Emerging Technologies for Energy Savings Performance Contracting in the Federal Sector

A report by the Alliance to Save Energy to the US DOE Federal Energy Management Program

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Overview

This document identifies an initial group of energy-saving emerging technologies (ETs) recommended for use in federal facilities, with an emphasis on technologies suitable for retrofit applications financed through Energy Savings Performance Contracts (ESPCs) and Utility Energy Service Contracts (UESCs) as well as other mechanisms.

NOTE: These technology recommendations are preliminary in nature and will further evolve based on feedback from federal facility energy managers and other agency officials, researchers at DOE national laboratories, and energy service companies (ESCOs).

The goal of these evolving recommendations is to provide guidance for DOE, other federal agencies, ESCOs and utility companies in using emerging technologies to uncover new potential for energy savings in the federal sector, while also helping to identify and reduce barriers to wider use of energy-efficient ETs both within and outside the federal sector. This report is accompanied by information for ESCOs and federal agencies to use in ESPC and UESC projects, including a list of emerging technologies recommended for ESPC use and a compilation of resources on these technologies.

While the initial list includes only hardware technologies, energy-saving *practices* should also be considered as ETs suitable for early adoption in federal facilities. In fact, FEMP and federal agencies have in the past played an important role in helping to introduce and commercialize important practices such as building commissioning, standard protocols for energy savings measurement and verification (M&V), advanced metering, and ESPCs themselves.

Finally, we recommend that any list of emerging technologies for federal use provide an option for project managers to add their own "site-specific ET," based on special opportunities identified for that project, but potentially applicable to other federal and non-federal facilities. Such site-specific ETs should meet the criteria described below.

This document should be read in conjunction with other recent reports by the Federal Energy Management Program and by Lawrence Berkeley National Laboratory (LBNL):

- "A Federal Initiative for Deployment of Emerging Technologies"
- A draft Action Plan titled "Deploying Emerging Technologies in ESPC Projects"
- "Case Studies in New and Emerging Technology Implementation via Super-ESPC"

Policy Background

The need for ETs to help agencies achieve "deeper" energy savings from their ESPC and UESC projects (among others) derives from two important policy goals for federal energy management: achieving aggressive savings targets over the next decade and beyond, and serving as a model and a market leader in energy efficiency.

Energy savings goals - The Energy Policy Act of 2005 directs federal agencies to reduce energy intensity in their facilities by 2 % per year from 2006 through 2015. In early 2007 this goal was increased to 3% annually (30% by 2015) by Executive Order 13423 on "Strengthening Federal Environmental, Energy, and Transportation Management." This new goal represents an acceleration of the historical rate of federal 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.

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. And DOE itself is a natural candidate to model these initiatives and set an example for other federal agencies.

ESPCs, UESCs, and Energy-Efficient Emerging 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 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 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). *The ESPC contract can include specific requirements set by the agency, such as the use of emerging technologies as part of the energy saving measures.*

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 emerging technologies would most likely be eligible for UESC financing, as long as the agency is willing to assume the performance risk and to repay the utility investment. In some cases (e.g., in California), regulatory agencies have directed utilities to help accelerate market introduction of energy-saving emerging technologies, so there may be a natural partnership with the federal commitment to ET.

Other Implementation Mechanisms

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

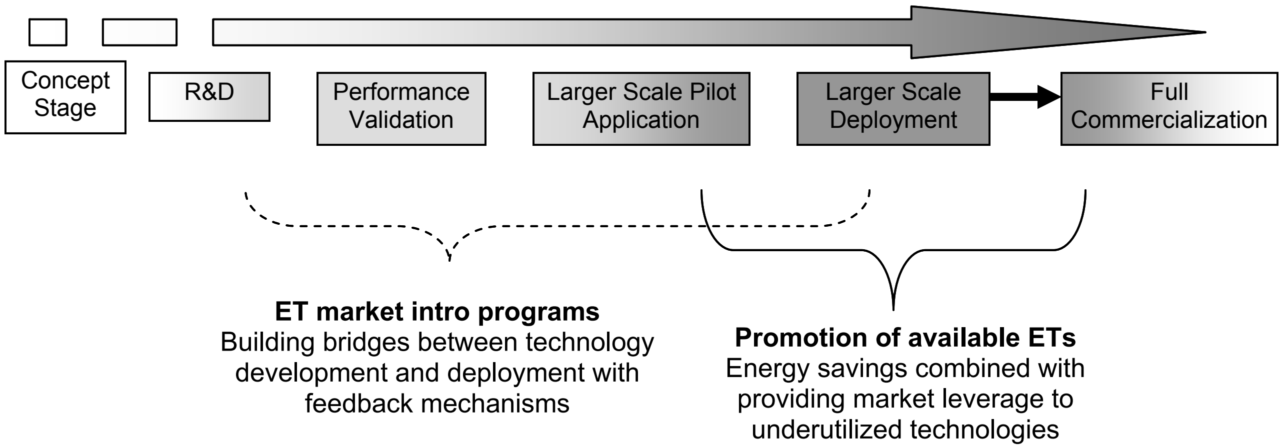
- **Technology procurement**
  Federal procurement of energy-relevant technologies is generally guided by FEMP guidelines for energy-efficient procurement. In specific cases, federal procurement can more specifically aim for emerging technologies instead of more common energy efficient technology options. Procurement of emerging technologies may be a viable option for some applications in the federal sector while it may not be as viable for others. It is therefore best to take a specific look at the potential for emerging technology procurement in different agencies.

- **Utility rebates**
  Financing for the procurement of emerging technologies could be supported by utilities that are subject to regulatory requirements to support the market for emerging technologies. These utilities could have an interest in offering rebates to federal procurement of technologies that fall under the regulation's definition of emerging technologies. An interactive map of states showing which ones offer utility rebate programs is shown on the FEMP utility management website.

- **Voluntary Programs, Codes and Standards**
  Larger-scale deployment of emerging 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.

Initial Technology Selection

The recommended technologies were selected from a wide range of emerging technologies, many of which have been developed, demonstrated, or supported by DOE, other federal agencies, state programs, or utility companies. Only technologies that are commercially available and proven, though underutilized, have been included in this report and the accompanying guidance. This is due to FEMP's objective of promoting available technologies that can provide near-term savings – as opposed to other DOE programs designed to help introduce pre-commercial technologies to the market. As a result, the technologies considered in this document are at the more advanced end of the spectrum of emerging technologies, shown in this schematic diagram:



Initial research to establish a list of applicable emerging technologies was based on a review of previous work by Andrew Nicholls of Pacific Northwest National Laboratory (PNNL), who had assessed the applicability of 86 EERE-supported emerging technologies to Federal facilities as well as on review of a screening study of "Energy Efficiency and Renewable Energy Technology for the Federal Sector" by H.E. Dillon, K.L. Gordon and J.B. Hollomon of PNNL (Dillon et al. 2004). Technology installation reviews and technical assessments by FEMP and the New Technology Installation Program (NTDP) were another major source of information. Other sources for emerging technologies listings and information used for the selection included the following:

- Federal Energy Management Program – *New Technologies* http://www1.eere.energy.gov/femp/new_technology/index.html
- Lawrence Berkeley National Laboratory http://www.lbl.gov/Tech-Transfer/techs/index.html#Energy
- National Renewable Energy Laboratory http://www.nrel.gov/buildings/technology_research.html
- Oak Ridge National Laboratory http://www.ornl.gov/sci/eere/buildings/emerging.htm
- Pacific Northwest National Laboratory http://eere.pnl.gov/building-technologies/emerging_tech.stm
- American Council for an Energy Efficient Economy http://www.aceee.org
- Emerging Technologies Coordinating Council http://www.etcc-ca.com
- Bonneville Power Administration – *Energy Efficiency Technology Roadmap* http://www.bpa.gov/corporate/business/innovation/docs/2006/RM-06_EnergyEfficiency-Final.pdf
- US Environmental Protection Agency – Environmental Technology Verification Program

Technology Evaluation Criteria

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.

The following criteria were used as a guideline for evaluating technologies that will help meet these objectives. Additional or revised criteria may arise in the future, as FEMP and federal agencies consider additional emerging technologies to add to the list.

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)?
2. **Federal sector savings potential**
   - How does the technology promise to meet the energy and non-energy needs of federal facilities?
3. **U.S. economy savings potential**
   - What is the technology's applicability and energy savings potential outside the federal sector?
4. **Cost-effectiveness**
   - What is the technologies cost-effectiveess taking into account both its present and expected future cost and performance?
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 following pages show how the technologies under consideration have been evaluated according to these criteria, to assess their potential and the ways in which federal agencies could these emerging technologies to achieve greater energy savings, both in their construction or retrofit projects and in day-to-day operations..

1. Federal market leverage

- *Is the technology commercially available but not yet well established in the market?*
- *How big a difference can the federal government make in improving the technology's market perspective?*
- *Is the technology at a juncture in its market development where federal support can free the way ahead?*

High

▲ Federal support can remove a significant hurdle to the technology's market success or push it past a threshold beyond which its full market potential can unfold.

Medium

▶ Federal promotion alone is unlikely to achieve a breakthrough for the technology, but can significantly accelerate market acceptance or provide the technology with a better point of market entry.

Low

▼ Either the technology's market success is growing at such a rate that federal promotion can only provide limited additional leverage, or it faces market hurdles that are unlikely to be completely overcome by federal support. *Note: a "low" rating for market leverage does not mean that the ET should not be considered for use, where applicable, in federal projects.*

2. Federal sector savings potential

What is the potential for energy savings in the federal sector through application of the technology by 2015?

The time frame for estimating the potential of an emerging technology would usually be longer, but the year 2015 is our initial focus since the federal sector is striving to achieve a 30 percent reduction in energy intensity by that year.

High

▲ High savings potential in the federal sector by 2015. The potential for savings in the federal sector is the product of the applicability of a technology times the savings potential per unit.

Medium

▶ Medium savings potential in the federal sector by 2015.

Low

▼ Low savings potential in the federal sector by 2015. Even where the energy savings potential within the federal sector is low, federal promotion of the technology may still be worth considering if federal market leverage could potentially open the way for substantial savings for the U.S. economy as a whole.

Emerging technologies which are not yet commercially available, not applicable to the federal sector, or beyond the status of an emerging technology have not been taken into consideration.

3. U.S. economy savings potential

What savings potential can be expected by 2020 if promotion of the technology in the federal sector leads to widespread application in the U.S. economy as a whole?

The time frame for the non-federal savings potential is longer than that for federal sector savings to take into account the time lag for spillover beyond the federal sector. Where available, the economy-wide savings potential for specific technologies was taken from ACEEE estimates of savings by 2020 (Sachs et al. 2004).

High

▲ Savings potential economywide is rated as high where the ACEEE study estimates savings from a technology to be at least 0.5 percent of projected U.S. building energy use by 2020 (more than 230 TBtu). Where ACEEE estimates are not available, the estimated savings potential is the product of the technology's applicability and the estimated savings per application.

Medium

► Savings potential is rated as medium where the ACEEE study estimates savings to be at least 0.2 percent of projected U.S. building energy use by 2020 (more than 95 TBtu). As above, where ACEEE assumptions are not available, the estimated savings potential is the product of applicability and estimated savings per application.

Low

▼ Savings potential is rated as low where the ACEEE study estimates savings at less than 0.2 percent of projected U.S. building energy use by 2020 (less than 95 TBtu).

4. Cost-effectiveness

How cost-effective is the use of the technology over its average useful life?

The cost of saved energy can be established by dividing the technology's cost by the amount of energy it is expected to save over its lifetime and assuming a 5 percent annual discount rate. ACEEE (Sachs et al. 2004) has done this assessment for several technologies.

High

▲ The technology's cost of saved energy is less than half the average cost of purchased energy (at today's average energy prices). In general, this means the cost of saved energy is about $0.04 per kWh or less.

Medium

▶ The cost of energy saved through the technology is less than the average cost of purchased energy. In general, this means the cost of saved energy is about $0.08 per kWh or less.

Low

▼ The cost of saved energy for the technology is more than the average cost of purchased (again, at today's prices). In general, this means the cost of saved energy is more than $0.08 per kWh.

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 emerging 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 applications such as communications or data centers requiring very high reliability.

5. Retrofit applicability

Can the technology easily be applied as a retrofit to existing buildings?

The retrofit applicability of the technology is an important factor determining its potential in the federal sector. Existing buildings offer the greatest opportunities for near-term energy savings. Retrofit applicability also determines whether a technology is suited for third-party financed energy performance improvements.

High

▲ The technology can easily be applied to existing facilities without more than minor disruption of the facilities' operating system.

Medium

▶ The technology can be applied to existing facilities without major disruption of the facilities' operating system. However, some system modifications may be required.

Low

▼ Cost-effective retrofit applications of the technology are difficult. It may require major changes in a facility's operating system or substantial renovations.

Technologies that do not offer themselves for retrofit application but have a substantial savings potential may be worth considering for inclusion in new construction programs.

List of Technologies Recommended for Consideration

The following is a preliminary list of commercially available technologies that show substantial potential in at least most of the above-mentioned criteria. All of these technologies are still emerging in terms of market penetration and could therefore benefit from more widespread application in the federal sector.

1. Lighting

1.1 Scotopic lighting
1.2 Addressable dimming fluorescent ballasts
1.3 Daylighting systems and integrated daylighting controls
1.4 CFL adaptor for recessed downlights
1.5 LED lighting for niche applications
1.6 High-output T5 high bay lighting

2. HVAC

2.1 Aerosol-based duct sealing for commercial buildings
2.2 Advanced rooftop air conditioning
2.3 High-efficiency heat pump systems
2.4 Demand-controlled ventilation with advanced controls
2.5 Air conditioning for climates with high or low sensible heat ratios
2.6 Thermal destratifiers
2.7 Condensing fuel-fired hydronic boilers

3. Water Heating

3.1 Heat pump water heaters
3.2 Solar water heaters
3.3 Condensing fuel-fired water heaters

4. Building Envelope

4.1 Highly insulating windows
4.2 Passive solar ventilation preheating
4.2 Cool roofs

5. Power Generation

5.1 Combined heat and power
5.2 Biomass
5.3 Fuel Cells
5.4 Distributed Wind Power
5.5 Photovoltaic systems

6. Sanitation

6.1 Low-flush (pressure-assisted) toilets

7. Special

7.1 Advanced metering
7.2 Best-in-class efficient equipment

Technology Evaluations

1 Lighting

1.1 Scotopic Lighting

Scotopic lighting takes advantage of the fact that for most people, vision is improved by scotopically enhanced illumination with high correlated color temperature (CCT), even if lighting levels are reduced. Scotopic 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. Scotopic light 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**
Federal promotion can help increase the experience of professional lighting designers and contractors with scotopic lighting. If early adoption by the federal government helped the technology achieve recognition by the Illuminating Engineering Society, it could find wide acceptance in the mainstream market.

▲ **Federal sector savings potential**
As a commercial sector practice, scotopic lighting has a particularly high potential in the federal sector.

► **U.S. economy savings potential**
We estimate savings averaging 20% of lighting energy where fluorescent lighting is used in applications such as offices, schools, and light-assembly. This translates to 158 TBtu annual savings by 2020 if used for 50% of lighting in classrooms, healthcare and offices (Sachs et al. 2004). A DOE-funded study estimates the technical potential for energy savings to be 0.4 quad (Hong et al. 2005).

▲ **Cost-effectiveness**
ACEEE assumes no additional cost for using spectrally enhanced lighting instead of conventional lighting (Sachs et al. 2004).

▲ **Retrofit applicability**
Lamps with high correlated color temperature for scotopic lighting can easily be installed to replace conventional lighting, but to achieve energy savings either the power and light out must be reduced or the number of lamps must be reduced.

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**
The technology is currently at a transition point from where it could advance to become standard practice in the market. Federal support could help give addressable dimming ballasts the extra push needed to advance past this point, along with improved standardization and reliability of control systems and more training and experience on the part of lighting designers and installers.

▲ **Federal sector savings potential**
As a commercial sector technology, addressable dimming fluorescent ballasts have a particularly high potential in the federal sector. 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**
A 1997 study showed that given the capability to set lighting levels according to their preferences, office occupants on average reduced lighting levels by about 25 percent (Embrechts and Bellegem 2004). Following the logic for energy savings achievable with scotopic lighting (see above) we estimate a medium savings potential for the U.S. economy.

► **Cost-effectiveness**
Assuming a $45 incremental cost for dimming fluorescent ballasts over static ballasts (Lee and Selkowitz 2005) and lighting savings of more than 25 percent compared to conventional ballasts for T8 lamps, the cost of saved energy is estimated to be below $0.08 per kWh in applications with about 2500 hours or more of lighting annually.

▲ **Retrofit applicability**
The technology can be retrofitted in relatively short time without major difficulties. Wireless ballast communications may be more practical in many cases than providing Ethernet or similar wiring to each fixture.

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**
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. The performance risks associated with daylighting systems and controls are often due to inexperienced lighting designers or contractors, or the absence of common protocols for communications and control; Thus, federal leadership can be particularly valuable a broader market base and consistent specifications.

▲ **Federal sector savings potential**
Low-rise commercial buildings with good savings potential from daylighting

constitute a substantial share of the federal building stock.

▲ **U.S. economy savings potential**
Assumed to save an average 50% of lighting compared to conventional lighting with T8 lamps. "Hybrid" solar lighting, a concept that combines a trackable rooftop collector, fiber-optics, and dual (solar and electric) light fixtures, is estimated to save 270 TBtu annually by 2020 if used in 1/3 of low-rise commercial buildings (Sachs et al. 2004).

► **Cost-effectiveness**
The cost of daylighting systems with integrated daylighting controls ranges widely, depending on the technology. Systems that integrate daylight controls with simple skylights or light-tubes and diffusers can be cost-effective at today's electricity prices. At present, the cost of "hybrid solar lighting systems" is high compared with simpler lighting retrofits. ACEEE estimates the cost of saved energy for hybrid solar lighting to be $0.265 per kWh (Sachs et al. 2004).

► **Retrofit applicability**
Daylighting systems can be retrofitted but effective daylighting systems are easier to achieve in new construction than in existing buildings that are not designed for daylighting.

1.4 CFL Adaptor for Recessed Downlights

Retrofit adaptor kits can convert 75-200 W incandescent downlights to allow 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**
Through large scale purchases, the federal government can significantly stimulate the market for the technology.

► **Federal sector savings potential**
The demand for upgrades of recessed downlights to compact fluorescent lighting is assumed to be lower in the federal sector than in the economy as a whole, since 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**
Assuming the conversion of 25 percent of the currently ~200 million recessed downlights, the technology could save about 300 TBtu annually (OIT 2001), which is about 0.64 percent of expected building energy use by 2020.

▲ **Cost-effectiveness**
An adapter for replacing a 150 Watt incandescent downlight with a 32 Watt CFL light costs about $115 (www.powerlux.com). Annual savings can be assumed to be about 600 kWh in commercial applications (OIT 2001), or $50-60/year cost savings for a payback slightly over 2 years.

▲ **Retrofit applicability**
The technology is designed for retrofit application and is easily installed.

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**
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**
Until at least 2015, substantial energy savings are not expected. The application of LED lighting can be very beneficial in certain cases due to the technology's long lifetime and reduced maintenance needs, but these will remain niche applications in the near term.

► **U.S. economy savings potential**
Starting around 2020, the savings potential expected to grow more rapidly as the technology matures. ACEEE assumes a 176 TBtu savings potential in the commercial sector and a 229 TBtu savings potential in the residential sector by 2020 (Sachs et al. 2004).

► **Cost-effectiveness**
Assuming a significant cost reduction from 2005 to 2010, ACEEE estimates the cost of saved energy from commercial LED applications to be $0.03/kWh (Sachs et al. 2004). This assumption takes into account the reduced lamp replacement cost due to longer LED lifetime. However, technology performance and costs will likely limit cost-effectiveness for the near future.

▲ **Retrofit applicability**
The technology can easily be retrofitted.

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**
Even without federal promotion, demand for the technology is increasing.

► **Federal sector savings potential**
The savings potential is high in any high-bay space, such as maintenance workshops, warehouses, and large retail buildings.

► **U.S. economy savings potential**
The savings potential is high in any high-bay space, such as maintenance workshops, warehouses, and large retail buildings.

▲ **Cost-effectiveness**
Case studies found the technology to be highly cost effective (e.g. Camp Pendleton: http://www1.eere.energy.gov/femp/news/news_detail.html?news_id=8304).

▲ **Retrofit applicability**
The technology can be readily retrofitted.

2 HVAC

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.

► **Federal market leverage**
While aerosol duct sealing is becoming established in smaller residential buildings, 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
▲ The savings potential in the federal sector is estimated to be high, as in the economy as a whole. The technology has been demonstrated in U.S. Navy facilities, where over 95 percent of leaks in the ductwork were sealed.

U.S. economy savings potential
▲ Energy savings are reported to be around 5-10 percent of heating and cooling energy in residences, where ACEEE estimates savings of 551 TBtu annually by 2020 if used in the top half of the nation's users of central heating and cooling systems (Sachs et al. 2004). There are no estimates for national savings in non-residential buildings, but the potential is likely to be large.

▲ **Cost-effectiveness**
ACEEE estimates the cost of saved energy from commercial duct sealing applications to be $0.025 or $2.47/MMBtu (Sachs et al. 2004).

▲ **Retrofit applicability**
The technology is most useful in the existing building stock, where manual duct sealing is much more difficult to implement compared with new construction.

2.2 Advanced Rooftop Air Conditioning

Automated fault detection and diagnosis 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**
Wider application of the highest efficiency tier established by CEE will help accelerate the market for high-efficiency equipment. If more leverage is intended from federal application of high-efficiency rooftop ACs, even higher levels of performance should be specified (EER around 14.0 – see measure 7.2, below).

Federal sector savings potential

Due to the large percentage of federal buildings with rooftop AC,[1] 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

High-efficiency rooftop AC is estimated to save 81 TBtu annually by 2020 in the residential sector if they account by then for 70 percent of installed units (Sachs et al. 2004). If this is accompanied by the installation of automated fault detection and diagnosis tools, the savings potential can be up to twice as high.

Cost-effectiveness

ACEEE estimates the cost of saved energy from advanced rooftop air conditioners to be $0.036 (Sachs et al. 2004). Automated fault detection and diagnosis, which in California applications is estimated to have a simple payback period of less than 1 year, is even more cost-effective and can facilitate maintenance and prolong equipment lifetime (Smith and Braun 2003).

Retrofit applicability

Rooftop air conditioning units require relatively frequent replacement. Fault detection and diagnosis (FDD) systems can also be applied as a retrofit to existing rooftop air conditioners.

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

Geothermal (or ground-coupled) heat pumps are a proven and widely available though underutilized technology that FEMP is promoting through a technology-specific Super ESPC for geothermal heat pumps (FEMP 2002). 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

Geothermal and hybrid-geothermal heat pumps[2] typically save 15-25 percent of total building energy use in nonresidential buildings (FEMP 2002). Through FEMP's Super ESPC program and additional efforts, a substantial percentage of the federal building stock can potentially be supplied with the technology. Nonetheless, geologically favorable locations are limited. Before 2015, the market for low-temperature heat pumps might not have matured enough for large-scale application.

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

[2] 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.

U.S. economy savings potential

► Without additional promotion of geothermal heat pumps, the non-federal market for this technology may be expected to grow only slowly. Once low-temperature heat pumps become more commonly available and reliable, they may bring substantial savings in parts of the country; ACEEE estimates 173 TBtu annual savings by 2020 (Sachs et al. 2004).

► **Cost-effectiveness**
Geothermal heat pumps can theoretically provide heat, cooling and hot water much more cost-effectively than competing technologies; low-temperature heat pumps are expected to become much more affordable. In reality, however, the cost-effectiveness of geothermal heat pumps depends strongly on the site while low-temperature heat pumps are still expensive, best suited to cooler climates, and in the early market stage.

► **Retrofit applicability**
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.

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

► **Federal market leverage**
The technology has been widely available for years and has a proven track record of performance. Therefore, most barriers to its cost-effective use have disappeared. However, considering the potential of widespread application, the technology is still underutilized. 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**
The technology offers the highest potential if applied in high-occupancy buildings such as office buildings, auditoriums, schools, and sports centers. If vigorously applied in federal facilities, the technology offers a substantial savings potential.

U.S. economy savings potential

► Assumed to save an average 13% of ventilation energy in high-use commercial buildings, the technology is estimated to save 163 TBtu annually by 2020 if used in 90 percent of buildings with large cooling and ventilation needs (Sachs et al. 2004).

▲ **Cost-effectiveness**
The technology has the most energy savings potential in buildings where occupancy fluctuates during a 24-hour period, is unpredictable, and peaks at a high level. A case study of CO_2 sensors installed in a 30 story office building assessed a 3-year simple payback for the installation of a $178,800 system (FEMP 2004).

► **Retrofit applicability**
The technology can be retrofitted and combined with existing HVAC systems. Industry literature states that the technology works best with constant volume or variable air volume systems.

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**
New, efficient two-stage evaporative and hybrid desiccant cooling systems have recently become commercially available. Application of these technologies is climate specific and some of these technologies are for the residential and small commercial sector only. Yet the performance of new technologies that recently entered the market can be validated through federal application.

▼ **Federal sector savings potential**
Applicability in the federal sector is moderate due to the climate-specific applicability of the technology and the limited applicability of evaporative cooling in larger non-residential buildings. Nevertheless, regional savings in small commercial and residential buildings can be substantial.

► **U.S. economy savings potential**
Although ACEEE estimates savings of only 37 TBtu annually by 2020 from the active desiccant Cromer Cycle technology (Sachs et al. 2004), U.S. DOE estimates around 60 TBtu from 10 percent market penetration in hot, humid climates (U.S. DOE 2001b). In addition, there is a sizeable savings potential from residential application of two-stage evaporative cooling in hot, dry climates.

▲ **Cost-effectiveness**
ACEEE estimates the cost of saved energy from combined desiccant cooling systems to be between $0.031 and $0.069 per kWh (Sachs et al. 2004). According to PIER, two-stage evaporative cooling is cost-competitive with conventional air conditioning and can bring immediate payback in hot and dry climates (PIER 2005).

► **Retrofit applicability**
These technologies can be retrofitted. Adjustments in the building's HVAC system will be necessary if dehumidification technologies or evaporative cooling have not previously been used. Rooftop space and structural support to install additional HVAC components can be a constraint in some cases.

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**
Demonstration projects for thermal destratifiers have recently been undertaken and evaluated by the U.S. Navy's Techval program. The commercialization of the technology is very much dependent on initial federal promotion to attain more demonstration results and familiarity with the technology.

► **Federal sector savings potential**
Applicability in the federal sector is moderate due to the limited number of buildings where the technology has high potential. In high-ceiling buildings such as airport hangars and other DoD facilities, however, savings can be up to 40 percent of heating and cooling energy.

▼ **U.S. economy savings potential**
Considering the technology's and limited applicability, economy-wide savings are assumed to be relatively low. Nonetheless, considerable potential for energy savings and comfort improvement exists in cold-climate high-bay buildings.

► **Cost-effectiveness**
The results of Techval case studies ranged from a simple payback in less than 7 years to applications where the technology used more energy than it saved (Ly 2007). The latter case, however, was due to lack of experience with the technology. As experience with the technology grows, cost-effectiveness is assumed to be moderate to high if the technology is applied in worthwhile locations.

▲ **Retrofit applicability**
The technology can easily be added to existing buildings that meet the conditions listed above.

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**
The federal building stock is estimated to include about 100,000 buildings with boilers, offering an annual retrofit potential of 3,000 units, in addition to new construction to be equipped with boilers (Consortium for Energy Efficiency 2001). 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**
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**
Outside the federal sector, there are only a moderate number of potential applications for the technology. Schools and apartment buildings offer themselves as opportunities for savings with condensing boilers. ACEEE estimates savings of only 23 TBtu annually by 2020 from the technology (Sachs et al. 2004).

▲ **Cost-effectiveness**
ACEEE estimates the cost of saved energy from condensing boilers to be $0.01 per kWh (Sachs et al. 2004).

► **Retrofit applicability**
The technology can be retrofitted. However, 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 Water Heating

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 first cost, along with performance and reliability problems with early models, especially for residential use, have prevented any 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**
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. The market barriers are high first cost, low production volume, and more complicated installation. A stable federal market, in military family housing and other smaller buildings, could provide manufacturers with the certainty needed to scale up manufacturing, offer more product choice, increase installers' familiarity with the product, and thus help lower costs.

▼ **Federal sector savings potential**
Applicability in the Federal sector is limited since electric water heating is far less common in commercial than in residential buildings.

► **U.S. economy savings potential**
Heat pump water heaters are estimated to save 158 TBtu annually by 2020 in the residential sector if 30% of electric storage water heaters are replaced (Sachs et al. 2004). Commercial sector potential is negligible.

▲ **Cost-effectiveness**
ACEEE estimates the cost of saved energy with residential heat pump water heaters to be $0.02 per kWh with a simple payback period of 4 years (Sachs et al. 2004).

▲ **Retrofit applicability**
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).

3.2 Solar Water Heaters

Solar heat that is absorbed by a rooftop solar collector is either directly picked up by the potable water as it flows through tubes attached to the absorber or is transferred by a heat transfer fluid that is pumped from the absorber through a heat exchanger to heat the potable water. Supplemental or back-up water heating is often provided by a fuel-fired or electric water heater.

► **Federal market leverage**
The federal government and some state governments already promote solar water heaters through tax incentives, which stimulate the market. Production volumes, supply chain familiarity, and thus the competitiveness of the technology can be further increased through widespread application in the federal sector.

► **Federal sector savings potential**
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. However, solar water heating has to compete against other new, more efficient gas and electric water heating technologies such as tankless or condensing units and heat pump water heaters.

► **U.S. economy savings potential**
If solar water heating multiplies its market share, savings can be huge. However, unless energy prices increase significantly, competition from gas and electric water heaters is likely to remain strong.

► **Cost-effectiveness**
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**
Solar water heaters can be added to many existing buildings without major adjustments, provided there is rooftop (or sometimes ground-level) space with good solar exposure.

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**
ACEEE describes residential condensing water heaters as a good candidate for promotion through FEMP, which would increase customer awareness even in the absence of a ENERGY STAR water heating program (Sachs et al. 2004).[3] However, since thousands of condensing water heaters have already been installed for commercial applications, federal leadership would provide somewhat less market leverage in this sector.

► **Federal sector savings potential**
Some commercial condensing water heaters have been installed in federal government facilities since the early 1990s, but a substantial potential remains (FEMP

[3] The ENERGY STAR program at DOE is currently considering a specification for heat pump water heaters, along with solar and tankless systems.

1998). Federal prisons, hospitals, and barracks are examples of facilities where the technology can provide substantial savings. In other federal facilities with lower demand for hot water, the savings potential is moderate.

▲ **U.S. economy savings potential**
On the residential side alone, the technology has an estimated potential to save 217 TBtu annually by 2020 by displacing 70% of gas storage water heaters (Sachs et al. 2004). Larger, commercial condensing water heaters provide additional potential.

► **Cost-effectiveness**
ACEEE estimates the cost of saved energy with residential condensing water heaters to be $6.39 per MMBtu of saved energy (Sachs et al. 2004). This translates into less than $0.08 per delivered kWh.

▲ **Retrofit applicability**
The technology is appropriate for most retrofit applications.

4. Building Envelope

4.1 Highly Insulating Windows

Highly-insulating windows with a substantially better insulating performance (a substantially lower U-factor) than commonly available products include windows with the combined performance of three glazing layers, low-E coatings, gas fills, well-insulated frames, and low-conductance spacers between the glass layers. Such products achieve U-factors of 0.25 or lower, and potentially as low as 0.15.

▲ **Federal market leverage**
Highly-insulating windows with a U-factor of 0.25 or less have been available since the 1980s. Yet high initial cost has prevented the technology from achieving economies of scale. Manufacturers instead are mostly concentrating their efforts on meeting building code and ENERGY STAR specifications (U-factor 0.35 in the north). Federal procurement could tip the scale by providing manufacturers with a significant incentive to add production capacity for highly-insulating windows.

▼ **Federal sector savings potential**
In the federal sector, highly-insulating windows are most applicable to new construction or major renovation of buildings with punched window openings such as DoD barracks, military family housing, medical facilities, or school buildings.

► **U.S. economy savings potential**
The technology has an estimated potential to save 144 TBtu annually by 2020 if applied in homes in climates with over 5500 heating degree days (Sachs et al. 2004).

► **Cost-effectiveness**
ACEEE estimates the cost of saved energy with highly-insulating windows to be $0.03 per kWh of saved energy (Sachs et al. 2004). This high cost-effectiveness assumption is based on window prices in a more mature, higher-volume market for the technology.

► **Retrofit applicability**
Upgrading to highly-insulating windows are a good option if old windows in cold climates need to be replaced. If the existing windows do not need replacement, it is not usually cost-effective to install highly insulating windows.

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**
The technology is still uncommon enough, and the application potential in the federal sector large enough, that larger-scale federal application can provide a significant

market pull by establishing an entry market, demonstrating results, and increasing familiarity with the technology.

▼ **Federal sector savings potential**
Building walls without windows, such as aircraft hangars or warehouses, are good opportunities for application of the technology. Due to the need for wall space and aesthetic concerns, typical office façades are less suitable. The technology is limited to climates with heating demands.

▼ **U.S. economy savings potential**
The technology has an estimated potential to save 9 TBtu annually by 2020 (Sachs et al. 2004). Most of this potential lies in the industrial sector (manufacturing facilities and warehouses), where aesthetic concerns are less important and window areas limited.

▲ **Cost-effectiveness**
ACEEE estimates the cost of saved energy with highly-insulating windows to be $2.41 per MMBtu of saved heating energy (Sachs et al. 2004), in addition to prolonging the life of aging external surface materials such as brick or stucco (Sachs et al.). Transpired air collectors are more efficient than glazed solar walls due to higher absorptance and lower reflectance of solar heat.

► **Retrofit applicability**
The technology can be applied to existing buildings but might require adjustments in the HVAC control system.

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**
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**
Cool roofs provide a 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**
ACEEE estimates the savings potential of residential cool colored roofs to be 144 TBtu by 2020 (Sachs et al. 2004). The savings potential in the commercial building sector, where cooling demand is higher, is likely to be even greater.

▲ **Cost-effectiveness**
ACEEE estimates the cost of saved energy with cool colored roofs to be $0.04 per kWh of saved energy (Sachs et al. 2004). The cost-effectiveness of would be even higher

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**
Cool roofs are most economical if installed at time of a planned re-roofing.

5. Power Generation

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**
The nationwide potential for CHP is great but underdeveloped. Dedicated federal promotion can potentially achieve a breakthrough for the technology. FEMP is placing a technology-specific emphasis on CHP systems, although no Super ESPC is currently planned specifically targeted to these technologies.

▲ **Federal sector savings potential**
The savings potential in the federal sector is at least equal to the potential across the U.S. economy. 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**
ACEEE estimates the savings potential of micro-CHP for commercial buildings alone to be 692 TBtu by 2020 (Sachs et al. 2004). In addition, there is a large savings potential from larger-scale CHP at a campus level, and perhaps for even smaller-scale CHP for multifamily and other residential buildings.

► **Cost-effectiveness**
ACEEE estimates the cost of saved energy with commercial micro-CHP using micro-turbines to be $0.05 per kWh of saved energy (Sachs et al. 2004). Presently, microturbines have not yet achieved this level of cost-effectiveness, but the cost-effectiveness of larger reciprocating engines is more favorable.

► **Retrofit applicability**
Combined heat and power can be added to existing facilities. Utilization of the technology's potential requires integration into the facility's heating and cooling system.

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**
FEMP is offering a Technology-Specific Super ESPC for Biomass and Alternative Methane Fuels.

► **Federal sector savings potential**
Biomass can be applied for co-firing coal-fired boilers at federal facilities. The best opportunities for economically attractive co-firing are at facilities where local or facility-generated supplies of biomass are abundant. 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**
For utility-scale power generation projects, acquiring steady, year-round supplies of large quantities of low-cost biomass can be difficult. However, vast resources of biomass exist across the United States and offer opportunities for commercial as well as industrial applications.

► **Cost-effectiveness**
Sites where waste wood supplies are readily available and conventional fuels are expensive offer good potential for cost-effective use of biomass. As a rule, boilers producing less than 35,000 pounds per hour (lb/hr) of steam are too small to be used in an economically attractive co-firing project (FEMP 2004b).

► **Retrofit applicability**
Biomass can be used for co-firing with existing coal-fired boilers. Modifications to existing emissions permits may be required for co-firing projects.

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**
Fuel cells have not yet been widely applied at federal sites. 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**
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
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
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
Fuel cells for combined heat and power or back-up power supply can be added to existing facilities. 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).

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
The technology is established enough that federal promotion is not the deciding factor anymore for its economy-wide success. Its potential in the federal sector itself, however, is far from exhausted.

Federal sector savings potential
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
Vast potentials for wind power exist in the West and the North. In more densely populated areas, this potential is best harvested though larger wind turbines. In rural areas, the potential for smaller, distributed wind power is great while electricity demand is limited.

Cost-effectiveness
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
Wind power can be added to existing power supply. A suitable site must be found for the generation and transmission system.

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**

Despite various supporting programs and high awareness of the technology, the price of photovoltaic electricity generation remains a major barrier. Any additional supporting activities that help grow market volume will help make the technology more competitive.

▲ **Federal sector savings potential**

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. The vast combined roof space of federal government facilities offers itself for photovoltaic system installations.

► **U.S. economy savings potential**

The savings potential from solar power across the U.S. is vast. Nonetheless, renewable energy technologies such as wind power compete not only with conventional power generation, but with renewable sources such as wind which is more competitive in some areas.

▼ **Cost-effectiveness**

The main strength of photovoltaic systems lies in their potential to reduce 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 photovoltaic technologies have not yet reached high cost-effectiveness.

► **Retrofit applicability**

PV panels can be applied on top of existing roofs. Photovoltaic shingles have been developed that can be installed as roof retrofits.

6. Sanitation

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**
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**
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**
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**
The technology is very cost-effective in high-use applications such as in public or commercial buildings.

▶ **Retrofit applicability**
Where toilets are replaced, these can easily be replaced with low-flush toilets.

7. Special

7.1 Advanced Metering

Advanced metering includes remotely read interval electricity meters or submetering. 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.

▲ **Federal market leverage**
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**
If implemented throughout the federal sector and followed up by consistent commissioning, the savings potential is very high.

► **U.S. economy savings potential**
Savings potential varies greatly depending on existing metering practices and potential for commissioning.

► **Cost effectiveness**
Varies with application; FEMP guidelines suggest rules of thumb for advanced metering applications.

▲ **Retrofit applicability**
Advanced metering can be easily retrofitted in most cases.

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 the market. For new or replacement equipment in a category covered by ENERGY STAR or FEMP specifications, agencies or ESCOs would go further, selecting a product from the top 1-5% most efficient models.

▲ **Federal market leverage**
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**
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**
The frontrunners of different technology categories are typically far ahead of the mainstream market.

► **Cost effectiveness**
Cost-effectiveness of top-of-the-line equipment varies by category.

► **Retrofit applicability**
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.

Additional Technologies to be Considered

Several of the technologies included in the preliminary list above are also featured in the report *Energy Efficiency and Renewable Energy Technology for the Federal Sector*, produced by PNNL in August 2004. However, some of the technologies from PNNL's report have not yet been evaluated for possible inclusion in the list. These are:

1. Temperature-Tolerant Reflector CFL
2. CFL Plug-In Ballast in a Socket
3. Task Ambient Luminaries
4. Liquid-Desiccant Heating/Cooling System Powered by Solar Energy
5. Heat Pipe Installed in Air Handling Unit
6. Commercial Laundry Waste Water Reduction

Other technologies will also come up for consideration in the future.

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