# IV.E.4 Analysis of $H_2$ Storage Needs for Early Market Non-Motive Fuel Cell Applications


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## Fiscal Year (FY) 2011 Objectives

- Engage end users in the airport ground support equipment (GSE), portable power, construction equipment, telecom power, and "man-portable" electronics industries to understand what pieces of their non-motive equipment would be good early market introduction points for fuel cells.
- From the engagements above, and with the highest priority equipment identified, determine how the equipment is used and their current requirements for power, duration, gravimetric and volumetric energy densities, as well as the required operating conditions (temperature, etc.).

## Technical Barriers

This project addresses the following technical barriers assigned to this project:

(A) System Weight and Volume

(B) Cost

(C) Efficiency

## Technical Targets

Data from early markets will allow DOE to determine the technical targets and research and development (R&D) needs for hydrogen storage that would enable the use of fuel cells for early market non-motive applications.

## FY 2011 Accomplishments

- Identified highest priority pieces of non-motive equipment in portable power, aviation GSE, construction equipment, cell phone backup power and portable electronics industries.
- Identified how that high priority equipment uses energy, the associated energy densities (gravimetric, volumetric), and what the environmental requirements are (temperature, etc.) for their use.
- Conducted extensive questionnaire surveys of end users and new technology experts about the use of current equipment and therefore the requirements for a new clean technology replacement.
- Held workshop at Sandia-CA, attended by end users of non-motive equipment in the construction industry, telecommunications, entertainment, portable power and aviation industries, as well as the Air Force.

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## Introduction

Historically the DOE has funded a great deal of work on hydrogen storage. Most of this hydrogen storage R&D has focused on hydrogen storage for light-duty vehicle applications. However, recently DOE has expanded the scope of its fuel cell technology interests to include non-motive early market applications of fuel cells. By non-motive equipment, we mean equipment that is not driven directly by a human being (i.e. does not possess a steering wheel). The equipment is either stationary, or, if portable, it is carried or towed by a person or vehicle. Examples of non-motive equipment included portable power generators, air compressors, airport luggage belt loaders (an example of aviation GSE) and backup power systems for cell phone towers. Additionally, the DOE is interested in how fuel cells might be used as power sources in "man portable" electronic systems, and what the implications are for the hydrogen storage required for using fuel cells for man-portable electronics.

It is highly likely that the hydrogen storage needs for non-motive uses of fuel cells are different than the well-known hydrogen storage needs for light-duty vehicle applications. In order for the DOE to understand the eventual hydrogen storage needs for non-motive fuel cell use, it's important to understand what the highest priority pieces of equipment are in the non-motive equipment realm that would best be suited for conversion to fuel cell power. Additionally, it is vital to fully understand how this non-motive equipment is actually used and what the demands are on the energy system. Toward that end, the goals of this project are to engage end-users, technical experts and manufacturing experts in various non-motive equipment realms, identify the highest priority pieces of equipment in each one of those realms, and understand in detail how that equipment is used. By understanding how that equipment is used currently, the DOE can better understand where the hydrogen storage performance gaps truly are if hydrogen-fueled fuel cell-based non-motive equipment were to meet or exceed the capabilities of the current equipment.

## Approach

To gather this information, we approached end-users, technical experts and mass manufacturers in the following areas: construction equipment, portable power, telecommunications, aviation, and portable electronics. A database of representatives in these markets was generated. Our initial step was to host a workshop at Sandia National Laboratories, Livermore, California on February 8, 2011. The workshop was attended by representatives from the construction equipment, portable power, telecommunications and aviation markets. In aviation, Department of Defense representatives from Travis Air Force Base were also present. During this workshop, the attendees were surveyed with multiple questionnaires to help identify how equipment is used in their respective realms. Also at this workshop, break-out sessions were held to extract the highest priority pieces of equipment in each one of these non-motive early markets, so that specific non-motive pieces of equipment were identified. After the workshop, the results of the surveys were quantified using a Kano-type analysis. In addition, selected representatives of the four areas were contacted again to gain a quantitative understanding, for the highest priority equipment items, of how this non-motive equipment is actually used and what the demands are on the energy system. Furthermore, a quantitative understanding of the operational requirements was gathered.

The portable electronics realm was not covered at the workshop. However this market was engaged after the workshop, using existing contacts in this market provided by the DOE, and also our own research in this area. Similarly, the highest priority portable electronic uses were identified by engaging the man-portable power industry (both end users and manufacturers), and gaining a quantitative understanding of what the needs are for power, duration, frequency of use, and environmental durability if fuel cells were to meet or exceed the capabilities of the current (typically battery-based) portable electronics power systems.

## Results

A picture of the attendees for the Sandia-CA workshop held on 2/8/2011 is shown in Figure 1. In all, 22 “end-users” and nine “technology experts” attended the workshop. There were a total of 40 attendees. In the morning the attendees heard fuel cell technology presentations from DOE (Scott McWhorter) and Sandia (Lennie Klebanoff). For the remainder of the morning, the group heard presentations on uses of equipment in construction (Torsten Erbel, Multiquip), entertainment (Russ Saunders, Saunders Electric), telecommunications (Kevin Kenny, Sprint) and in aviation ground support (Roger Hooson, San Francisco International Airport). In the afternoon, break-out sessions were held in the areas of construction equipment, portable power, aviation GSE, and telecom backup power. For each breakout session, we sought to identify the top three highest-priority pieces of equipment to target in each category, and for each one solicit information on the following questions: Who is using it?, How is it being used?, What are the environmental and worksite conditions?, What are the performance requirements?, What is the cost sensitivity?, What works well now, what doesn’t, what could be improved?

From the breakout sessions, the highest priority pieces of equipment were found to be:

**Aviation GSE**

1. 5–10 kW power generators, the power basis for light towers, light crosses, light ropes, and hand tools. These

**FIGURE 1.** Workshop Attendees Visiting Sandia-CA on February 8, 2011

were identified as high priority because there are so many of them. These are typically Honda gasoline generators.

2. 90–120 kW portable power based on diesel generators and turbine systems for aircraft electrical support and engine start.
3. Heater carts, run on diesel, 400,000 Btu, 160 hp, used to heat the interiors of aircraft during maintenance. It is important to heat the aircraft during maintenance periods because one cannot allow condensation on the avionics during maintenance.

Some key pieces of learning from the Aviation GSE breakout session were that such equipment is very cost sensitive, the end-users have little desire to pay extra for fuel cell versions. This group also stated that although the fuel cell life cycle savings over diesel equipment carries weight, that argument has a time horizon of only five years or less.

**Portable Power**

This breakout session identified the following high-priority pieces of equipment:

1. 2–6.5 kW: gasoline generator replacement
2. 60–100 kW: diesel generator replacement
3. 3–5 kW: office trailer generator

Some key learning from this group are that only 2,500 hours of operational life are expected for current small units (~5 kW). In addition, while the capital expense for small generator sets is currently $400-$600/kW, the yearly operating expense can be $700/kW. So the current diesel equipment is very expensive to maintain and operate.

**Telecom Backup Power**

In this realm, the highest priority item is a 5–30 kW backup power system. Some key learning from this area are that cell phone towers are often placed in very high density areas, making the footprint of a fuel cell-based backup power system very critical.

**Construction Equipment**

This breakout session identified the following high-priority pieces of equipment:

1. Lighting: Light towers, portable message boards, remote message boards, arrow signs. These are ubiquitous items, currently diesel-powered.
2. Air Compressors: Noisy, much room for improvement of this technology.
3. Scissor Lifts: Want quiet, non-polluting equipment, and more reliable than battery-based.

Some key learning from this breakout session are that construction equipment is very cost sensitive. Lifecycle costs, even project-cycle costs are considered. Furthermore, construction equipment must be very durable. The attendees indicated that because fuel cells "load follow", and only generate power to meet the load demanded, this "smart technology" aspect may be a way for a fuel cell system to gain acceptance faster.

The questionnaires were analyzed using the Kano methodology. An example of how the Kano methodology was used is shown in Figure 2. The question being asked is: "How would you feel if this equipment could be refueled quickly?" In this example, the collection of data points in

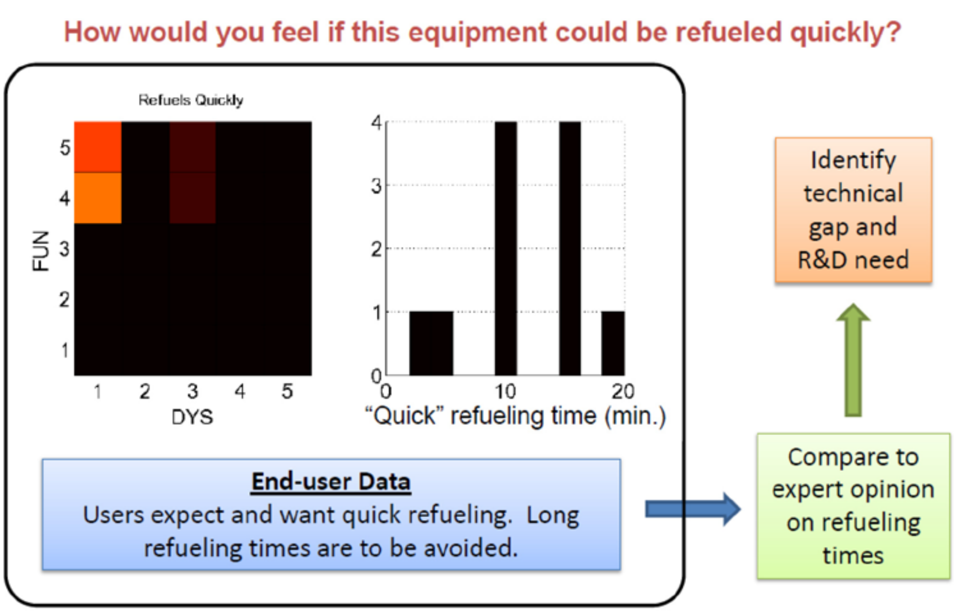


**FIGURE 2.** Figure Describing an Example Use of Kano Methodology in Extracting Information from Surveys

the upper-left corner of the left-hand figure reveals that end-users not only want quick refueling times, but expect it. That means if refueling times are long, they will be dissatisfied with the equipment. The right-hand figure shows how the end-users define “quick” in terms of number of minutes needed to refuel a tank. Overall, the conclusion is that a hydrogen fuel tank needs to be able to be refueled in about 10–15 minutes or less to gain user acceptance. This data can then be compared to the capability of current hydrogen storage technology to see if improvements in actual refueling times are needed.

**Work is ongoing collecting similar market feedback from the portable electronics community.**

## Conclusions and Future Directions

We have engaged end-users, manufacturers and technology experts in the non-motive equipment realms of construction equipment, portable power, aviation GSE and portable electronics. We have identified high-priority early market non-motive pieces of equipment that would benefit by conversion to fuel cell operation. We have gained a quantitative understanding of the energy requirements for these items, how they are used, and what the environmental requirements are. With this information, the DOE will be able to identify the performance gaps in current hydrogen storage technology that would allow fuel cells to be used in these early market non-motive applications.

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