Thermal Energy

Breakout Session

April 3, 2012

Discussion Points

- **Base Thermal Generation**
  - Reactor Concepts / Modularization
  - Fossil and Renewable Concepts
- **Thermal Energy Transport**
  - Heat Deposition to Process
  - Thermal Hydraulics
  - Heat Exchange
  - Heat Upgrading
- **Thermal Energy Storage**
- **Chemical Energy Conversion**
  - Hydrogen Generation
  - Liquid Fuel Production
  - Fossil Fuel Extraction and Processing
- **Materials & Equipment Fabrication**
  - High Temperature Systems
  - Component Fabrication

What problem are we trying to solve?

What is the MARKET size for each "problem"?

- Dictates R&D funds available

What can be uniquely solved by hybrid energy systems?

Problems to address:

- **Need for hydrogen production**
  - Clean process (reduced GHG emissions)
  - Consider resource needs / availability (i.e. water)
- **Uprating of fuels**
- **Shale oil extraction – huge market**
- **Increased efficiency**
- **Multi-purpose reactors: Entry of nuclear energy into the transportation industry**

Research Objectives

- Carbon free electricity production
- Improved fossil energy use
- Infrastructure development for large-scale production of a commodity that can be transported, stored and used as a feedstock in a carbon-free fashion

Base Thermal Generation

- **Reactor selection cannot be custom for a given process**
- **Generally assume steady state only: Desire to place flexibility downstream of reactor (chemical plant or thermal storage)**
- **Resource utilization / siting needs**
- **Trade study:**
  Address what concepts are feasible when coupled with energy storage and chemical applications (consider dynamic linkages)
- **Trade study:**
  Thermally coupling of various reactor types to different processes – economics, licensing, risk assessment, technical issues, siting…
- **Low temperature generation: (nearer term applications)**
  - Possibly more closely coupled than high T generation systems
  - **Gap:** Is the heat of sufficient quality for desired tasks?
  - **Gap:** Temperature upgrading
- **High temperature generation:**
  - Higher efficiency
  - Possibility for air cooling
  - **Gap:** Efficient heat transmission

Thermal Energy Transport

- **Thermal coupling**
  - Importance of thermal interface – possible scaled demonstration of thermal coupling solutions?
- **Need a clear understanding of customer needs, market needs**
- **Heat upgrading trade study: Methods to increase steam temperature to enable more process applications**
- **Different technology routes depending on scale of the operation**
- **Heat exchanger designs**
- **Working fluid characterization**
- **Feedback / sub-system interaction**
  - Nuclear plant – chemical plant feedback and sub-system prioritorization (NPP – grid – CP)
  - Safety issues, licensing mandates
- **Possible early demonstration:**
  Nuclear plant coupled to a chemical process (single input / single output)

Thermal Energy Storage

- **What is the thermal energy storage capacity requirement?**
- **<u>General Requirements</u>**
  - Enable load following
  - Maintain consistent reactor inlet temperature
  - Match sub-system time constants (energy storage, reactor, chemical plant, grid)
  - Provide high density storage medium (e.g. liquid hydrocarbons)
- **Possible solutions**
  - Molten salts as storage medium (leverage solar thermal programs)
  - Phase change materials with high heat capacity
- **Research Areas:**
  - Thermal storage systems specifically coupled to a reactor
  - Development of highly dense storage systems

Chemical Energy Conversion

- **Negative electric prices (i.e. paying the grid for power) – what can we do with the excess electricity?**
- **Reduce capital cost of processes**
- **Commodity production and storage – what makes sense?**
  - Methanol, ammonia, hydrogen, syncrude…

Research Areas:

- **Hydrogen generation for multiple applications**
- **Hydrogen storage and transport (gas vs. liquid)**
- **Electrolysis (QC, cell durability, scale-up, on-line maintenance)**
  - GOAL: Reduce capital costs for electrolyzers
- **CO production**
  - CO_2 source?
- **Liquid Fuel Production**
  - Require H_2 for higher density fuel and syngas production
- **Fossil Fuel Extraction and Processing**

Materials and Equipment Fabrication

- **High temperature systems face increased materials challenges**
- **Concern: Material availability and qualification**

- **Research areas:**
  - Working fluids:
    - Analysis of working fluid chemistry and properties and effect of structural materials
    - Process control – impurities, chemistry control
    - Freeze-thaw issues for some working fluids (i.e. molten salts)
  - Heat exchanger design (conventional vs. advanced)
    - Stress-corrosion cracking
    - Design reliability
  - Equipment for heat transport over long distances

Identified Key Research Areas

- **NHES sub-system interfaces – specific focus on coupling**
  - Thermal coupling of different reactor concepts
  - Dynamic links for different reactor designs
- **Economics and technical challenges of transporting heat (high vs. low T, distances)**
- **Thermal storage options – requirements, scalability for demonstration (high volume to surface area ratio)**
- **Parametric and sensitivity study for working fluid selection, material compatibility**
- **Integrated system operations to demonstrate system coupling solutions, thermal energy transfer, storage, etc.**
  - What can be learned from a small-scale hardware demonstration?
  - What is the scalability of sub-systems?
  - What will provide reasonable accuracy / understanding of system operation?

Priority Research Areas

- **Equipment Coupling**
- **Thermal Energy Storage – coupling to a nuclear reactor (consideration of temperature and capacity)**
- **Methods for efficient carbon-free hydrogen production (sustainable and economical)**
- **Methods to exploit excess heat / excess electricity**
- **Heat transfer fluid development, characterization**