SAND2011-1758C

Analysis of H_2 Storage Needs for Early Market Non-motive Fuel Cell Applications

Project ID # ST096

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Project Overview

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Timeline

Project start date: 11/1/2010

Project end date: 9/30/2011

Percent complete: 45%

Partners

- NREL, PNNL
- Equipment End Users (Viking Steel, Southwest Airlines, Paramount, etc.)
- Hydrogen Technology Experts (Ovonic Hydrogen Systems, Linde Gas, Lincoln Composites, etc.)

Barriers (H_2 Storage)

A. System Weight & Volume

B. Cost

C. Efficiency

D. Durability

E. Charge/discharge rates

F. Lifecycle assessments

Budget

Total project funding:

- DOE share: $300,000
- Contractor share: $0

NREL: National Renewable Energy Laboratory; PNNL: Pacific Northwest National Laboratory

Relevance

- DOE is including in the scope of its H_2 storage program early market uses of fuel cells in non-motive applications:
  A. Construction equipment
  B. Telecom backup
  C. Portable power
  D. Airport ground support equipment
- DOE wants to understand the H_2 storage performance gaps that hinder fuel cell use in these pieces of equipment.

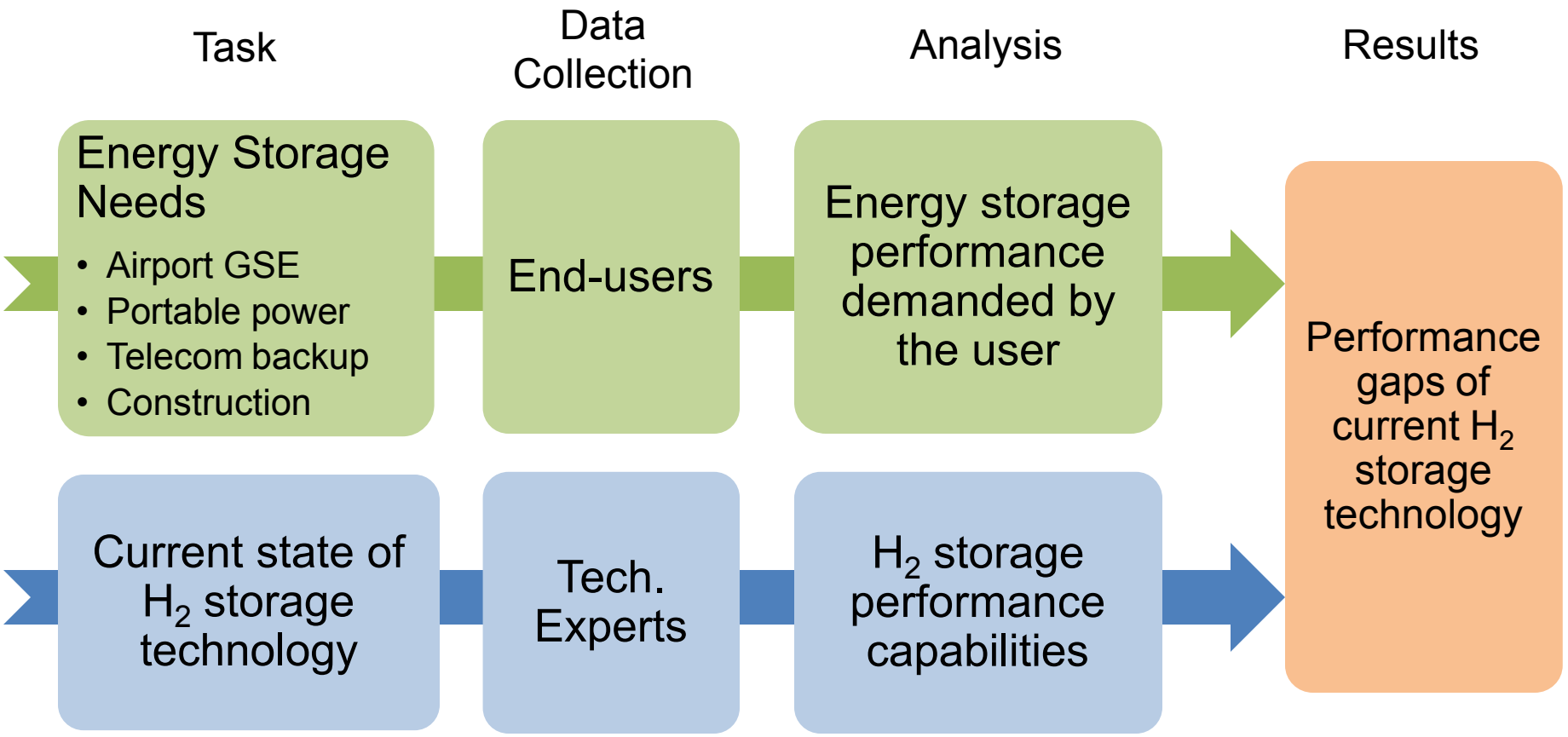

A


B


C


D

General Approach



GSE: Ground Support Equipment

Data Collection: Workshop

End-User Workshop at Sandia National Laboratories
Livermore Valley Open Campus (LVOC), Feb. 8, 2011

Agenda:

- Morning presentations on DOE H2 Program, H2 Technology, Portable Power, Construction Equipment, Airport Ground Support Equipment (GSE), Cell Tower Backup Power.
- Afternoon Breakout Sessions identifying high-priority equipment and their use.
- End user and manufacturer questionnaires.

22 "End Users"
9 "Tech. Experts"

Workshop Breakout Sessions

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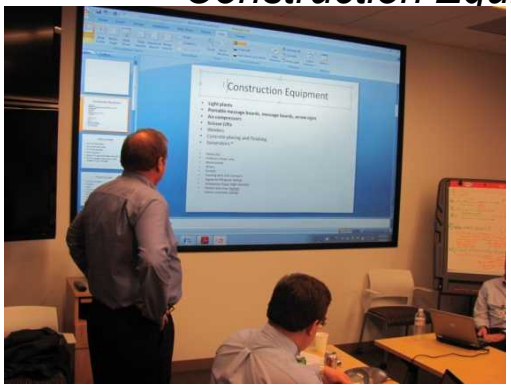
Four concurrent breakout sessions to interactively identify:

- ❖ Top 3 pieces of equipment to target in each category, and for each one:
- 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?

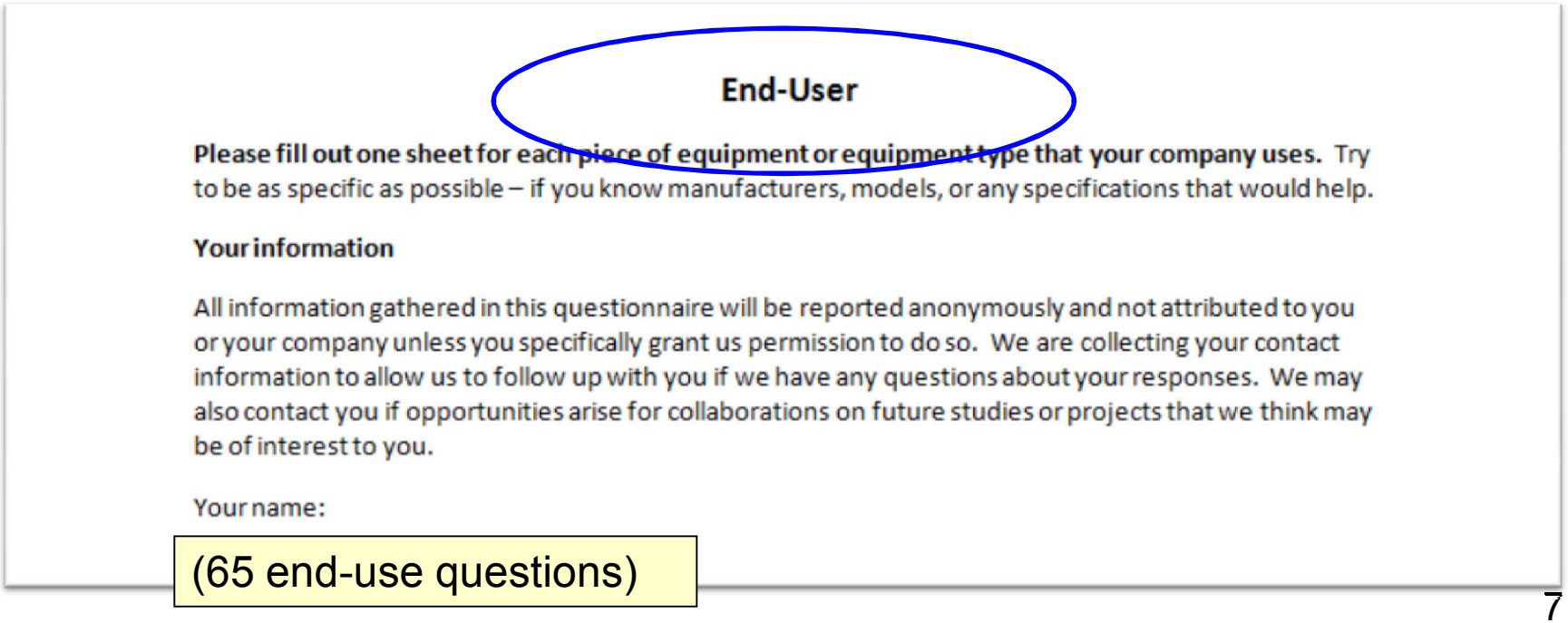
End users summarize their breakout sessions for the group:

Construction Equipment *Portable Power* *Telecom Backup* *Airport GSE*



Questionnaire: End-User

- "End User": those who use, supply, or manufacture construction equipment, portable power, telecom backup power, or airport ground support equipment
- Goal: Identify current high-priority equipment, understand how the equipment is used.



End-User

Please fill out one sheet for each piece of equipment or equipment type that your company uses. Try to be as specific as possible – if you know manufacturers, models, or any specifications that would help.

Your information

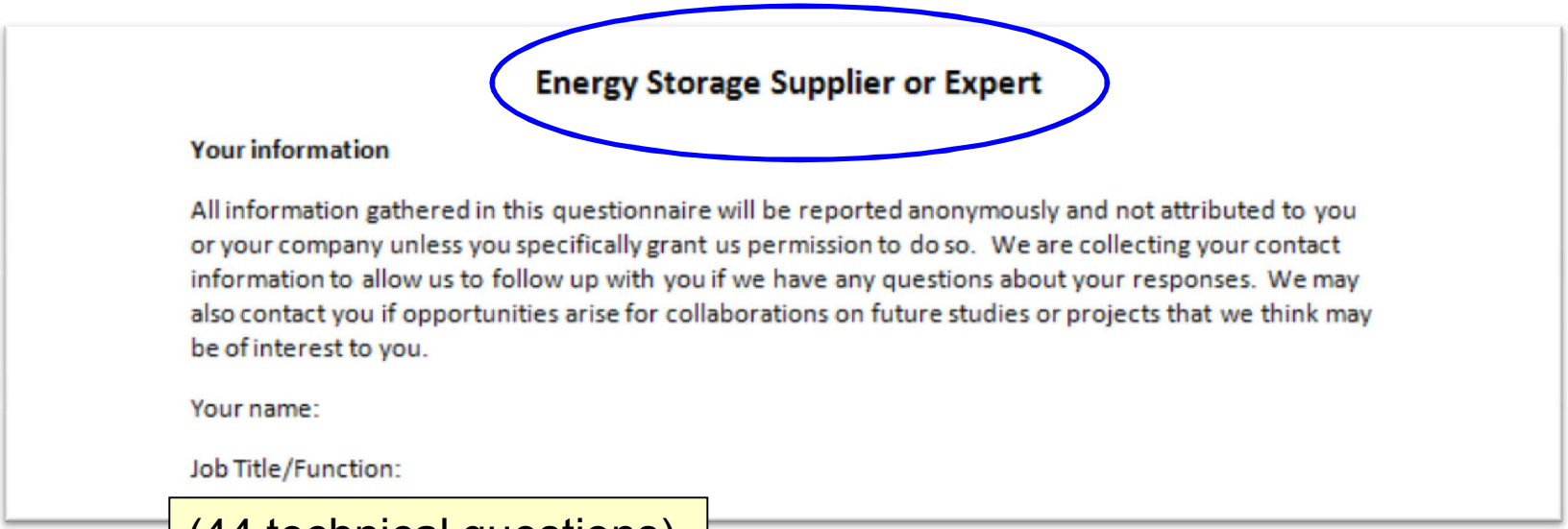
All information gathered in this questionnaire will be reported anonymously and not attributed to you or your company unless you specifically grant us permission to do so. We are collecting your contact information to allow us to follow up with you if we have any questions about your responses. We may also contact you if opportunities arise for collaborations on future studies or projects that we think may be of interest to you.

Your name:

(65 end-use questions)

Questionnaire: Tech Expert

- "Tech Expert": Hydrogen storage manufacturers, researchers, or others familiar with the technical details of hydrogen storage.
- Goal: gather opinions and information about current capabilities of hydrogen storage technology.



Energy Storage Supplier or Expert

Your information

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Your name:

Job Title/Function:

(44 technical questions)

Data Collection: Post-Workshop

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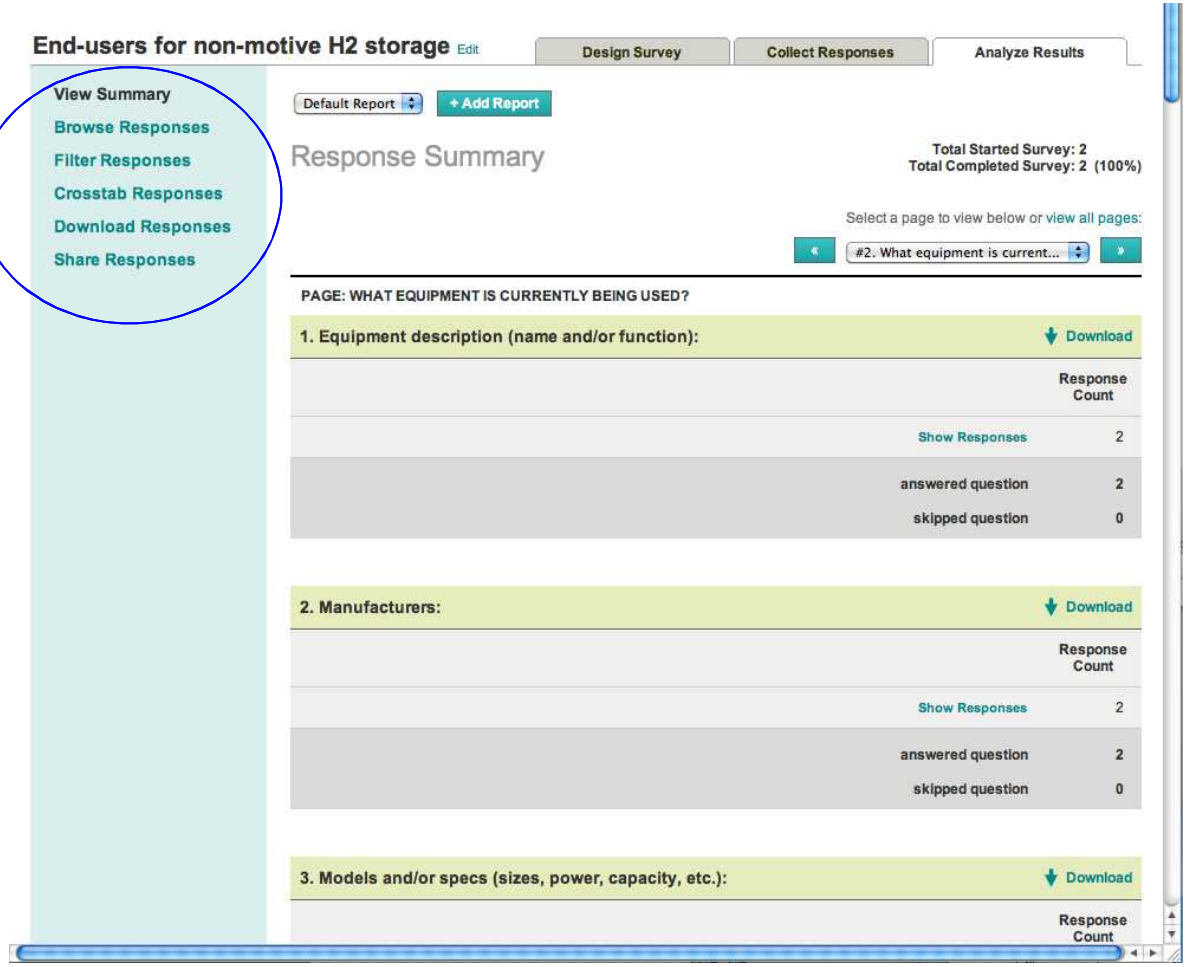
Using the internet, information can be exported in Excel and .csv format for post-processing at Sandia



Targeted information gathering addresses disconnect between priority equipment and in-hand information.

Using Kano Model

A way to characterize customer satisfaction. Distinguishes between required, linearly satisfied, and "wow" characteristics.

15. How would you feel if this equipment: Was rarely in the shop for maintenance or repairs?

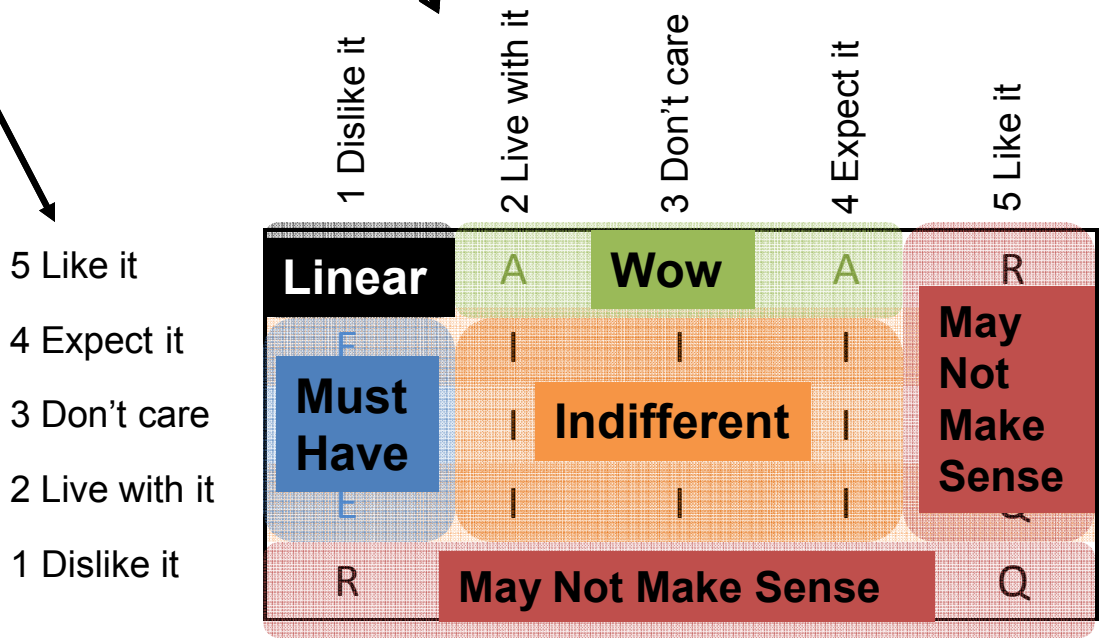
◯ Like it ◯ Expect it ◯ Don't Care ◯ Live with it ◯ Dislike it

"Functional Question"

16. How would you feel if this equipment: Required frequent maintenance or repairs?

◯ Like it ◯ Expect it ◯ Don't Care ◯ Live with it ◯ Dislike it

"Dysfunctional Question"



Use of Kano method inspired by NREL, using their Matlab code to compile results.

Analysis: Example

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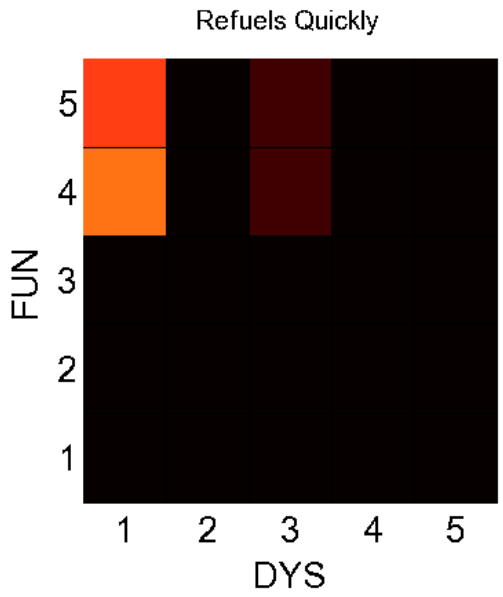
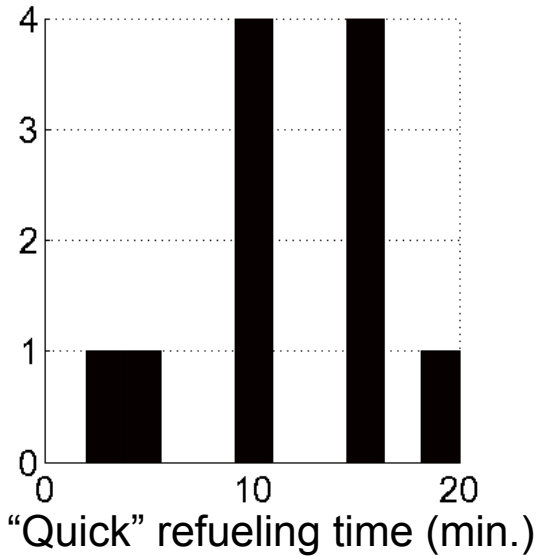
How would you feel if this equipment could be refueled quickly?





End-user Data

Users expect and want quick refueling. Long refueling times are to be avoided.

Compare to expert opinion on refueling times

Identify technical gap and R&D need

Note: FUN = functional question
DYS = dysfunctional question

Analysis: Open-Ended Questions

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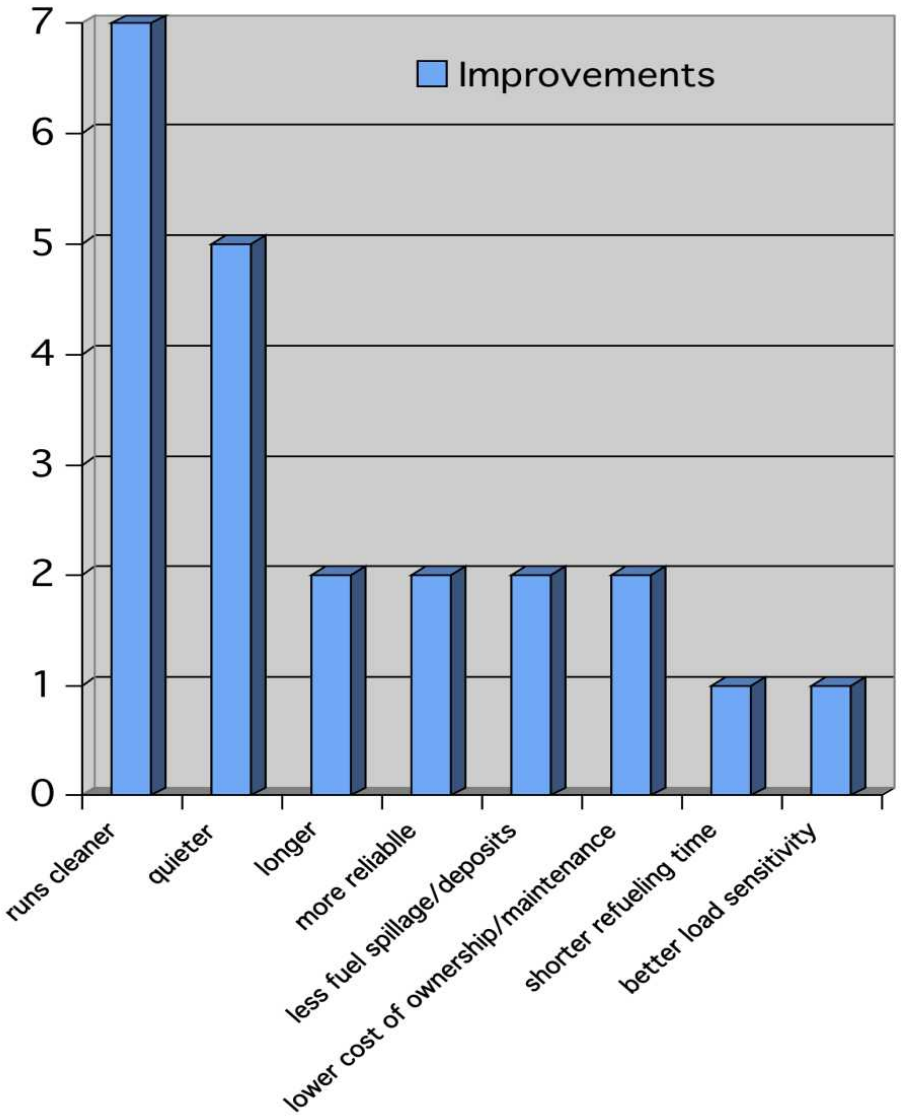
Q. #63: Thinking about all the problems you have with this equipment, which ones would you like to see improved the most?



In this example, findings show importance of low emissions and quiet operation. This type of question helps identify the important issues and focus the study.

Stakeholder Resources

- Database currently has 55 “members”
  - 37 end users
  - 18 experts (fuel cell and storage manufacturers, H_2 infrastructure, researchers)
- At the workshop (31)
  - 22 End-users
  - 9 Experts
- Received questionnaires at the workshop (19)
  - 14 End-users
  - 5 Experts
- Database grows with each collaboration activity.
  - For example, roughly 10 more relevant end-users from Military Energy Alternatives workshop.
- Database and contact actions shared between the three labs (SNL, NREL, and PNNL).

Collaborations & Other Activities

- We collaborate with NREL (motive equipment study) and PNNL (Technical Readiness Assessment study) via:
  - Regular telecons.
  - Shared resources (SharePoint site).
  - Co-developing questionnaires, approaches, sharing information, coordinating contacts, etc.
- NREL workshop at FCHEA Meeting, Feb. 16, 2011
  - Not very fruitful due to “motive” composition of attendees.
- 6th Annual Military Energy Alternatives Conference workshop, Feb. 24, 2011
  - Assisted DOE (Ned Stetson) in leading H_2 storage workshop.
  - Helpful, identified portable power as having widespread interest in military applications.

FCHEA: Fuel Cell and Hydrogen Energy Association

Schedule: First Four Months

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December:

- ✓ Events: PowerGen Orlando, attend and invite stakeholders to Feb. 8 workshop.
- ✓ Tasks: Develop approach, compile stakeholders, begin organizing workshop, review current storage status.

January

- ✓ Tasks: Prepare for workshop, develop stakeholder RFI.

February

- ✓ Events: Stakeholder workshop at Livermore Valley Open Campus (LVOC) Feb. 8. Attend FCHEA meeting in Washington D.C. Feb. 14-16 with NREL.
- ✓ Tasks: Conduct workshop, distribute RFI, collect responses; web-based RFI established by March 1. Start to analyze responses.

March

- Events: Prepare AMR presentation, present workshop results to DOE
- Tasks: Collecting information, analyzing responses, determining needs, begin determining hydrogen storage performance gaps.

RFI: Request for Information; AMR: Annual Merit Review

Schedule: Final Five Months

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April

- Tasks: Have the workshop results, applications, and requirements identified. Determine hydrogen storage performance gaps.

May

- Events: AMR
- Tasks: Reporting, determine hydrogen storage performance gaps.

June

- Tasks: Reporting, submit draft report to partners for their review.

July

- Tasks: Receive feedback from partners. Re-analysis based on feedback.

August

- Tasks: Reporting, submit final report.

Summary

- **Workshop provided a good start for gathering information from End Users and Tech Experts:**
  - Guidance and focus through breakout sessions
  - Hard data through questionnaires
  - Both end-user and technical experts queried
  - Proved valuable both for us and the participants
- **Questionnaire processing reveals:**
  - Trends in how equipment is used
  - Missing information in our current data set
- **Our growing database along with targeted follow-up will fill in the missing information.**
- **Collaboration with NREL and PNNL helpful.**
- **Maintaining original schedule.**

Technical Back-Up Slides

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List of Technical Back-Up Slides

1. Three-Lab Approach

<u>Feb. 8 Workshop Details:</u>

2. Breakout A: Airport GSE
3. Breakout B: Portable Power
4. Breakout C: Telecom Backup
5. Breakout D: Construction Equipment

Three-Lab Approach

National Renewable Energy Laboratory:

- Motive Equipment
- PI: Jennifer Kurtz

Sandia National Laboratories:

- Non-motive Equipment
- PI: Lennie Klebanoff

Pacific Northwest National Laboratory:

- Technical Readiness Assessment
- PI: Ewa Rönnebro

H_2 Storage Needs for Early Market Applications

Lab cooperation leverages strengths and increases efficiency, producing a complete product for the DOE.

Breakout A: Airport GSE

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Top 3 Priority Pieces of Equipment:

1. **5 – 10 kW power generators**, the power basis for light towers, light crosses, light ropes, and hand tools. High priority because there are so many of them. 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, to heat the interiors of aircraft during maintenance.

Roger Hooson (SFO) summarizes GSE breakout results

Other Key Learning:

- Equipment very cost sensitive, little desire to pay extra for fuel cell versions
- The fuel cell life cycle savings over diesel equipment carries weight, but is limited to about 5 years or less in horizon.

GSE: Ground Support Equipment

Breakout B: Portable Power

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Top 3 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

Other Key Learning:

- Just 2500 hr lifetimes expected on small units
- Refueled once per day
- Diesel while operating, gasoline must turn off
- Motion picture sets require ~50db or remotely located with long cords
- Capital expense for small gen sets $400-$600/kW
- Operating expense up to $700/kW/yr
- Difficult to operate at low load = wet stacking
- Low load continues to consume 30-40% fuel

Russ Saunders (Saunders Electric) reports portable power breakout results

Breakout C: Telecom Backup

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Top Priority Piece of Equipment:

5 kW – 30 kW battery or fossil-fuel generator replacements: FCC-mandated to maintain power at telecom towers.

Other Key Learning:

- Cost sensitive: 2 - 3 year payback required.
- Economic analysis needed to show benefits of emission reduction between competing technologies, show differential life cycle costs, in financial language understood by industry.
- Sometimes located in dense, urban areas. Code setback requirements for H_2 storage not likely to be met as-is.
- Fueling is big concern, both current (spills) and future (availability of H_2 and getting to a remote site in emergency conditions).

Kevin Kenny (Sprint) reports backup power breakout results

Breakout D: Construction Equip.

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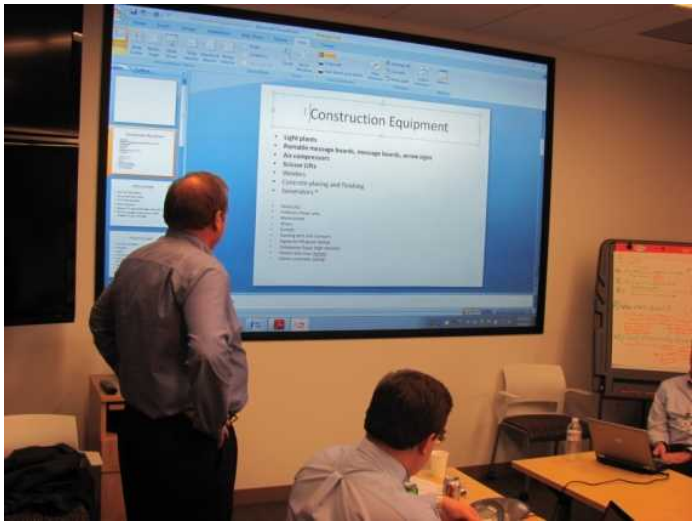
Top 3 Priority Pieces of Equipment:

1. **Lighting**: Light towers, portable message boards, remote message boards, arrow signs: Ubiquitous, diesel-powered
2. **Air compressors**: Noisy, much room for improvement
3. **Scissor lifts**: Want quiet, non-polluting, and more reliable than battery



Torsten Erbel (Multiquip) reports construction equipment breakout results

Other Key Learning:

- Equipment very cost sensitive. Lifecycle costs, even project-cycle costs are considered
- Construction and road equipment must be very durable.
- Using less energy via “smart” technology (e.g., load following) may be a way for a new system to gain acceptance.