SuperGrid 2 Breakout Session:

Hydrogen R&D Applicable To The SuperGrid

Panel Members:

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Seven Issues/Topics Were Discussed and Summarized:

1. **Trade-Off Analyses Needed**
2. **H2 Production Methods**
3. **H2 Piping And Distribution Equipment And Components**
4. **H2 Storage Systems Applicable To The SuperGrid**
5. **SuperGrid Public Acceptance and Training of Staff/Students**
6. **H2 Commercial Applications/Commercial use of SuperGrid**
7. **From the H2 perspective, Analyze Start-Up And Shut-Down Issues Of The SuperGrid**

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Component:

1. Trade-Off Analyses Needed (Part Of Macro-Scoping Study Needed) To Determine Phase Of Hydrogen 'Best' Appropriate To SuperGrid

Goals –
Determine if liquid or gaseous H2 is preferred. This tradeoff analysis should be performed, at a miniumum, as a function of type of superconductor used, technology available, economics, safety, para vs ortho H2 content.

R & D Needs –
a) Determine spec's for H2 phase, temp., pressure, flow-rate, and cost of equipment, efficiency, and tradeoff curves/tables are to be determined.

b) Also needed are test experiments to determine/verify performance of H2 cooled superconductors that use gas versus liquid phases of hydrogen.

Current Technical Activities

- **What is being Done: virtually, none**
- **Who/Where: Not applicable**
- **Important References: Paul Grant slides at SuperGrid 2 Workshop and website materials on Paul Grant's web page.**

Suggested R &D

- **Level of Effort Estimate ($/years?):**

a) **2M over one year is needed for the scoping study. The H2 part of this scoping study is about 300k. These scoping studies have an estimated period of performance of 1 year.**
b) **Test experiments of H2 gas and H2 liquid cooled systems : 5M over 2 years**

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2. **Hydrogen Production Methods Will Have To Be Developed And Tested That Produce H2 By Large Scale, Medium Scale, And Small Scales Systems; e.g.,**
   - **a) H2 Production Via Fossil Sources (CH4, Oil, Coal);**
   - **b) H2 Production Via Renewables (Biomass, Hydro, Wind, Solar, Algae)**
   - **c) H2 Production Via Nuclear (Look Into The Sulfur Iodide (SI) Process And The Calcium Bromine Process (CA-Br) Process.**
   - **d) H2 Production Via Electrolysis (High Temperature Electrolysis, And Standard Temperature Electrolysis).**

Goals –
Determine/develop, and test preferred designs for the production of H2 via "a, b, c and d, above.

R & D Needs –
Determine spec's for each production method above, its efficiency, cost, and maintenance requirements. Also look into CO2 capture and sequestration; H2 separation via absorption membranes.

Current Technical Activities

- **What is being Done: some studies to develop and test various H2 production methods. Idaho National Lab is looking into the SI process and Argonne Lab is looking into the Ca-Br process. These are 2 of the "127" processes that have been identified for using nuclear processes to generating H2.**
- **Who/Where: various DOE labs are doing some of this work. Details will have to be determined via interviews/calls with DOE staff and DOE lab staff.**
- **Important References: Guess is numerous references are available. Details will have to be determined via interviews/calls with DOE staff and DOE lab staff.**
- **All the above work is related to Hydrogen Economy work by DOE and other agencies in the US and foreign organizations. What needs to be looked into is the preferred hydrogen production systems that are applicable to the SuperGrid (i.e., Nuclear generation and high/medium pressure electrolysis systems) in**

the long term and H2 production in the short term (e.g., steam reforming of methane and low pressure electrolysis systems).

Suggested R &D

- **Level of Effort Estimate ($/years?):**

a) **H2 Production development and testing: 100M over 5 years. Include in this work CO2 capture and sequestration. The portion of these costs directly related to the SuperGrid is likely 10M of the 100M quoted above. Also evaluate the other "127" chemical methods to produce H2.**
b) **Test experiments of H2 gas and H2 liquid cooled systems: 50M over 5 years. The portion of these costs directly related to the SuperGrid is likely 5M over 5 years. This work should also assess corrosion issues.**
c) **R&D and prototype testing of electrolysis methods will require about 1M/yr now and about 20M/yr for all the testing needed. Electrode development efforts will require about 20M over 5 years. High pressure concentrator cell development and testing will require about 20M over 5 years.**

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3. Hydrogen Piping And Distribution Equipment And Components

Goals –
Determine/develop, and test preferred designs for H2 piping and distribution equipment/components.

R & D Needs –
a) Assess existing pipelines and issues/R&D topics to be investigated.
b) Materials: assess design, performance and maintenance issues of liquid and gas piping and distribution systems. Look the following areas, at a minimum: imbrittlement, seals, valves, joints, coating.
c) Leak detection and location methods/devices
d) Trade-off studies of how low a pressure is a H2 pipeline viable.

Current Technical Activities

- **What is being Done: See above a, b, c and d.**
- **Who/Where: Various DOE labs are doing some of this work. Details will have to be determined via interviews/calls with DOE staff and DOE lab staff.**
- **Important References: The guess is that numerous references are available. Details will have to be determined via interviews/calls with DOE staff and DOE lab staff.**
- **All the above work is related to Hydrogen Economy work by DOE and other agencies in the US and foreign organizations. What needs to be looked into is the preferred hydrogen pipeline distribution systems that are applicable to the SuperGrid**

Suggested R &D

- **Level of Effort Estimate ($/years?):**

a) **200k over 1 year**
b) **20M over 5 years**
c) **100k/yr for two years**
d) **200k over one year.**

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4. Hydrogen Storage Systems Applicable To The SuperGrid

Goals –
Determine/develop, and test preferred designs for H2 storage applicable to the SuperGrid.

R & D Needs –
a) Assess existing H2 storage methods applicable to the SuperGrid (i.e., low temperature H2 gas and H2 liquid storage methods, which need to be focused on the SuperGrid pipes used as the storage medium by operating the pipes at about a 10% increase/decrease over their nominal piping pressure). Also look into the H2 storage system needed for SuperGrid startup and maintenance activities.
b) Perform design, development and testing of H2 storage applicable to the SuperGrid, which has to consider large scale storage.

Current Technical Activities

- **What is being Done: Very little, if at all**
- **Who/Where: Virtually nobody**
- **Important References: many references are available for storage systems related to H2 vehicles, but virtually none are available applicable to the SuperGrid.**

Suggested R &D

- **Level of Effort Estimate ($/years?):**

a) **200k over 1 year (note: DOE is spending about 30M in '04 on storage related to vehicle applications.**
b) **2M/yr for about 5 years.**

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5. SuperGrid Public Acceptance and Training of Staff/Students

Goals –
Build and achieve public acceptance of the SuperGrid into all of the SuperGrid R&D activities "from day 1"

R & D Needs –
a) Develop public acceptance strategy / approach for each of the R&D phases deployed.
b) Train utility staff and students to participate in and be a part of the SuperGrid development process

Current Technical Activities

- **What is being Done: Very little, if at all**
- **Who/Where: Virtually nobody**
- **Important References: None**

Suggested R &D

- **Level of Effort Estimate ($/years?):**

a) **5M/yr for about 10 years**
b) **100M/yr for 20 years (spread over e.g., Universities, National Labs, NSF, and College/Graduate School scholarships)**

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Component:

6. Hydrogen Commercial Applications/Commercial use of SuperGrid

Goals –
Evaluate and promote commercial applications/uses associated with the development/operation of the SuperGrid

R & D Needs –
a) Develop/evaluate the benefits of putting spokes of the SuperGrid next to H2 highways, next to oil/gas refineries, pharmaceutical plants. Alter designs of SuperGrid to be sure these potential uses/applications are promoted.
b) Determine commercial use of oxygen from H2 electrolyzers and alter/update design of high pressure electrolyzers to take advantage of this commercial application of the SuperGrid

Current Technical Activities

- **What is being Done: Very little, if at all**
- **Who/Where: Virtually nobody**
- **Important References: None**

Suggested R &D

- **Level of Effort Estimate ($/years?):**

a) **200k/yr for about 2 years**
b) **200k/yr for 2 years**

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Component:

7. From the Hydrogen Perspective, Analyze Start-Up And Shut-Down Issues Of The SuperGrid

Goals –
Evaluate start-up and shut-down issues under normal and emergency conditions, from the H2 perspective.
Note: this effort needs to be done on the superconductor and many other components of the SuperGrid.

R & D Needs –
a) Assess/evaluate start-up/shut-down time and equipment needed to start and stop the SuperGrid for the first time and other times. This may impact the design of the SuperGrid in significant ways if start and/or normal shutdown time periods are too long (e.g., months).
b) Assess/evaluate start-up and shut down issues associated with emergency conditions (e.g., grid outages that cause SuperGrid spokes to be put into a forced outage, and SuperGrid outages that will send transients onto the local grid it is connected to). These events need to include vacuum system failures, inverter failures, ground faults, short circuits from the superconductor through the hydrogen cryogen, piping failures, superconductor failures, lightning strikes, earthquakes, etc.). Change design of SuperGrid to respond to emergency energy 'dump' scenarios (e.g., after an earthquake, lightning strike). This effort needs to include a complete FMEA analysis (i.e., failure modes and effects analyses).

Based on the results of tests of critical components that will impact normal and emergency outages, the design of the SuperGrid will likely change in important ways not originally expected.

Current Technical Activities

- **What is being Done: Very little, if at all**
- **Who/Where: Virtually nobody**
- **Important References: None**

Suggested R &D

- **Level of Effort Estimate ($/years?):**

a) **4M/yr for about 10 years. Based on test results, this budget may have to be increased by factors of 2 or 3.**
b) **8M/yr for 10 years**
c) **Note: Based on test results, this budget may have to be increased by factors of 2 or 3.**