared to other technologies being considered for demonstration and validation.

3) Probability of project success has two key components that are combined to form a single criteria. Can we test the technology? This is the probability that we can adequately test the technology in order to prove or disprove that it reliably saves energy when compared to other technologies being considered for demonstration and validation. The second component is will the Navy adopt the technology? This is defined as the probability that the Navy will adopt the technology for widespread use once it has been demonstrated to reliably save energy when compared to other technologies being considered for demonstration and validation.

4) Mission impact is neutral or improved is defined as the probability that the technology will not negatively impact the Navy mission when compared to other technologies being considered for demonstration and validation. Neutral impact would be where except for energy savings, the implementation of the technology is transparent to the end users. An example of improved mission impact would be improved power quality, improved indoor air quality or improved lighting.

5) Overall environmental impact is neutral or improved is defined as the probability that the when the technology is evaluated as a whole, the total impact is negative or neutral when compared to other technologies being considered. This does not mean that there are no negative environmental impacts, rather that the positive impacts outweigh the negative.

6) < 10 year simple payback is defined as the probability that the technology will have less than a ten year simple payback when compared to other technologies being considered for demonstration and validation.

7) Reliability is defined as the probability that a technology will have the least amount of down time due to unscheduled repairs when compared to other technologies being considered for demonstration and validation.

8) Low maintenance is defined as the probability that a technology will have the least cost both in time and dollars for regularly scheduled maintenance when compared to other technologies being considered for demonstration and validation.

9) Technology easy to remove or abandon in place if it does not work is defined as the probability that if a technology does not work it can be easily removed or abandoned in place when compared to other technologies being considered for demonstration and validation.

Appendix 6: Technology Fact Sheets

The following list provides examples of available fact sheets about technologies included in our screening. These fact sheets are all no longer than 2 pages and thus provide easy references. Federal Technology Alerts include longer, more detailed reports, but are introduced by short, two-page overviews. Copies of fact sheets that were developed by Lawrence Berkeley National Laboratory and the Alliance to Save Energy as part of our technology screening are included in this appendix.

Spectrally Enhanced Lighting

Emerging Technology Profile: *Spectrally Enhanced ("Scotopic") Lighting*
➔ Included in this appendix

Addressable Dimming Fluorescent Ballasts

Emerging Technology Profile: *Addressable Dimming Fluorescent Ballasts*
➔ Included in this appendix

CFL Adapter for Recessed Downlights

Inventions & Innovation Success Story: *PowerRimTM High-Wattage Energy-Saving Compact Fluorescent Light (CFL) Adaptor for Recessed Downlights*
http://www1.eere.energy.gov/inventions/pdfs/powerlux.pdf

LED Lighting for Niche Applications

Buildings Technology Program: *Energy Efficient Lighting and Light-Emitting Diodes*
http://www.netl.doe.gov/ssl/PDFs/LED-FAQ.pdf

High Output T5 High Bay Lighting

Emerging Technology Profile: *High Bay Lighting: High-Output T5 Retrofits*
➔ Included in this appendix

Aerosol-Based Duct Sealing for Commercial Buildings

Emerging Technology Profile: *Aerosol-based Duct Sealing for Commercial Buildings*
➔ Included in this appendix

Advanced Rooftop Air Conditioning, Automated fault detection

Technical Brief: *Automatic Diagnosis for Ailing Rooftop Air Conditioners*
http://www.esource.com/esource/getpub/public/pdf/cec/CEC-TB-10.pdf

High-Efficiency Heat Pump Systems, Geothermal or hybrid geothermal heat pumps

Program Overview: *FEMP's Geothermal Heat Pump Program*
http://www1.eere.energy.gov/femp/pdfs/ghp_prog_overvw.pdf

Federal Technology Alert: *Ground-Source Heat Pumps Applied to Federal Facilities*
http://www1.eere.energy.gov/femp/pdfs/FTA_gshp.pdf

Demand-Controlled Ventilation with Advanced Controls

Federal Technology Alert: *Demand-Controlled Ventilation Using CO2 Sensors*
http://www1.eere.energy.gov/femp/pdfs/fta_co2.pdf

Air Conditioning for Climates with High or Low Sensible Heat Ratios, Two-stage evaporative cooling

Technical Brief: *The Next Stage in Evaporative Cooling*
http://www.esource.com/esource/getpub/public/pdf/cec/CEC-TB-12.pdf

Air Conditioning for Climates with High or Low Sensible Heat Ratios, Hybrid desiccant cooling

Federal Technology Alert: *Two-Wheel Desiccant Dehumidification System*
http://www1.eere.energy.gov/femp/pdfs/FTA_two-wheel.pdf

Condensing Fuel-Fired Hydronic Boilers / Water Heaters

Federal Technology Alert: *Modulating/Condensing Fuel-Fired Water Heater and Hydronic Boiler*
http://www1.eere.energy.gov/femp/pdfs/FTA_Modulating-updat.pdf

Heat Pump Water Heaters

Federal Technology Alert: *Commercial Heat Pump Water Heaters*
http://www1.eere.energy.gov/femp/pdfs/FTA_HPWH.pdf

Federal Technology Alert: *Residential Heat Pump Water Heaters*
http://www1.eere.energy.gov/femp/pdfs/FTA_res_heat_pump.pdf

Solar Water Heater

Federal Technology Alert: *Solar Water Heating*
http://www1.eere.energy.gov/femp/pdfs/FTA_solwat_heat.pdf

Federal Technology Alert: *Parabolic Trough Solar Water Heating*
http://www1.eere.energy.gov/femp/pdfs/FTA_para_trough.pdf

Condensing Fuel-Fired Water Heaters

Federal Technology Alert: *Modulating/Condensing Fuel Fired Water Heater and Hydronic Boiler*
http://www1.eere.energy.gov/femp/pdfs/FTA_Modulating-updat.pdf

Passive Solar Ventilation Preheating

Solar Buildings: *Transpired Air Collectors*
http://www.nrel.gov/docs/fy06osti/29913.pdf

Federal Technology Alert: *Transpired Collectors (Solar Preheaters for Outdoor Ventilation Air)*
http://www1.eere.energy.gov/femp/pdfs/FTA_trans_coll.pdf

Cool Roofs

Federal Energy Management Programs: *How to Buy "Cool" Roof Products*
http://www1.eere.energy.gov/femp/pdfs/roof.pdf

Combined Heat and Power, Microturbines

Federal Technology Alert: *Summary of Results from Testing a 30-kW-Microturbine and Combined Heat and Power (CHP) System*
http://www1.eere.energy.gov/femp/pdfs/fta_microturbinechp.pdf

Combined Heat and Power, General

Federal Energy Management Program: *CHP Program Overview*
http://www.ornl.gov/sci/femp/pdfs/FEMP-CHP-prog-ovr-final0205.pdf

Biomass

Federal Technology Alert: *Biomass Cofiring in Coal-Fired Boilers*
http://www1.eere.energy.gov/femp/pdfs/fta_biomass_cofiring.pdf

Fuel Cells

Federal Technology Alert: *Natural Gas Fuel Cells*
http://www1.eere.energy.gov/femp/pdfs/FTA_natgas_fuelcell.pdf

Distributed Wind Power

Federal Technology Alert: *Wind Energy*
http://www1.eere.energy.gov/femp/pdfs/21265.pdf

Photovoltaic Systems

Federal Technology Alert: *Photovoltaics*
http://www1.eere.energy.gov/femp/pdfs/FTA_pv.pdf

Low Flush (Pressure-Assisted) Toilets

Federal Technology Alert: *Domestic Water Conservation Technologies*
http://www1.eere.energy.gov/femp/pdfs/22799.pdf

Appendix 7: Technology Evaluation Matrix

Emerging Technology Evaluation for Application in the Federal Sector

? High ? Medium ? Low

Lighting

Technology	Federal (Market) Leverage	Savings Potential: Federal	Savings Potential: US economy	Cost Effectiveness	Retrofit Applicability	Special Benefits	Sub-Categories
Scotopic Lighting	?	?	?	?	?		
Addressable Dimming Fluorescent Ballasts	?	?	?	?	?		
Daylighting Systems and Integrated Daylighting Controls	?	?	?	?	?	Occupant comfort and performance	a) Hybrid solar lighting b) Daylight harvesting and controls
CFL Adapter for Recessed Downlights	?	?	?	?	?		
LED Lighting for Niche Applications	?	?	?	?	?	Low maintenance	
High Output T5 High Bay Lighting	?	?	?	?	?		

HVAC

Technology	Federal (Market) Leverage	Savings Potential: Federal	Savings Potential: US economy	Cost Effectiveness	Retrofit Applicability	Special Benefits	Sub-Categories
Aerosol-Based Duct Sealing for Commercial Buildings	?	?	?	?	?	Unique solution	
Advanced Rooftop Air Conditioning	?	?	?	?	?		a) Automated fault detection and diagnosis b) High-efficiency units
High-Efficiency Heat Pump Systems	?	?	?	?	?		a) Geothermal and hybrid geothermal HP b) Low-temperature HP
Demand-Controlled Ventilation with Advanced Controls	?	?	?	?	?		
Air Conditioning for Climates with High or Low Sensible Heat Ratios	?	?	?	?	?		a) Two-stage evaporative cooling, b) Hybrid desiccant cooling
Thermal Destratifiers	?	?	?	?	?	Occupant comfort	
Condensing Fuel-Fired Hydronic Boilers	?	?	?	?	?		

Water Heating

Technology	Federal (Market) Leverage	Savings Potential: Federal	Savings Potential: US economy	Cost Effectiveness	Retrofit Applicability	Special Benefits	Sub-Categories
Heat Pump Water Heaters	?	?	?	?	?		
Solar Water Heaters	?	?	?	?	?		
Condensing Fuel-Fired Water Heaters	?	?	?	?	?		

Building Envelope							
Technology	Federal (Market) Leverage	Savings Potential		Cost Effectiveness	Retrofit Applicability	Special Benefits	Sub-Categories
		Federal	US economy				
Highly Insulating Windows	?	?	?	?	?	Occupant comfort	
Passive Solar Ventilation Preheating	?	?	?	?	?		
Cool Roofs	?	?	?	?	?		

Power Generation							
Technology	Federal (Market) Leverage	Savings Potential		Cost Effectiveness	Retrofit Applicability	Special Benefits	Sub-Categories
		Federal	US economy				
Combined Heat and Power	?	?	?	?	?	Reliable electricity supply	a) Microturbines b) Efficient gas-fired reciprocating engines c) Stationary fuel cells
Biomass	?	?	?	?	?	Reliable electricity supply	
Fuel Cells	?	?	?	?	?		
Distributed Wind Power	?	?	?	?	?		
Photovoltaic Systems	?	?	?	?	?		

Sanitation							
Technology	Federal (Market) Leverage	Savings Potential		Cost Effectiveness	Retrofit Applicability	Special Benefits	Sub-Categories
		Federal	US economy				
Low-Flush (Pressure-Assisted) Toilets	?	?	?	?	?	Water savings	

Special							
Technology	Federal (Market) Leverage	Savings Potential		Cost Effectiveness	Retrofit Applicability	Special Benefits	Sub-Categories
		Federal	US economy				
Advanced Metering	?	?	?	?	?		a) Remote read b) Interval meters c) Submetering
Best-in-Class Equipment	?	?	?	?	?		Several

Evaluated New or Advanced Technologies for Application in the Federal Sector

A	All or most federal facilities
M	Many federal facilities
S	Special conditions (see measure description)

Technology	ESPC Applic-ability	Application	Description	Notes	Mechanisms			
					ESPCs / UESCs	Utility Rebates	Leases	New Construction
Lighting								
Spectrally Enhanced Lighting	A	Residential and Commercial	Spectrally enhanced (or scotopic) lighting has optimized color temperature that improves vision even while lighting levels are reduced.	Spectrally enhanced lighting allows for installation of lamps with lower power. Flourescent and HID lamps with a CCT of more than 5000 Kelvin provide the clearest vision.	X	X		
Addressable Dimming Fluorescent Ballasts	A	Office buildings	Individually addressable dimming ballasts combined with Digital Addressable Lighting Interface (DALI) controls.	Multiple savings: daylight + occupancy control, demand response, occupant-preferred light levels, help avoid overlighting for lumen depreciation.	X	X		X
Daylighting Systems and Integrated Daylighting Controls a) Hybrid solar lighting b) Daylight harvesting and controls	M	Offices, warehouses, etc. Hybrid solar: low-rise	Daylight collection devices (tubular skylights, hybrid solar lighting, etc.) combined with daylighting controls. Lighting levels are controlled through photosensors and/or occupants via remote controls. Good potential to improve occupant comfort and performance.	Hybrid solar lighting best applied in low-rise (up to 2 floors) buildings.	X			X
CFL Adapter for Recessed Downlights	M	Residential and Commercial	Retrofit adaptor kit for conversion of 75 -200 W incandescent downlights to CFLs. Electric ballast is housed in trim ring of the fixture, allowing heat dissipation and ballast operation in high-temperature environments.	Permits downlight retrofits with CFLs by placing the ballasts in a cool zone. Passed UL and FCC approvals.	X	X		
LED Lighting for Niche Applications	S	Special, Outdoors	Current products are effective for niche applications, such as task lights, street lighting, signage, refrigerator lighting, or airport runway lighting.	Low maintenance and long life are advantages. Lumens per watt still lower than most CFLs, but ideal for directional lighting. Potential to replace CFL downlights.	X	X		
High Output T5 High Bay Lighting	S	High-bay buildings	Tubular flourescent lamps with 5/8" diameter.	The small diameter provides for good optical control and enables use in applications traditionally reserved for HID systems.	X			
HVAC								
Aerosol-Based Duct Sealing for Commercial Buildings	A	Commercial	Aerosol is blown through ducts and seals leaks from the inside.	Already relatively common in residential, but not much in commercial sector.	X			
Advanced Rooftop Air Conditioning a) Automated fault detection and diagnosis b) High-efficiency units	A	Commercial	**High-efficiency rooftop AC units:** EERs/ILPVs of 12.0/12.4 for 65-240 Mbtu/h (CEE tier 3 for unitary air conditioners) or **Automated Fault Detection and Diagnosis for Rooftop AC:** Sensors embedded in rooftop units monitor conditions at various points in cooling cycle. Communicates diagnostic info to facility manager.	The winners of a 2002 technology procurement by FEMP and DOD achieved EERs as high as 13.5 and IPLVs as high as 14.0.	X	X		X
High-Efficiency Heat Pump Systems a) Geothermal and hybrid geothermal heat pumps b) Low-temperature heat pumps	M	Residential and Commercial	**Geothermal or Hybrid-Geothermal Heat Pumps:** Can provide heating, cooling, and hot water. Efficiency up to 44% higher than air-source heat pumps. **Low Temperature Heat Pumps:** Significantly better efficiency at below 40° outdoor temperature than conventional heat pumps.	Technology-specific Super ESPC available for geothermal heat pumps.	X	X		X
Demand-Controlled Ventilation with Advanced Controls	M	High-occupancy	CO2 sensors monitor CO2 levels in the air inside a building, air-handling system uses data from sensors to regulate amount of ventilation air admitted	Best savings where occupancy is variable and unpredictable. Reliability has been greatly increased by studies (e.g. with VSAT simulation).	X			X
Air Conditioning for Climates with High or Low Sensible Heat Ratios a) Two-stage evaporative cooling b) Hybrid desiccant cooling	S	Redidential and light commercial	**Hot&Dry Climate:** Two-Stage Evaporative Cooling - Coolers that use both direct and indirect evaporative cooling; **Hot&Humid Climate:** Hybrid Desiccant Cooling Systems combine desiccant with vapor-compression cooling system	These technologies maximize cooling and dehumidification efficiency in climates with sensible heat ratios that vary stongly from the national average.	X	X		X
Thermal Destratifiers	S	High-bay buildings	Fans blow down hot air in high bay buildings to reduce thermal stratification.	Evaluated by Navy Techval to potentially reduce heating and cooling needs by up to 40 percent	X			X
Condensing Fuel-Fired Hydronic Boilers	S	Residential and Commercial	Recovery of latent heat of water produced in combustion process allows for much higher utilization of heating energy than with best available non-condensing boilers.	Requires carful system design/control if replacing a conventional with a condensing boiler.	X	X		X

Water Heating								
Heat Pump Water Heaters	**M**	Residential	Approximately 50% electricity use compared to electric resistance storage water heaters - EEF 2.0+	Condensate recovery system for cooling purposes could be added, plus reliability improvements and noise reduction.	X	X	X	X
Solar Water Heaters	**M**	Residential and Commercial	Utilization of thermal solar energy for water heating in addition to or instead of fuel-fired or electric water heaters	Lightweight polymer materials in place of glass and copper materials may increase efficiency. Technology-specific Super ESPC available.	X	X	X	X
Condensing Fuel-Fired Water Heaters	**M**	Residential and Commercial	Recovers latent heat of water produced in combustion process allows for much higher utilization of heating energy than with conventional water heaters (>20% efficiency increase).	Many products can be installed as combination space and water heating units. Efficiency can come close to 100%.	X	X	X	X
Building Envelope								
Highly Insulating Windows	**M**	Residential and small commercial	NFRC-certified whole-window U-factor of 0.25 or less. Typically involves triple-glazing or suspended film in glazing unit.	High window insulation values may eliminate need for perimeter heating.		X		X
Passive Solar Ventilation Preheating	**S**	Commercial	Collects solar heat at south-facing walls to preheat ventilation air before it enters the building. Solar heat is collected either through transpired air collectors in a perforated façade or through a glazed solar collection wall.	Makes sense in cold climate and where much ventilation is needed. Potential esthetic issues with transpired air collectors, but glazed systems less efficient due to reflectance.	X			X
Cool Roofs	**S**	Residential	Roofs with high light reflectance due to light colors or with colored materials with high infrared reflectance	For colored roofs, different materials with a reflectance of 0.25-0.60 have been developed	X	X		X
Power Generation								
Combined Heat and Power a) Microturbines b) Efficient gas-fired reciprocating engines	**M**	Commercial	Generates electricity while using the waste heat for space heating, water heating, or for space cooling with absorption refrigeration or desiccant cooling. CHP systems minimize transmission losses by providing electricity on site.	Performance is best where both electric and space conditioning needs are large and relatively similar.	X	X		X
Biomass	**S**	Commercial, industrial	Energy from plants and plant-derived materials, including wood, food crops, grassy and woody plants, residues from agriculture or forestry, the organic component of municipal and industrial wastes and even the fumes from landfills.	Technlogy-specific Super ESPC available.	X	X		
Fuel Cells	**S**	Commercial, data centers	Electrochemical devices that combine hydrogen and oxygen to produce electricity, with water and heat as its by-product	Potential for combined heat and power and back-up power for facilities with crucial supply reliability needs	X	X		
Distributed Wind Power	**S**	Outdoors	Refers to small, modular wind-power-generating technologies that can be located at or near the location where the energy is used.	Small, distributed wind turbines can be used to power remote sites.	X	X	X	
Photovoltaic Systems	**M**	Residential and Commercial	PV systems convert sunlight to electricity via solar cells.	Technlogy-specific Super ESPC and incentives (tax credits, utility incentives) available.	X	X	X	X
Sanitation								
Low-Flush (Pressure-Assisted) Toilets	**M**	Commercial	1.0 gpf pressure-assisted toilets (EPAct requirement is 1.6 gpf maximum)	Loud flush sound makes it less acceptable for residential market	X	X		X
Special								
Advanced Metering	**A**	Residential and Commercial	Advanced metering through remote read, interval meters or submetering		X	X		X
Best-in-Class Efficient Equipment	**A**	Residential and Commercial	Includes the top-performing tier of equipment in all classes.	For new or replacement equipment in a category covered by Energy Star or FEMP efficiency specifications, agencies or ESCOs would select a product from the top 1-5% most efficient models.	X	X	X	X

Emerging Technologies - Information Sources

Lighting

	Report Type	Source	Date	URL
Scotopic Lighting	Website	DOE	2007	http://www1.eere.energy.gov/femp/new_technology/techdemo_comp5.html
	2-pager	FEMP	2007	Download
	ACEEE Study (p. 134)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Field Evaluation	PNNL	2006	http://www.eere.energy.gov/buildings/info/documents/pdfs/selpies_field_eval_083006.pdf
	Economic Analysis	DOE	2006	http://www.eere.energy.gov/buildings/info/documents/pdfs/selpies_economics_validation_083006.pdf
Addressable Dimming Fluorescent Ballasts	Short report	ACEEE	2007	http://www.aceee.org/emertech/2006_LightingControls.pdf
	2-pager	FEMP	2007	Download
	Website/ detailed reports	LBNL	2004	Http://windows.lbl.gov/comm_perf/nyt_lighting-controls.html
Daylighting Systems and Integrated Daylighting Controls A) Hybrid solar lighting	Technology Focus	FEMP	2007	http://www1.eere.energy.gov/femp/pdfs/tf_hybridsolar.pdf
	ACEEE Study (p. 124)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Website	ORNL	---	http://www.ornl.gov/sci/solar/Sunlight%20Webpage/SunlightInitiative.htm
Daylighting Systems and Integrated Daylighting Controls B) Daylight harvesting and controls	Short report	DOE	2000	http://www1.eere.energy.gov/femp/pdfs/light_controls.pdf
	Website	FEMP	---	http://www1.eere.energy.gov/femp/procurement/eep_light_controls.html
	Website	Other	---	http://www.daylighting.org/
	ACEEE Study (p. 114)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
CFL Adapter for Recessed Downlights	2-pager	DOE	2001	http://www1.eere.energy.gov/inventions/pdfs/powerlux.pdf
LED Lighting for Niche Applications	2-pager	NETL	2006	http://www.netl.doe.gov/ssl/PDFs/LED-FAQ.pdf
	ACEEE Study (p. 126)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Website	NETL	2007	http://www.netl.doe.gov/ssl/
High Output T5 High Bay Lighting	Case study	FEMP	2005	http://www1.eere.energy.gov/femp/newsevents/fempfocus_article.cfm/news_id=8969
	2-pager	FEMP	2007	Download
	Web site	Natural Resources Canada	---	http://www.oee.rncan.gc.ca/industrial/equipment/high-bay/index.cfm?attr=24)
	2-pager	PG&E	2006	http://www.pge.com/docs/pdfs/biz/rebates/small_business/06HighBayFluorescent.pdf
	Case study	SMUD	2002	www.smud.org/education-safety/images-safety/cat_pdf/T5.pdf
	Short report	Other	2003	www.informinc.org/fs_P3highbay.pdf

HVAC

	Report Type	Source	Date	URL
Aerosol-Based Duct Sealing for Commercial Buildings	ACEEE Study (p. 90)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	2-pager	FEMP	2007	Download
	Field Evaluation	U.S. Navy	----	http://airius.us/pdf/d1hughes.pdf
	Website	LBNL	2003	http://epb.lbl.gov/aerosol/index.html
Advanced Rooftop Air Conditioning A) Automated fault detection	2-pager	CEC	---	http://www.esource.com/esource/getpub/public/pdf/cec/CEC-TB-10.pdf
	Field Evaluation	CEC	2003	http://energy.ca.gov/reports/2003-11-18_500-03-096-A1.PDF
	Detailed report	Other	----	http://poet.lbl.gov/diagworkshop/proceedings/braun.pdf
Advanced Rooftop Air Conditioning B) High-efficiency units	Website	FEMP	2002	http://www1.eere.energy.gov/femp/newsevents/fempfocus_article.cfm/news_id=7331
	ACEEE Study (p. 62)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
High-Efficiency Heat Pump Systems A) Geothermal or hybrid geothermal heat pumps	2-pager	FEMP	2002	http://www1.eere.energy.gov/femp/pdfs/ghp_prog_overvw.pdf
	Federal Technology Alert	FEMP	2001	http://www1.eere.energy.gov/femp/pdfs/FTA_gshp.pdf
	Technology Focus	FEMP	2004	http://www1.eere.energy.gov/femp/pdfs/ghptf.pdf
	Technology Installation Review	FEMP	2001	http://www1.eere.energy.gov/femp/pdfs/hyhgp_tir.pdf
	ACEEE Study (p. 84)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Field Evaluation	ORNL	---	http://www1.eere.energy.gov/femp/pdfs/fortpolk.pdf
	Economic Analysis	Other	---	http://www.repartners.org/tools/doc/GHPEcoAtlanta.doc
	Website	FEMP	2006	http://www1.eere.energy.gov/femp/financing/superespcs_ghpresources.html
High-Efficiency Heat Pump Systems B) Low-temperature heat pumps	ACEEE Study (p. 82)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Presentation	ACEEE	----	http://aceee.org/conf/06et/tp1-1_hadleyhallowell.pdf
Demand-Controlled Ventilation with Advanced Controls	Federal Technology Alert	FEMP	2004	http://www1.eere.energy.gov/femp/pdfs/fta_co2.pdf
	ACEEE Study (p. 102)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Field Evaluation	Other	---	http://airius.us/pdf/d1hughes.pdf
Air Conditioning for Climates with High or Low Sensible Heat Ratios A) Two-stage evaporative cooling	Technology Installation Review	FEMP	2007	http://www1.eere.energy.gov/femp/pdfs/tir_coolerado.pdf
	2-pager	CEC	2005	http://www.esource.com/esource/getpub/public/pdf/cec/CEC-TB-12.pdf
	ACEEE Study (p. 74)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf

	Report Type	Source	Date	URL
Thermal Destratifiers	Field Evaluation	U.S. Navy	2007	http://www.govenergy.com/pdfs/new_tech/Ly_NewTech_track_S1.pdf
	Field Evaluation	U.S. Navy	---	http://airius.us/pdf/d1hughes.pdf
Condensing Fuel-Fired Hydronic Boilers	Federal Technology Alert	FEMP	1998	http://www1.eere.energy.gov/femp/pdfs/FTA_Modulating-updat.pdf
	ACEEE Study (p. 106)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf

Water Heating

	Report Type	Source	Date	URL
Heat Pump Water Heaters	ACEEE Study (p. 50)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Detailed Report	EPA	2006	http://www.epa.gov/etv/pdfs/vrvs/600etv06063/600etv06063.pdf
	Federal Technology Alert	FEMP	2000	http://www1.eere.energy.gov/femp/pdfs/FTA_HPWH.pdf
	Federal Technology Alert	FEMP	1995	http://www1.eere.energy.gov/femp/pdfs/FTA_res_heat_pump.pdf
	Detailed Report	FEMP	2007	http://www1.eere.energy.gov/femp/pdfs/tir_heatpump.pdf
	Website	DOE	2005	http://www.eere.energy.gov/consumer/your_home/water_heating/index.cfm/mytopic=12840
Solar Water Heaters	Federal Technology Alert	FEMP	1998	http://www1.eere.energy.gov/femp/pdfs/FTA_solwat_heat.pdf
	Federal Technology Alert	FEMP	2000	http://www1.eere.energy.gov/femp/pdfs/FTA_para_trough.pdf
	Website	DOE	2006	www.eere.energy.gov/buildings/info/components/waterheating/solarhot.html
Condensing Fuel-Fired Water Heaters	Federal Technology Alert	FEMP	1998	http://www1.eere.energy.gov/femp/pdfs/FTA_Modulating-updat.pdf
	ACEEE Study (p. 46)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf

Building Envelope

	Report Type	Source	Date	URL
Highly Insulating Windows	ACEEE Study (p. 170)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Website	Other	---	http://www.efficientwindows.org
	Website	LBNL	---	http://windows.lbl.gov/adv_Sys/superwindows/default.htm
Passive Solar Ventilation Preheating	2-pager	NREL	2006	http://www.nrel.gov/docs/fy06osti/29913.pdf
	Federal Technology Alert	FEMP	1998	http://www1.eere.energy.gov/femp/pdfs/FTA_trans_coll.pdf
	ACEEE Study (p. 100)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Brochure	NREL	---	http://www.nrel.gov/docs/fy01osti/30176.pdf
Cool Roofs	ACEEE Study (p. 182)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	2-pager	DOE	2000	http://www1.eere.energy.gov/femp/pdfs/roof.pdf
	Website	LBNL	---	http://coolcolors.lbl.gov
	Website	DOE	---	http://www.energystar.gov/index.cfm?c=roof_prods.pr_roof_products

Power Generation

	Report Type	Source	Date	URL
Combined Heat and Power A) Microturbines	Federal Technology Alert	FEMP	2007	http://www1.eere.energy.gov/femp/pdfs/fta_microturbinechp.pdf
	Detailed Report	EPA	---	http://epa.gov/chp/documents/microturbine_tech.pdf
	ACEEE Study (p. 144)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
Combined Heat and Power B) Efficient gas-fired reciprocating engines	Technology Focus	FEMP	2000	http://www1.eere.energy.gov/femp/pdfs/chp_tf.pdf
Combined Heat and Power C) General	2-pager	FEMP	---	http://www.ornl.gov/sci/femp/pdfs/FEMP-CHP-prog-ovr-final0205.pdf
	Economic Analysis	FEMP	2002	http://www.ornl.gov/sci/femp/pdfs/chp_market_assess.pdf
	Website	DOE	---	http://www.oe.energy.gov/randd/distributed_energy.htm
	Detailed Report	EPA	2002	http://epa.gov/chp/documents/catalog_of_%20chp_tech_entire.pdf
	Website	EPA	2007	http://www.epa.gov/chp
	Website	CEC	2004	http://www.energy.ca.gov/distgen/equipment/chp/chp.html
	Website	ORNL	2007	http://www.ornl.gov/sci/femp/index.shtml#chp
Biomass	Federal Technology Alert	FEMP	2004	http://www1.eere.energy.gov/femp/pdfs/fta_biomass_cofiring.pdf
	Detailed Report	EPA	2007	http://epa.gov/chp/documents/biomass_chp_catalog.pdf
Fuel Cells	Federal Technology Alert	FEMP	1995	http://www1.eere.energy.gov/femp/pdfs/FTA_natgas_fuelcell.pdf
	Technology Installation Review	FEMP	2005	http://www1.eere.energy.gov/femp/pdfs/fuelcell_tir.pdf
	Detailed Report	EPA	---	http://epa.gov/chp/documents/fuelcells.pdf
	ACEEE Study (p. 144)	ACEEE	2004	http://www.aceee.org/pubs/a042full.pdf
	Presentation	ORNL	2003	www.ornl.gov/femp/pdfs/020501-Hughes-fuelcell-WashingtonDC.pdf
Distributed Wind Power	2-pager	FEMP	1996	http://www1.eere.energy.gov/femp/pdfs/21265.pdf
	Technology Focus	NREL	1997	http://www1.eere.energy.gov/femp/pdfs/WindTF.pdf
Photovoltaic Systems	Federal Technology Alert	NREL	1998	http://www1.eere.energy.gov/femp/pdfs/FTA_pv.pdf
	Technology Focus	FEMP	2005	http://www1.eere.energy.gov/femp/pdfs/pv_techfocus.pdf
	Website	FEMP	2007	http://www1.eere.energy.gov/femp/renewable_energy/renewable_solar.html

Sanitation

	Report Type	Source	Date	URL
Low-Flush (Pressure-Assisted) Toilets	Federal Technology Alert	FEMP	—	http://www1.eere.energy.gov/femp/pdfs/22799.pdf
	Website	FEMP	---	http://www1.eere.energy.gov/femp/water/water_bmp4.html
	Detailed Report	PNNL	2005	http://www.pnl.gov/main/publications/external/technical_reports/PNNL-15320.pdf

Special

	Report Type	Source	Date	URL
Advanced Metering	Detailed Report	FEMP	2006	http://www1.eere.energy.gov/femp/pdfs/adv_metering.pdf
	Presentation	ORNL	2007	http://www.govenergy.com/pdfs/metering/Sharp_Meteringtrack_S4.pdf
Best-in-Class Efficient Equipment	Website	DOE	-	http://www.energystar.gov/products
	2-pager	FEMP	2007	Download
	Website	FEMP	2007	http://www1.eere.energy.gov/femp/procurement/