

# Report of the DOD-DOE Workshop on Converting Waste to Energy Using Fuel Cells

*DOD-DOE MOU Workshop Summary and Action Plan*



FUEL CELL TECHNOLOGIES PROGRAM

DOE Office of Energy Efficiency and Renewable Energy

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## Executive Summary

This report documents the results of a workshop held on January 13, 2011 and organized by the U.S. Department of Energy (DOE) and the U.S. Department of Defense (DOD) on waste-to-energy using fuel cells in support of a Memorandum of Understanding<sup>1</sup> (MOU) entered into on July 22, 2010. The purpose of this MOU, entered into by the DOD and the DOE, is to coordinate efforts to enhance national energy security and demonstrate federal government leadership in transitioning to a low-carbon economy. A key focus area of the MOU is DOD-DOE collaboration on a broad range of innovative, technology-driven solutions to reduce petroleum use, among other objectives.<sup>2</sup> As a large developer and end user of technology, DOD will aim to speed the movement of innovative energy technologies and technical expertise from DOE's research laboratories to military end users, using military installations as test beds and early markets.

One of the solutions being explored under the MOU is the use of hydrogen and fuel cell applications to curb the use of logistics fuel across several DOD agencies. DOD and DOE have identified three key near-term opportunities for hydrogen and fuel cell use: developing and installing fuel cells for auxiliary power in airport ground support equipment and on board military aircraft, leveraging waste as feedstock for fuel cell applications in fixed and deployed military operations, and developing and using fuel cells for auxiliary power on military ships and in ports and/or pier-side applications.

This paper includes the results of the January 13, 2011, workshop which focused on the second of these three opportunities: utilizing biowaste as an energy feedstock and converting this feedstock into heat and/or power using fuel cells.

DOD is the single largest energy user in the United States; in 2008, it consumed 1,126 trillion British thermal units (Btu) of energy.<sup>4</sup> DOD is highly dependent on liquid fossil fuels, which represent 76% of its total energy consumption.<sup>5</sup> It also relies on grid-supplied electricity to provide power for its permanent installations.

DOD's high energy use comes at a high economic and environmental cost. In 2008, DOD paid approximately \$20 billion for energy (\$16 billion for fuel and \$4 billion for facility energy, primarily electricity),<sup>6</sup> and emissions resulting from this energy use totaled 73.5

"If the Pentagon and its subsidiary branches were to form a country, the Department would rank among the top 60 energy consuming nations in the world and the top 50 greenhouse gas emitters."<sup>3</sup>

<sup>1</sup> U.S. Department of Energy (DOE) and U.S. Department of Defense (DOD), *Memorandum of Understanding between U.S. Department of Energy and U.S. Department of Defense* (Washington, DC: DOE and DOD, July 22, 2010), <http://www.energy.gov/news/documents/Enhance-Energy-Security-MOU.pdf>.

<sup>2</sup> Ibid.

<sup>3</sup> Schuyler Null, *Defense Sustainability: Energy Efficiency and the Battlefield* (Washington, DC: Global Green, February 2010), <http://www.globalgreen.org/docs/publication-112-1.pdf>.

<sup>4</sup> Schuyler Null, *Defense Sustainability: Energy Efficiency and the Battlefield* (Washington, DC: Global Green, February 2010), <http://www.globalgreen.org/docs/publication-112-1.pdf>.

<sup>5</sup> Defense Logistics Agency, *Defense Energy Support Center Fact Book* (Fort Belvoir, VA: Defense Logistics Agency, 2009).

<sup>6</sup> Ibid.

million metric tons of carbon dioxide equivalent.<sup>7</sup> DOD's high energy dependence and reliance on imported fossil fuels (60% of its liquid fuel is imported from foreign sources)<sup>8</sup> also make it vulnerable to price spikes and supply disruptions that could potentially strain fuel-intensive field operations and operations at essential facilities such as hospitals and laboratories.

DOD is looking for new ways to generate its electricity and fuel its vehicles in order to reduce its dependence on imported liquid fuels and sometimes unreliable grid-supplied electricity, reduce its energy costs, and enhance energy security. Meeting these goals will require fundamental shifts in energy use to provide comprehensive energy solutions that are both effective and economical.

## Fuel Cells: Producing Energy from Biowaste

“Waste-to-energy” (WTE) technologies can enable DOD to convert waste products (including municipal solid waste, wastewater, sewage sludge, landfill gas, construction debris, agricultural and livestock waste, and food waste, among other types) into an energy feedstock. WTE technologies use thermal, chemical, or physical processes to convert raw waste streams into usable fuel for energy conversion devices (such as combustion engines, boilers, gas turbines, and fuel cells). Fuel cells can use the biowaste-derived feedstock (reformed biogas or liquid fuel) to produce heat, power, and hydrogen, with only water as a byproduct (for most fuels).

Fuel cells are a promising clean energy technology for several reasons. They use pure hydrogen or hydrocarbon fuel, which can be generated from a variety of renewable resources; produce low or even no greenhouse gas emissions at the point of use; offer more than two times the efficiency of traditional combustion technologies (and even higher efficiencies in combined heat and power [CHP] applications); and can be scaled to power a variety of applications, including specialty vehicles (e.g., forklifts and

### The Obama Administration's Clean Energy Goals

The Obama Administration's clean energy goals include long-range targets for reducing greenhouse gas emissions and petroleum use. By 2035, 80% of America's electricity should come from clean sources, including wind, solar, nuclear, clean coal, and natural gas. In his State of the Union address, President Obama also put forward measures to ensure that the U.S. will be the first country to put 1 million advanced technology vehicles on its roads. In addition, Executive Order 13514 requires federal agencies to reduce its greenhouse gas pollution 28% by 2020, increase energy efficiency, reduce fleet petroleum consumption (30% by 2020), put in place net-zero energy buildings by 2030, and meet other sustainability measures.<sup>9</sup>

<sup>7</sup> Jeffrey Marqusee, “DOD Installation Energy” (presentation, Advanced Research Projects Agency-Energy Advanced Building Energy Technologies Workshop, Hilton, Arlington, VA, December 15, 2009), [http://arpa-e.energy.gov/portals/0/Documents/ConferencesandEvents/Pastworkshops/BuildingTechnologies/BuildingTechnologies2/bt\\_marqusee.pdf](http://arpa-e.energy.gov/portals/0/Documents/ConferencesandEvents/Pastworkshops/BuildingTechnologies/BuildingTechnologies2/bt_marqusee.pdf).

<sup>8</sup> Defense Logistics Agency, *Defense Energy Support Center Fact Book* (Fort Belvoir, VA: Defense Logistics Agency, 2009).

<sup>9</sup> Office of the Press Secretary, “Fact Sheet: The State of the Union: President Obama's Plan to Win the Future,” The White House, January 25, 2011, <http://www.whitehouse.gov/the-press-office/2011/01/25/fact-sheet-state-union-president-obamas-plan-win-future>; Office of the Press Secretary, “President Obama Sets Greenhouse Gas Emissions Reduction Target for Federal Operations,” The White House, January 29, 2010, <http://www.whitehouse.gov/the-press-office/president-obama-sets-greenhouse-gas-emissions-reduction-target-federal-operations>.

airport tugs), stationary power generation units (for backup and prime power), auxiliary power units for heavy-duty trucks, engines for cars and light-duty trucks, and portable electronic equipment.

## Drivers for DOD Waste-to-Energy Fuel Cell Projects

Several drivers are motivating DOD to pursue WTE projects, including the need to reduce its dependence on unreliable sources of fuel and electricity, reduce its energy costs, and enhance its energy security. An additional driver motivating DOE interest in WTE projects is DOD's need to comply with increasingly stringent climate change, clean air, energy efficiency, waste reduction, and sustainability requirements. These include goals and mandates established under the Obama Administration's clean energy policies (see sidebar), the 2005 Energy Policy Act, the 2005 Army Energy Strategy, Executive Order 13423, the Energy Independence and Security Act of 2007, Fiscal Year 2007 Army Environmental Requirements and Technology Assessments, and Defense Science Board recommendations.<sup>10</sup>

The maturation of fuel cell technologies is another key driver motivating DOD to pursue WTE fuel cell projects. Stationary fuel cells operating on natural gas are an established, commercially available technology. In addition, the integration of stationary fuel cells with anaerobic digesters has been successfully demonstrated. Fuel cells have accordingly begun to enter the commercial market for applications such as forklifts, emergency backup power, and prime power for critical loads.<sup>11</sup> The market for fuel cells is growing rapidly; worldwide fuel cell shipments increased by 49% annually between 2008 and 2009.<sup>12</sup>

The improving economics of fuel cell and WTE technologies are another driver motivating DOD interest in WTE fuel cell projects. Distributed fuel cell application costs are declining as grid power costs are increasing. Over time, the gap between them will continue to widen.

DOE-funded research and development has also made significant progress in overcoming cost and technical barriers to fuel cell technology commercialization. Recent notable accomplishments include an 80% reduction in the projected high volume cost of automotive fuel cells (from \$275/kilowatt [kW] in 2002 to \$51/kW in 2010).<sup>13</sup>

A final driver motivating DOD to pursue WTE fuel cell projects is an increase in available financial incentives. Recent legislation effectively increased the investment tax credit for qualified fuel cell property purchases from \$1,000/kW to \$3,000/kW. Although federal entities such as the DOD are not directly eligible for this tax credit, private third-party purchasers can take advantage of the credit and provide power to the federal entity potentially at reduced cost. Selected states (California, New York, Connecticut, and Texas) are also offering tax incentives for WTE fuel cell projects.

<sup>10</sup> Franklin H. Holcomb, "Waste-to-Energy Projects at Army Installations" (presentation, Converting Waste to Energy Using Fuel Cells Workshop, Capital Hilton, Washington, DC, January 13, 2011), [http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/waste\\_holcomb.pdf](http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/waste_holcomb.pdf)

<sup>11</sup> "Commercially Available Product Catalog," Fuel Cell and Hydrogen Energy Association, <http://www.fchea.org/index.php?id=86>.

<sup>12</sup> U.S. Department of Energy Office of Energy Efficiency and Renewable Energy, "2010 Fuel Cell Technologies Market Report" (June 2011) ([http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2010\\_market\\_report.pdf](http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2010_market_report.pdf))

<sup>13</sup> "U.S. Department of Energy Hydrogen Program Record #10004: Fuel Cell System Cost—2010," U.S. Department of Energy, September 16, 2010, [http://www.hydrogen.energy.gov/pdfs/10004\\_fuel\\_cell\\_cost.pdf](http://www.hydrogen.energy.gov/pdfs/10004_fuel_cell_cost.pdf); Fuel Cell Technologies Program, "Progress and Accomplishments in Hydrogen and Fuel Cells," U.S. Department of Energy, March 2011, <http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/accomplishments.pdf>.

## Opportunities for DOD Waste-to-Energy Fuel Cell Projects

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Fuel cell systems can be used to provide electricity or CHP for hospitals, laboratories, dormitories, mess halls, office buildings, and other permanent facilities; emergency power and prime power for critical loads; and portable power. There is also an opportunity for fuel cell-powered auxiliary power units, forklifts, and light duty vehicles. Another opportunity for WTE fuel cell applications are “trigeneration” projects—which produce combined heat, hydrogen, and power (CHHP)—because they can best maximize revenues and current state incentives. These systems can provide CHP for buildings while using excess energy to generate hydrogen for use in light duty vehicles.

Leveraging waste as feedstock for fuel cells is of particular interest to DOD because it can help the agency address its own requirements for efficiency, security, and cost reduction as well as external requirements for sustainability, emissions reduction, and waste reduction. Among its many benefits, using biowaste-derived feedstock for fuel cell applications can help DOD minimize waste by converting it to electricity, reduce the need to transport waste off site for disposal (which can be expensive and can also put tactical operations at increased risk), generate reliable power on site, reduce fuel and electricity purchases, diversify its fuel mix, and reduce its greenhouse gas emissions.

DOD is well positioned to take advantage of WTE opportunities because it can easily access a wide variety of on-base and on-ship waste streams suitable for conversion into fuel cell ready feedstock. Sources of suitable waste include gas from wastewater treatment plants (WWTPs) and landfills, food waste (such as spent cooking oil from mess halls), compost heaps, plastic waste, and paper waste (office paper and cardboard). DOD may also be able to access additional waste streams from neighboring communities and through programs and partnerships with other government agencies (such as the U.S. Environmental Protection Agency’s AgSTAR Program).

One opportunity for the DOD-DOE collaboration is to leverage biowaste currently on site at many Air National Guard (ANG) bases as feedstock for CHP fuel cells. DOE is currently reviewing projects at both ANG’s Joint Forces Training Base (JFTB) in Los Alamitos, California, and the Eglin Air Force Base in Florida.

## Potential Impacts

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Converting waste to energy could significantly reduce emissions and waste while generating power that DOD would otherwise have to purchase. This potential has been illustrated by the success of other commercial, government, and military biowaste-to-energy projects (see sidebar).

DOE estimates that using fuel cells to provide prime power and heat could save DOD approximately 2 megawatt-hours of electricity per year per base, assuming a grid efficiency of 30%.<sup>14</sup> For example, based on current energy usage data provided by JFTB and efficiency data provided by a Verizon case study, JFTB would save on average 4,000 Therms/month (400 million Btu/month or 117,000 kilowatt-hours

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<sup>14</sup> Greg Moreland, “Alternative Technology for GSE: Fuel Cells, are they the Future?” (presentation, U.S. Department of Energy, Fuel Cell Technologies Program, February 23, 2011), <http://cygnusaviationexpo.com/z-pdf/2011/GS-Seminar1.pdf>.



[kWh]/month) and 48,000 Therms (4.8 billion Btu or 1.4 million kWh) at 80% efficiency using both the heat and power generated by the fuel cell.<sup>15</sup>

Carrying the DOD-DOE WTE collaboration forward across all ANG bases (to date there are 134) could result in major energy savings. Assuming a grid efficiency of 30%, aggregate energy savings could reach 188 million kWh or 634 billion Btu annually.<sup>16</sup>

## Challenges

A number of challenges must be overcome before the military can realize the full potential of WTE applications. Key challenges include the following:

- **Technical and performance issues** such as WTE systems' high degree of complexity (too complex for tactical operations); uncertain performance in comparison to incumbent technologies; and ability to handle non-homogeneity and seasonal variations in moisture content of waste streams; as well as the need for further development and demonstration of gas purification systems, biorefining, and hydrogen delivery and distribution.
- **Cost challenges**, including the high cost of fuel cell and WTE conversion technologies, lengthy payback periods, and lack of information on the full burdened cost of waste and a clear value proposition that could help justify WTE project costs.
- **Waste stream supply issues** such as the variability and small size of the available waste streams on bases, the risks inherent in relying on external waste sources, and waste stream location (the best waste streams are not often colocated with the best fuel cell CHP applications).
- **Funding and financing issues**, including restrictions in government contracting; a lack of seed money for start-up projects; and the need for third-party financing for most projects, which adds basis points due to higher risk and complexity due to the additional contract negotiations required.
- **Scale issues**, including the lack of small-scale, low-cost biomass gasifiers, pyrolysis units, gas cleanup, and other technologies that would enable development and deployment of compact, rugged, transportable systems for tactical operations.
- **A lack of support for decision making**, including a lack of defined, documented economic, environmental, and technology performance metrics to inform the decision-making process and states' varying definitions of municipal solid waste, biomass, and WTE.
- **The lack of specific project management expertise or resources** to successfully plan, finance, deploy, and manage WTE projects. These are complex projects that require special expertise and a significant amount of time to plan, fund, and execute.
- **Poor public perception** of municipal solid waste WTE facilities and a lack of public knowledge about fuel cells.

<sup>15</sup> Greg Moreland, "Alternative Technology for GSE: Fuel Cells, are they the Future?" (presentation, U.S. Department of Energy, Fuel Cell Technologies Program, February 23, 2011), <http://cygnusaviationexpo.com/z-pdf/2011/GS-Seminar1.pdf>.

<sup>16</sup> Fuel Cell Technologies Program, *Report of the DOD-DOE Workshop on Fuel Cells in Aviation* (Washington, DC: U.S. Department of Energy, May 2011).

## Biowaste-to-Energy Project Examples

### Gills Onions, Oxnard, California

HDR Engineering installed a system at Gills Onions to turn 250,000 pounds of onion waste per day into clean methane gas. This waste is now a source of fuel for a 600-kilowatt (kW) solid oxide fuel cell system that provides power and heat to the onion processing facility. Impressive results include a 99% reduction of waste and 47% electrical efficiency. Even more impressive—with \$800,000 in annual energy and hauling savings, the system will recoup investment costs in fewer than 6 years.

### U.S. Department of Energy (DOE) Savannah River Site, South Carolina

The DOE Savannah River project consists of a cogeneration facility and two steam heating facilities that use clean biomass as their primary boiler fuel. The project is expected to save more than \$34 million and 100,000 tons of greenhouse gas emissions in its first year, and will eventually eliminate the burning of 161,000 tons of coal per year.

### Hill Air Force Base, Utah

The first-ever landfill gas-to-energy project initiated under the DOE Biomass Alternative Methane Fuel Energy Savings Performance Contract program was launched at Hill Air Force Base, a very large industrial site in Utah with electrical demand exceeding 45 megawatts. The project uses landfill gas from the nearby Davis County landfill to power three internal combustion engine generators. In the three years since its launch, the system has produced more than 50 million kilowatt-hours of electricity—saving more than \$2 million—and increased its generation capacity from 1,250 kW to 2,250 kW.

## Suggested Action Items and Next Steps

The facilitated sessions worked to identify some near-term actions that can advance WTE use in military applications. As described previously, DOE is already scoping out opportunities for WTE at ANG bases, and the actions below would help better define and evaluate the potential for WTE in military operations.

- **Identify appropriate candidates for WTE projects**, such as military installations with large residential populations that have on-base WWTPs and/or landfills; are engaged with neighboring communities from which waste streams could be sourced; have multiple applications for the project's fuel products; have facilities that can utilize CHP or that have mission-critical energy demands; or are located near biomass-rich resources such as agricultural, food processing, livestock, or forestry operations.
- **Identify opportunities where DOD can lead or influence** outside vendors to develop WTE projects in cases where an installation's waste disposal or treatment needs are currently handled by municipalities or private vendors.

- **Propose a WTE Working Group** to the DOD-DOE MOU Executive Committee at its initial meeting. The WTE Working Group would assist in developing the necessary knowledge base for project decision making and assist in coordinating and collaborating on the deployment of WTE at targeted facilities.
- **Develop a project screening tool:** Convene a DOE or DOD national laboratory group to develop technical and economic information for the tool, and include stakeholders such as utilities.
- **Develop a detailed guidance document on third-party financing and contracting mechanisms** at federal sites.
- **Assess current fuel cell WTE demonstration projects** (in both public and private operations) and document lessons learned and best practices. Develop case studies on successful projects.
- **Host a workshop with DOD to determine next steps** in implementing a plan that would reach a 50% adoption rate across ANG. Further opportunities exist to leverage biowaste on site at other DOD facilities, which will also be explored in collaboration with DOD.<sup>17</sup>

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<sup>17</sup> Fuel Cell Technologies Program, *Report of the DOD-DOE Workshop on Fuel Cells in Aviation* (Washington, DC: U.S. Department of Energy, May 2011).



# 1. Introduction to the Waste-to-Energy Workshop

## Background

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The U.S. Department of Defense (DOD) and U.S. Department of Energy (DOE) entered into a Memorandum of Understanding (MOU) for the purpose of coordinating efforts to enhance national energy security and demonstrate federal government leadership in transitioning to a low-carbon economy. A key focus area of the MOU is DOD-DOE collaboration on a broad range of innovative, technology-driven solutions to reduce petroleum use, among other objectives.<sup>18</sup> As a large developer and end user of technology, DOD will aim to speed the movement of innovative energy technologies and technical expertise from DOE's research laboratories to military end users, using military installations as test beds and early markets. Activities undertaken through this collaboration can also help DOD installations meet the requirements of additional regulations that impact their strategies for energy use. These regulations include the 2005 Energy Policy Act, 2005 Army Energy Strategy, Executive Order 13514, the Energy Independence and Security Act of 2007, Fiscal Year 2007 Army Environmental Requirements and Technology Assessments, and the Defense Science Board recommendations.<sup>19</sup>

To facilitate cooperation in identifying opportunities to use waste-to-energy (WTE) technologies under the MOU, the DOE Office of Energy Efficiency and Renewable Energy's Fuel Cell Technologies Program (FCT) hosted a workshop on January 13, 2011. The workshop focused on utilizing biowaste as an energy feedstock and identifying opportunities to convert this feedstock into heat and/or power using fuel cells. One of the outcomes of the workshop was to identify opportunities to leverage biowaste currently on site at many Air National Guard (ANG) bases. DOE is currently scoping projects at both ANG's Joint Forces Training Base and the United States Air Force's Eglin Air Force Base.

This workshop was the second of three workshops that FCT is conducting with DOD and industrial stakeholders to explore potential collaboration under the DOD-DOE MOU.

## Goals and Objectives

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The workshop brought together nearly 70 representatives from the Army, Navy, Air Force, national laboratories, and industry. The workshop's goals included the following:

- Identify DOD and DOE WTE and fuel cell opportunities
- Identify challenges to coordinating these initiatives and determine actions to address these challenges

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<sup>18</sup> U.S. Department of Energy (DOE) and U.S. Department of Defense (DOD), *Memorandum of Understanding between U.S. Department of Energy and U.S. Department of Defense* (Washington, DC: DOE and DOD, July 22, 2010), <http://www.energy.gov/news/documents/Enhance-Energy-Security-MOU.pdf>.

<sup>19</sup> Franklin H. Holcomb, René S. Parker, Thomas J. Hartranft, Kurt Preston, Harold R. Sanborn, and Philip J. Darcy, *Proceedings of the 1st Army Installation Waste to Energy Workshop*, ERDC/CERL TR-08-11 (Washington, DC: U.S. Army Engineer Research and Development Center, Construction Engineering Research Laboratory, August 2008), <http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA491416>.



- Determine specific ways that fuel cells and related technologies can help DOD and DOE comply with Executive Order 13514<sup>20</sup>
- Identify the next steps for collaboration

## Approach

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As shown in the agenda in Figure 1, the first half of the workshop featured presentations from DOD and DOE representatives as well as 10 presentations from industry and national laboratory experts. During the second half of the workshop, two groups of 20–30 attendees participated in facilitated discussion sessions that identified opportunities, challenges, and actions for collaboration on WTE initiatives that will help leverage biowaste as feedstock for fuel cells.

## 2. Plenary Session Summaries

The agenda comprised a general overview of the DOD-DOE MOU and opportunities for WTE technologies. Leaders from DOD and DOE began the workshop by providing their perspectives on the execution of the MOU. Additional presentations discussed previous and present research, development, and demonstration activities undertaken by industry, the Army, and the national laboratories.

The following topics were addressed throughout the workshop:

- Hydrogen and fuel cell research and development: needs and opportunities
- Waste streams: composition and processing
- WTE demonstrations: challenges and results

The following sections summarize key points from the workshop presentations.

### DOE Perspectives

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**PRESENTER: Steven Chalk, Deputy Assistant Secretary for Renewable Energy, Office of Energy Efficiency and Renewable Energy**

Mr. Chalk opened the workshop plenary session by introducing several of DOE's high-level goals and discussing the importance of collaborating with DOD. He highlighted the fact that fuel cells, unlike other renewable technologies such as solar, are still an American technology and there is an opportunity to leverage this technical advantage to secure the world market.

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<sup>20</sup> Exec. Order No. 13514, 74 Fed. Reg. 194 (October 8, 2009), [http://www.whitehouse.gov/assets/documents/2009fedleader\\_eo\\_rel.pdf](http://www.whitehouse.gov/assets/documents/2009fedleader_eo_rel.pdf).

Figure 1. Workshop Agenda

- I. Introduction**
- II. Workshop Purpose and Format**
- III. Presentations**
  - a. *U.S. Department of Energy (DOE) Perspectives*  
Steven Chalk, Deputy Assistant Secretary for Renewable Energy, Office of Energy Efficiency and Renewable Energy
  - b. *U.S. Department of Defense (DOD) Perspectives*  
John Conger, Assistant Under Secretary of Defense (Installations and Environment)
  - c. *DOE Fuel Cell Technologies Program Overview*  
Sunita Satyapal, Program Manager, Fuel Cell Technologies Program, Office of Energy Efficiency and Renewable Energy
  - d. *Fuel Cell Hydrogen Energy Association Industry Overview*  
Ruth Cox, Director, Fuel Cell Hydrogen Energy Association
  - e. *Waste-to-Energy and Fuel Cell Technologies Overview*  
Robert Remick, Director, National Renewable Energy Laboratory, Hydrogen Technologies Center
  - f. *Gills Onions Project, a Success Story*  
Dave Reardon, PE, National Director, HDR Engineering, Inc.
  - g. *Waste-to-Energy Projects at Military Bases*  
Frank H. Holcomb, Chief, Energy Branch, U.S. Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory
  - h. *Fuel Cell Combined Heat and Power Waste-to-Energy Projects*  
Frank Wolak, Vice President, FuelCell Energy
  - i. *Waste Gas Cleanup: Challenges and Applications*  
Brian Weeks, Engineering Manager, Gas Technology Institute
  - j. *Waste-to-Energy Power Production at DOE and DOD*  
Joe Price, Business Manager, Ameresco
  - k. *Power Purchase Agreements*  
Robert Westby, Program Manager, National Renewable Energy Laboratory, Federal Energy Management Program
- IV. Facilitated Discussion**
  - a. Opportunities Identification
  - b. Challenges Identification
  - c. Plan of Action
- V. Conclusion**

## DOD Perspectives

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PRESENTER: **John Conger, Assistant Under Secretary of Defense (Installations and Environment)**

Mr. Conger gave a broad overview and perspective of DOD and its role in energy security. He reiterated that mission is first and any technology that is to be adopted by DOD will have to meet mission-critical demands. He noted that, domestically, DOD is committed to being a leader in energy intensity reduction across its suite of technology demands.

## DOE Fuel Cell Technologies Program Overview

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PRESENTER: **Sunita Satyapal, Program Manager, Fuel Cell Technologies Program, Office Energy Efficiency and Renewable Energy**

Dr. Satyapal presented an overview of the FCT Program and the progress the United States has made regarding hydrogen and fuel cell research, development, and demonstration. Along with the general program overview, Dr. Satyapal highlighted the vast amount of biogas resources in the United States. Following are key take-away points made on the potential opportunities of WTE in the United States:

- Approximately 12.4 million metric tons (MT)/year of methane is available from U.S. landfills, and about 0.5 million MT/year is available from wastewater treatment plants (WWTPs)<sup>21</sup>
- If 50% of the methane from landfills was available for use, enough renewable hydrogen could be produced to support about 8 million vehicles (approximately 8 million kilograms [kg]/day of hydrogen)<sup>22</sup>
- If 50% of the methane from WWTPs was available, enough renewable hydrogen could be produced to support about 340,000 vehicles (approximately 340,000 kg/day of hydrogen)<sup>23</sup>

Dr. Satyapal concluded by emphasizing the history of collaboration between FCT and other government organizations, including DOD, and the need to leverage DOE technical resources to fulfill the requirements of the MOU while meeting U.S. energy security goals.

## Fuel Cell Hydrogen Energy Association Industry Overview

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PRESENTER: **Ruth Cox, Director, Fuel Cell Hydrogen Energy Association**

Ms. Cox began her discussion by giving an overview of the Fuel Cell Hydrogen Energy Association (FCHEA), outlining its mission and member-driven strategy. She explained that FCHEA is industry focused and its membership spans the entire supply chain of the fuel cell industry. She summarized opportunities for using waste and by-product hydrogen, and provided the following five high-value areas:

- **Distributed Generation:** Power at the point-of-use reduces the need for congested, faulty, and inefficient transmission and distribution lines

<sup>21</sup> A. Milbrandt, *A Geographic Perspective on Current Biomass Resource Availability in the United States*, NREL/TP-560-39181 (Washington, DC: U.S. Department of Energy, December 2005), <http://www.nrel.gov/docs/fy06osti/39181.pdf>.

<sup>22</sup> Ibid.

<sup>23</sup> Ibid.

- **Resource Maximization:** The technology can get the most out of fuels and take advantage of existing gas infrastructure and waste gas streams
- **Renewable Integration:** Excess renewable power can be stored as hydrogen and used for power on demand or to fuel vehicles
- **Environment:** Fuel cells increase efficiency and reduce emissions of all kinds
- **Economy:** The technology will save money, create jobs, and support domestic economic growth

Ms. Cox also noted three needs that must be addressed in initiating fuel cell WTE projects. First, there is the need to integrate fuel cells and hydrogen with DOE and DOD biomass, biofuels, and biogas programs. Second, there is the need for further funding for gas purification system development. Finally, demonstration projects should include chlor-alkali, biorefining, and hydrogen delivery and distribution infrastructure.

## Waste-to-Energy and Fuel Cell Technologies Overview

PRESENTER: **Robert Remick, Director, National Renewable Energy Laboratory, Hydrogen Technologies Center**

Dr. Remick provided a broad overview of WTE and how fuel cells can support the integration of WTE technologies into the power grid and end-use applications. Sources of waste that can be converted into fuel for fuel cells through both anaerobic digestion and gas cleanup systems include landfills, dairy farms, and WWTPs. In various installed combinations, these waste streams can be reformed on site or injected into an existing gas infrastructure. They can be converted directly into electricity or into pure hydrogen for transportation applications.

Dr. Remick described everyday waste streams, such as methane, gas and the potential of a typical WWTP based on a 110,000-person community and shown in Table 1.

Table 1. Comparison by Generator Type

Generator Type	Megawatt-hours/year
Phosphoric acid fuel cell	2,900
Molten carbonate fuel cell	3,300
Microturbine	1,800
Reciprocating engine	1,500

Dr. Remick concluded with the following take-away points:

- Stationary fuel cells operating on natural gas are a commercial technology

- The integration of stationary fuel cells with anaerobic digesters is a demonstrated technology
- A reasonable business case can be made for both at current costs, when federal and state incentives are available
- The integration of stationary fuel cells with biomass gasification is a developing technology that is in need of demonstration

## Gills Onions Project, a Success Story

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PRESENTER: **Dave Reardon, PE, National Director, HDR Engineering, Inc.**

Mr. Reardon kicked off the industry-focused presentations by giving an overview of the successful execution of WTE using fuel cells at Gills Onions in Oxnard, California. Gills Onions is the third-largest onion producer in the nation, and its 100,000 square-foot onion processing facility in Oxnard processes 800,000 pounds of onions 6 days a week. The facility generates 250,000 pounds/day of waste onion, which must be hauled off site, resulting in a messy operation that leaves trails of onion juice on roadways—ultimately introducing sulfur into surrounding soil. In addition to logistic complications, the disposal operations cost Gills Onions \$400,000 per year.

Because of the issues and cost of the onion waste, Gills brought in HDR Engineering to solve the problem. HDR installed a system to process the onion waste and turn it into clean methane gas, which could then be used as fuel for a fuel cell. HDR then installed a 600 kilowatt (kW) solid oxide fuel cell system to provide power and heat to the onion processing facility. Results from the installation were impressive—a 99% reduction of waste and an electrical efficiency of 47% at 480 volts, with overall efficiency increasing when using heat from the fuel cell.

The gas cleanup and fuel cell cost Gills Onions \$9.6 million; however, with \$800,000 in annual energy and hauling savings, the system is set to reach an internal return on investment in fewer than 6 years. Mr. Reardon concluded by reiterating that sustainable projects can be done economically and have social and environmental benefits. He also encouraged the audience to “think holistically” about its waste streams and how they can be integrated for the most efficient processing.

## Waste-to-Energy Projects at Military Bases

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PRESENTER: **Frank H. Holcomb, Chief, Energy Branch, U.S. Army Corps of Engineers, Engineer Research and Development Center, Construction Engineering Research Laboratory**

Mr. Holcomb prefaced his WTE discussion with a brief overview of the Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), and how energy directives from various levels of government drive its energy decisions. He noted that the Army faces requirements for energy performance established by legislation, Presidential Executive Orders, Office of the Secretary of Defense mandates, and Army policies. The directives that have the greatest influence on the Army are listed in Appendix A. He then outlined some of the results and lessons learned from the WTE workshop hosted by ERDC-CERL in August 2008. The workshop, similar to the WTE workshop, sought to evaluate the current status and potential direction of WTE technologies compared to tactical

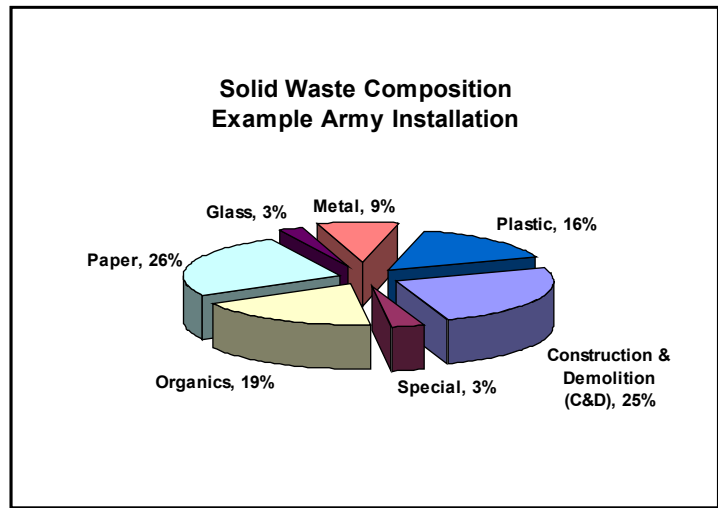


applications and operations. One result of the workshop was waste stream identification on Army installations, as shown in Figure 2.

He then reported on several demonstration projects, including a downdraft gasifier, and tactical WTE programs. Mr. Holcomb concluded with the following points:

- The “burdened” cost of waste needs to be determined.
- Third-party financing is required in most cases.
- Privatization of utilities is an issue.
- Siting and permitting can be a barrier.
- WTE systems for tactical operations will have very different requirements.

Figure 2. Solid Waste Composition Example Army Installation<sup>24</sup>



## Fuel Cell Combined Heat and Power (CHP) Waste-to-Energy Projects

PRESENTER: **Frank Wolak, Vice President, FuelCell Energy**

Mr. Wolak gave the audience an overview of FuelCell Energy and its distributed fuel cell molten carbonate stationary fuel cell systems. FuelCell Energy has many projects deployed around the country; in several circumstances, these projects are operating on waste-derived biogas. Successful client installations include the Gills Onions project and several WWTPs, including the Fountain Valley WWTP in Orange County, California. He also provided the audience with Table 2, which outlines the typical composition of biogas from various waste streams.

<sup>24</sup> ERDC/ CERL TR-03-11 US Army Corps of engineers, August 2008

Table 2. Typical Composition of Biogas from Various Waste Streams<sup>25</sup>

Composition	Natural Gas	Biogases			
		Waste Water	Food Waste	Animal Waste	Landfill
<b>Methane (Vol%)</b>	80–100	~50–60	~50–70	45–60	40–55
<b>Carbon Dioxide (Vol%)</b>	< 3	30–40	25–45	35–50	35–50
<b>Nitrogen (Vol%)</b>	< 3	< 4	< 4	< 4	< 20
<b>Oxygen (Vol%)</b>	< 0.2	< 1	< 1	< 1	< 2
<b>Hydrogen Sulfide (H<sub>2</sub>S), parts per million (ppm)</b>	< 0.1	< 400	< 10,000	< 300	< 200
<b>Non-H<sub>2</sub>S Sulfur (ppm)</b>	< 10	< 1	< 1,000	< 30	< 30
<b>Halogens (ppm)</b>	< 0.1	< 0.2	< 0.2	< 0.2	< 100
<b>Moisture (percentage)</b>	< 0.02	~3	~3	~3	~3

## Waste Gas Cleanup: Challenges and Applications

PRESENTER: **Brian Weeks, Engineering Manager, Gas Technology Institute**

Mr. Weeks began with an overview of the Gas Technology Institute (GTI), a not-for-profit research organization. He then discussed the basics of renewable natural gas (RNG), which he described as possibly the lowest carbon renewable fuel available today, outside of wind and solar power, and stated that a sustainable gas network will include renewable sources. RNG can be cleaned up and used in the natural gas pipeline system, although doing so presents numerous challenges. While RNG and conventional natural gas are both 95%–98% methane after cleanup, RNG constituents are not well understood; utility and interstate pipeline tariffs do not typically address all RNG components; and methods for treating raw biogas can be expensive. However, it is important to treat RNG to prevent negative impacts to pipeline infrastructure, end-use applications, and fuel cell applications. GTI is involved in several RNG cleanup projects, including cleaning up landfill gas to produce liquefied natural gas for vehicle fuel at the Altamont Landfill in Livermore, California.

Mr. Weeks also discussed a system that generates hydrogen from RNG and includes a RNG cleanup system, a biomethane reformation system, and hydrogen purification. He concluded by sharing research and development recommendations, such as developing resource baseline data, initiating data analysis for operation of end-use equipment with various levels of biogas contaminants, and building a pilot gasification plant utilizing biomass feedstock.

<sup>25</sup> FuelCell Energy Market Research, January 2011

## Waste-to-Energy Power Production at DOE and DOD

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PRESENTER: **Joe Price, Business Manager, Ameresco**

Mr. Price summarized two WTE power production initiatives led by DOE and the United States Air Force. The DOE Savannah River site required both steam and power, and faced aging infrastructure and new, stricter requirements for clean air, energy efficiency, and sustainability. DOE used the Energy Saving Performance Contract (ESPC) program—which allows federal agencies to leverage private investment for renewable energy and energy efficiency ventures—to convert the site into the largest federal biomass facility in the country. The DOE Savannah River project consists of a biomass cogeneration facility and two steam heating facilities. Both types of boilers rely on clean biomass as the primary fuel. In its first year, the project is expected to save more than \$34 million and 100,000 tons of greenhouse gas emissions. It will eventually eliminate the burning of 161,000 tons of coal each year.

Mr. Price also discussed the landfill gas-to-energy project launched at Hill Air Force Base, a very large industrial site in Utah with electrical demand exceeding 45 MW. The project is the first ever initiated under the DOE Biomass Alternative Methane Fuel ESPC program. It uses landfill gas—a potent greenhouse gas produced from decaying waste—from the nearby Davis County landfill to power three internal combustion engine generators with electrical interconnection and a web-based control system. The project started in January 2005 with a 1,250 kW capacity, which was raised to 2,250 kW in August 2008. Since launching, the initiative has produced more than 50 million kilowatt-hours of electricity, saving more than \$2 million.

## Power Purchase Agreements

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PRESENTER: **Robert Westby, Program Manager, National Renewable Energy Laboratory, Federal Energy Management Program**

Mr. Westby presented the methods and economics of federal renewable energy project implementation. He observed that federal renewable energy projects are generally economically viable when they can leverage federal tax credits, the sale or purchase of power produced, and state incentives. Renewable energy project economics are typically very thin and incremental project costs can have significant impacts. Mr. Westby shared an example of a photovoltaic power purchase agreement (PPA) that included 64% funding from state incentives, 22% from federal tax credits, and 14% from the sale of power. He also provided a table detailing California solar incentive rebate levels by incentive step and rebate type.

Mr. Westby offered general observations on financing projects involving stationary fuel cell applications. He noted that tri-generation applications, such as combined heat, hydrogen, and power (CHHP) facilities, are attractive because they maximize revenues and state incentives. In terms of state incentives, Mr. Westby described California's as particularly enticing. He then summarized project costs to consider for stationary applications utilizing molten carbonate technology, including equipment and installation, the cost of capital, and operation and maintenance. Project revenues include federal and state incentives, as well as the sale of power.

Mr. Westby also discussed successful implementation methods including PPAs, ESPCs, Utility Energy Service Contracts, Enhanced Use Leases (EULs), and energy joint ventures. He also mentioned the

National Renewable Energy Laboratory's financial evaluation capabilities for project development, which include its fuel cell power model, solar advisor model, and financial pro forma spreadsheets.

### 3. Key Points from Facilitated Discussion

The facilitated discussion sessions worked to identify opportunities, challenges, and actions for collaboration on WTE initiatives that will help leverage biowaste as feedstock for CHP fuel cells. A summary of the discussion is provided below. Raw results from the breakout sessions are included in Appendix D.

#### Opportunities

**Strategic Value:** WTE has the potential to contribute to the military's goals of net-zero water, energy, and waste at military bases; zero-footprint base camps; lower petroleum consumption and greenhouse gas emissions; reduced burdened costs of energy and waste; and improved energy independence and security of fixed and deployed operations. Participants noted that there are opportunities for WTE aboard ships and submarines, where converting plastic, paper, cardboard, food waste, medical waste, solid sludge, and waste oil to energy would increase renewable power generation and reduce the security risk encountered when ships are required to dump wastes at port.

**Project Siting:** Military bases with large residential populations are likely the best candidates for WTE because they generate the largest amount of municipal solid waste, sewage sludge, and food waste. Bases that operate their own landfills and WWTPs (versus those where these facilities are privatized or owned and operated "outside the fence") will be the easiest targets operationally. However, there are also opportunities for military bases located near civilian residential communities or farming or forestry operations to build cooperative relationships and combine resources to increase the available waste feedstock volume and generate renewable energy for use both on and off base.

Participants also identified a number of specific military facilities that may offer opportunities for DOD WTE applications, including Hill Air Force Base; Marine Corps Base Quantico (specifically the closed landfill there); 29 Palms in California; Los Alamitos; and military bases in Hawaii, San Diego, and San Antonio, where there are multiple military installations. Specific suggestions also included Fort Hood Hospital (which is beginning construction in the fall of 2011) and U.S. Department of Veterans Affairs hospitals. Military installations with mandated forestry biomass management programs, or that are in biomass-rich areas, such as the southeastern United States, also offer good opportunities.

**Fuel Cell and Hydrogen Applications:** Military facilities offer a host of potential end-use applications for fuel cells and hydrogen, including vehicle fleets, ground support equipment, material handling equipment, backup and emergency power for mission-critical operations, and CHP. By clustering applications that can utilize the biogas or hydrogen generated from waste feedstock, and by identifying multiple positive cash flows for the WTE system products and by-products, project economics can be improved.

**Financing:** Because energy projects at DOD fixed installations have become increasingly reliant on third-party financing, DOD has developed a valuable body of experience and lessons learned using a variety of

contracting mechanisms, including ESCPs, EULs, and PPAs. DOD is currently the only federal agency authorized to issue 30-year PPAs, which increases the economic viability of a project by lowering the risk for an investor, providing the operator with a guaranteed long-term revenue stream, and generally lowering DOD's cost for electricity (versus the local utility provider). The 30-year PPA opportunity should be leveraged for WTE projects. Some states (e.g., Connecticut, California, New York, and Texas) provide special tax incentives for fuel cells, and capitalizing on these incentives as well as the federal tax incentive can improve project economics.

## Challenges

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The military must overcome a number of challenges before it can realize the full potential of WTE applications. Key challenges include the following:

- **Technical and performance issues**, such as WTE systems' high degree of complexity (they can be too complex for tactical operations), uncertain performance in comparison to incumbent technologies, and ability to handle non-homogeneity and seasonal variations in the moisture content of waste streams, as well as the need for further development and demonstration of gas purification systems, biorefining, and hydrogen delivery and distribution.
- **Cost challenges**, including the high cost of fuel cell and WTE conversion technologies, lengthy payback periods, and the lack of information on the full burdened cost of waste and a clear value proposition that could help justify WTE project costs.
- **Waste stream supply issues**, such as the variability and small size of the available waste streams on bases, the risks inherent in relying on external waste sources, and waste stream location (the best waste streams are not often colocated with the best fuel cell CHP applications).
- **Funding and financing issues**, including restrictions in government contracting; a lack of seed money for start-up projects; and the need for third-party financing for most projects, which adds basis points due to higher risk and complexity in light of the additional contract negotiations required.
- **Scale issues**, including the lack of small-scale, low-cost biomass gasifiers, pyrolysis units, gas cleanup, and other technologies that would enable development and deployment of compact, rugged, transportable systems for tactical operations.
- **A lack of support for decision making**, including a lack of defined and documented economic, environmental, and technology performance metrics to inform the decision-making process and states' varying definitions of municipal solid waste, biomass, and WTE.
- **The lack of specific project management expertise or resources** to successfully plan, finance, deploy, and manage WTE projects. These are complex projects that require special expertise and a significant amount of time to plan, fund, and execute.
- **Poor public perception** of municipal solid waste WTE facilities and a lack of public knowledge about fuel cells.



## Suggested Action Items and Next Steps

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Workshop participants had very little time to discuss specific opportunities for follow-up actions or next steps, but a number of opportunities were briefly identified, as presented below. These activities will be considered as DOE and DOD continue to collaborate under the DOD-DOE MOU. As described previously, DOE is already reviewing opportunities for WTE at ANG bases, and the following actions would help better define and evaluate the potential for WTE in military operations.

- **Identify appropriate candidates for WTE projects**, such as military installations with large residential populations that have on-base WWTPs and/or landfills; are engaged with neighboring communities from which waste streams could be sourced; have multiple applications for a project's fuel products; have facilities that can utilize CHP or that have mission-critical energy demands; or are located near biomass-rich resources such as agricultural, food processing, livestock, or forestry operations.
- **Identify opportunities where DOD can lead or influence** outside vendors to develop WTE projects in cases where an installation's waste disposal or treatment needs are currently handled by municipalities or private vendors.
- **Propose a WTE Working Group** to the DOD-DOE MOU Executive Committee at its initial meeting. The WTE Working Group would assist in developing the necessary knowledge base for project decision making and in coordinating and collaborating on the deployment of WTE at targeted facilities.
- **Develop a project screening tool** by convening a national laboratory group to develop technical and economic information for the tool, and include stakeholders such as utilities.
- **Develop a guidance document on third-party financing and contracting mechanisms** at federal sites.
- **Assess current fuel cell WTE demonstration projects** in both public and private operations and document lessons learned and best practices. Develop case studies on successful projects.
- **Host a workshop with DOD to determine next steps** in implementing a plan that would reach a 50% adoption rate across ANG. Further opportunities exist to leverage biowaste on site at other DOD facilities, which will also be explored in collaboration with DOD.<sup>26</sup>

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<sup>26</sup> Fuel Cell Technologies Program, *Report of the DOD-DOE Workshop on Fuel Cells in Aviation* (Washington, DC: U.S. Department of Energy, May 2011).

## Appendix A. Federal Energy Mandates Impacting the U.S. Army

Mandate Topic	Energy Performance Target (Source)
<b>Energy use in federal buildings</b>	Reduce 3% per year to total 30% by 2015 (2003 baseline) (Executive Order [EO] 13423, Energy Independence and Security Act [EISA] 2007)
<b>Greenhouse gas emission reduction</b>	Identify greenhouse gas emission reduction targets to be met by 2020 from 2008 baseline (EO 13514) Army target: 34% (Secretary of the Army memorandum to the Office of the Secretary of Defense)
<b>Energy metering for improved energy management</b>	Meter electricity by October 2012 (Energy Policy Act [EPACT] 2005) Meter natural gas and steam by October 2016 (EISA 2007)
<b>Electricity use for federal government from renewable sources</b>	At least 3% of total electricity consumption (fiscal year [FY] 2007–FY 2009), 5% (FY 2010–FY 2012), 7.5% (FY 2013+) (EPACT 2005, National Defense Authorization Act 2007)
<b>Total consumption from renewable sources</b>	At least 50% of required annual renewable energy consumed from “new” renewable sources (EO 13423) 25% by 2025, “Sense of Congress” (EISA 2007)
<b>Hot water in new and renovated federal buildings from solar power</b>	30% by 2015 if life cycle is cost effective (EISA 2007)
<b>Fossil fuel use in new and renovated federal buildings</b>	Reduce 55% by 2010; 100% by 2030 (EISA 2007)
<b>Net-zero buildings</b>	All new buildings that enter design in 2020 and after achieve net-zero energy by 2030 (EO 13514) New federal buildings achieve net zero by 2030 (EISA 2007)
<b>Fleet vehicle petroleum consumption</b>	Reduce 20% by 2015 (Base 2005) (EISA 2007) Reduce by 2% per year through FY 2020 (Base 2005) (EO 13423, EO 13514)
<b>Fleet vehicle alternative fuel use</b>	Increase 10% by 2015 (Base 2005) (EISA 2007) Increase by 10% annually to reach 100% (Base 2005) (EO 13423)
<b>Water consumption</b>	Reduce consumption intensity by 2% annually between FY 2008 and FY 2015 (2007 baseline) (EO 13423) Reduce consumption by 2% annually for 26% total by FY 2020 (2007 baseline) (EO 13514)

## Appendix B. Acronyms and Abbreviations

ANG	Air National Guard
Btu	British thermal unit
CHHP	combined heat, hydrogen, and power
CHP	combined heat and power
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
EISA	Energy Independence and Security Act
EO	Executive Order
EPACT	Energy Policy Act
ERDC-CERL	Engineer Research and Development Center, Construction Engineering Research Laboratory
ESPC	Energy Saving Performance Contract
EUL	enhanced use lease
FCHEA	Fuel Cell Hydrogen Energy Association
FCT	Fuel Cell Technologies Program
FY	fiscal year
GTI	Gas Technology Institute
JFTB	Joint Forces Training Base
kg	kilogram
kW	kilowatt
kWh	kilowatt-hour
MOU	memorandum of understanding
MT	metric ton
PPA	power purchase agreement
RNG	renewable natural gas
WTE	waste-to-energy
WWTP	wastewater treatment plant

## Appendix C. Participant List

Name	Organization
Ken Burt	U.S. Navy
Nathan Butler	U.S. Navy, Naval Facilities Engineering Command
John David Carter	Argonne National Laboratory
Daniela Caughron	U.S. Army
Steve Chalk	U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy
John Christensen	National Renewable Energy Laboratory
Deryn Chu	U.S. Army, Army Research Laboratory
Julius Coats Jr.	U.S. Army
Pete Devlin	U.S. Department of Energy, Fuel Cell Technologies Program
Harry Fair	Institute for Strategic and Innovative Technologies
Chinbay Fan	Gas Technology Institute
Ahmed Ferguson	United States Marine Corps
Karl Fryklind	HDR Incorporated
Leo Grassilli	U.S. Navy
Tom Gross	Logistics Management Institute
Bill Haris	U.S. Army, Tank Automotive Research, Development and Engineering Center
Jamie Holladay	Pacific Northwest National Laboratory
Nick Josefick	U.S. Army, Construction Engineering Research Laboratory
Jay Keller	Sandia National Laboratories
Marvin Kirshenbaum	Argonne National Laboratory
Shawna McQueen	Energetics Incorporated
Henry Molintas	U.S. Navy
Greg Moreland	SRA International
Dimitrios Papageorgopoulos	Fuel Cell Technologies Program, Office of Energy Efficiency and Renewable Energy
Rene Parker	Select Engineering Services
Leo Plonsky	Defense Logistics Agency
James Powers	U.S. Department of Energy

Name	Organization
Peter Protopappas	SRA International
Dave Reardon	HDR Inc.
Bob Remick	National Renewable Energy Laboratory
Xiaoming Ren	U.S. Army
Sunita Satyapal	U.S. Department of Energy, Fuel Cell Technologies Program
Shannon Sauter	U.S. Army, Fort Hood
Joette Sonnenberg	Savannah River National Laboratory
Dave Stinton	Oak Ridge National Laboratory
Bill Taylor	U.S. Navy
Fred Thielke	U.S. Department of Veterans Affairs
Ben Tongue	Lockheed Martin
Corinne Valkenburg	Biomass Program, Office of Energy Efficiency and Renewable Energy
Parul Volman	U.S. Army
Brian Weeks	Gas Technology Institute
Robert Westby	National Renewable Energy Laboratory
Frank Wolak	FuelCell Energy
Joe Wong	U.S. Department of Energy

## Appendix D. Raw Results of Breakout Sessions

The following tables include the “raw” output from the facilitated brainstorm discussion session of the workshop, during which participants recorded written responses to specific questions and posted them to a central “storyboard.”

Table D-1. Opportunities for Converting Waste-to-Energy Using Fuel Cells in Military Applications

Breakout Group #1	Breakout Group #2
<ul style="list-style-type: none"> <li>• Advertise concept as part of uninterrupted power or mission-critical solution.</li> <li>• Incorporate waste-to-energy (WTE) fuel cell projects into “net-zero water, energy, and waste” military base solutions.</li> <li>• Identify wastewater treatment plants (WWTPs), especially those that are owned by the military and have not been privatized.</li> <li>• Target installations with large residential populations to leverage waste streams such as municipal solid waste, sewage, and food waste for biogas conversion into fuel-cell-ready feedstock.</li> <li>• Identify the potential for U.S. Department of Defense (DOD) bases to collect biomass from neighboring communities in order to transform it into energy.</li> <li>• Leverage sites with existing landfills to harvest landfill gas.</li> <li>• Convert office paper and cardboard collected on base into energy.</li> <li>• Collect and convert municipal biomass such as landscaping waste, wood chips, and construction debris.</li> <li>• Team with the U.S. Environmental Protection Agency AgSTAR program to convert agricultural solid waste (e.g., manure) into fuel cell feedstock.</li> <li>• Collect and convert black liquor (spent cooking oil) from mess halls.</li> <li>• Use in combined heat, hydrogen, and power (CHHP) scenarios, such as WWTPs.</li> <li>• Consider tapping waste heat from Navy gas turbines to produce CHHP.</li> <li>• Improve waste streams on bases, segregate waste products for easy conversion to fuel.</li> <li>• Convert port-dumped waste that currently represents a security risk.</li> <li>• Convert shipboard plastic, paper, cardboard, and solid sludge into usable gases.</li> <li>• Leverage submarine plastic waste that is currently dumped at port.</li> <li>• Hill Air Force Base: <ul style="list-style-type: none"> <li>○ Expand project to include fuel cell applications and hydrogen infrastructure.</li> <li>○ Hill Air Force Base appears similar to the BMW facility in South Carolina.</li> </ul> </li> <li>• Use waste from algal bio-oil production for energy</li> </ul>	<ul style="list-style-type: none"> <li>• Explore ways to leverage and utilize community compost heaps for fuel cell WTE projects.</li> <li>• Examine opportunities to utilize shipboard food waste as fuel for fuel cell WTE projects.</li> <li>• Identify and develop fuel cell WTE projects for baseload power generation.</li> <li>• Identify opportunities at U.S. Department of Veterans Affairs hospitals for fuel cell WTE projects.</li> <li>• Identify military installations located in states with tax incentives that promote fuel cell WTE projects (e.g., California, New York, Connecticut, and Texas).</li> <li>• Leverage DOD installations that currently utilize renewable energy technologies (e.g., 29 Palms in California).</li> <li>• Identify and leverage DOD installations with mandated forestry biomass management.</li> <li>• Leverage the landfill at Marine Corps Base Quantico. The landfill has closed and presents an opportunity for fuel cell WTE projects.</li> <li>• Utilize waste streams for Hawaiian military installations for hydrogen, power, and heat. Benefits include reducing Hawaii’s petroleum use, thus reducing Hawaii’s electricity costs.</li> <li>• Identify fuel cell WTE opportunities near U.S. Department of Energy (DOE)-supported coal gasification sites.</li> <li>• Identify biomass-rich DOD installations, particularly in the United States Northwest and Southeast, where woody biomass is widespread (e.g., perimeter clearing, family housing, and facility training).</li> <li>• Investigate if Los Alamitos is still receiving certified green waste from the surrounding community of Los Alamitos.</li> <li>• Leverage and identify opportunities in San Diego, California, because of stringent California Air Resources Board requirements and a favorable command structure.</li> <li>• Evaluate the strengths and weaknesses of existing fuel cell WTE projects to identify lessons learned and best practices.</li> <li>• Develop case studies to accelerate commercialization of gasification, gas conditioning (cleanup), and high-temperature fuel cells combined heat and power.</li> <li>• Identify locations where existing waste-based fuel resources are not being utilized (e.g., vented).</li> </ul>



Breakout Group #1	Breakout Group #2
<p>production.</p> <ul style="list-style-type: none"> <li>• Investigate use of volatile organic compounds or solvents as waste products for fuel cell feedstocks.</li> <li>• Convert shipboard waste oil into fuel for fuel cells.</li> <li>• Leverage the potential for cost reduction opportunities in tactical operations or foreign operations using fuel cells.</li> </ul>	<ul style="list-style-type: none"> <li>• Leverage stationary fuel cells that can produce water for on site use.</li> <li>• Identify multiple positive cash flows that can result from wasted energy such as waste power and heat, and by-products such as ash and hydrogen.</li> <li>• Leverage and display a full suite of solutions from fuel cell WTE projects (e.g., hydrogen for vehicles, material handling equipment, and ground support equipment).</li> <li>• Leverage potential carbon credit sales to finance fuel cell WTE projects.</li> <li>• Leverage food waste and wastewater at sites identified for fuel cell WTE projects.</li> <li>• Leverage lessons learned from private sector fuel cell WTE projects.</li> <li>• Facilitate federal interagency communications, including the dissemination of “wins” and lessons learned from fuel cell WTE projects.</li> <li>• Enhance return on investment (ROI) of fuel cell WTE projects by focusing deployment at facilities that need reliable power and heat (e.g., hospitals, laboratories, and food processing plants).</li> <li>• Examine the possibility of installing WTE fuel cells at Fort Hood hospital. Hospital construction begins in the summer or fall of 2011.</li> <li>• Target areas like San Antonio, Texas, where there are multiple military installations.</li> <li>• Leverage DOD’s ability to issue 30-year power purchase agreements.</li> <li>• Remember to include all biomass and waste landfill gas resources.</li> <li>• Explore strategies to reduce fuel cell installation costs.</li> <li>• Identify DOD installations with the multiple characteristics that make WTE attractive.</li> <li>• Create Venn diagram (decision matrix) using challenges and financing options.</li> <li>• Identify what kind of ROI is reasonable or needed; show that ROI of WTE system is not too long.</li> <li>• Leverage the closing DOD landfill in the Virgin Islands and identify areas in Puerto Rico where electricity prices reach \$0.50/kilowatt-hour.</li> <li>• Identify opportunities for DOD-DOE partnering to provide web-based tools.</li> <li>• Pursue DOD collaboration with local communities to supplement waste to ensure economies of a project.</li> </ul>

Table D-2. Challenges to Converting Waste-to-Energy Using Fuel Cells in Military Applications

Breakout Group #1: Challenges	Breakout Group #2: Challenges
<ul style="list-style-type: none"> <li>• Projects often do not proceed because there is no plan for moving forward from a feasibility study or funding plan.</li> <li>• Pyro-gasifiers for biofuels are more than net-zero energy.</li> <li>• There is a need for a “broker” to help put deals together; currently this is a complex process that requires special expertise and lots of time to put the pieces and partners together.</li> <li>• Need for centralized expertise, financial management, and project development—there is a lot of uncharted territory.</li> <li>• Cost is a barrier, seed money is needed to get projects off the ground (e.g., for feasibility studies and development of implementation plans).</li> <li>• Lack of a clear economic incentive and projects have long payback periods.</li> <li>• We do not have monetary values for mission-critical functions (e.g., safety, security, and environment). <ul style="list-style-type: none"> <li>○ Difficult to monetize intangibles and externalities.</li> <li>○ Difficult to develop the “burdened cost” of waste, which could help justify project costs.</li> </ul> </li> <li>• Lack of value proposition versus incumbent technologies. <ul style="list-style-type: none"> <li>○ There is a perception of technology risk (e.g., lack of performance guarantee).</li> </ul> </li> <li>• Every state defines or incentivizes municipal solid waste, biomass, and WTE differently.</li> <li>• Size is an issue for tactical operations—must be compact, ruggedized, and transportable.</li> <li>• There are risks to relying on external sources of feedstock (for off site sourcing).</li> <li>• The amount of waste streams on bases is not enough to make a big impact on total energy use.</li> <li>• Lack of small-scale, low-cost gasifier, pyrolysis cleanup, etc.</li> <li>• Current systems are too complex—they will need to be simpler for tactical operations.</li> </ul>	<ul style="list-style-type: none"> <li>• Current waste streams are not usable or easily converted to fuel cell feedstocks.</li> <li>• Unpredictable quantities of waste.</li> <li>• Difficult to find ways to monetize benefits of fuel cell WTE projects.</li> <li>• Restrictions in government contracting, including the Federal Acquisition Regulation.</li> <li>• Waste streams are not colocated with the best fuel cell combined heat and power applications.</li> <li>• Negative public perception of municipal solid waste WTE facilities.</li> <li>• Difficult to initiate interagency communication between DOD (e.g., Ft. Hood) and DOE entities.</li> <li>• Due to the risks of fuel cells, WTE projects financing basis points being added versus conventional technologies.</li> <li>• Competing goals—waste minimization versus WTE.</li> </ul>