HTGR Potential Market and Preliminary Economics

Briefing for
Nuclear Energy Advisory Committee

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Outline

- Potential market for HTGR produced energy
- Evaluations of HTGRs integrated with industrial processes
- Possible business model for HTGR process heat to industry
- Economic analyses for industrial applications
- Conclusions and uncertainties
Energy Production and Consumption in U.S. – the Potential Market

U.S. Primary Energy Flow by Source and Sector, 2009
(Quad -- Quadrillion (1x10^15) Btu)

Supply Sources
- Petroleum 35.3
- Natural Gas 23.4
- Coal 19.7
- Renewable Energy 7.7
- Nuclear Electric Power 8.1

Demand Sectors
- Transportation
- Industrial
- Residential & Commercial
- Electric Power

U.S. Greenhouse Gas Emissions by Sector, 2009
(Million metric tons, CO2 equivalent
AEO 2010, May 2010)

- Transportation 1845 Mt
- Industrial 1034 Mt
- Residential 1194 Mt
- Commercial 1434 Mt

5507 Mt Total

Notes:
1. Does not include biofuels that have been blended with petroleum – biofuels are included in “Renewable Energy.”
2. Excludes supplemental gaseous fuels.
3. Includes less than 0.1 quadrillion Btu of coal coke net exports.
4. Includes conventional hydroelectric power, geothermal, solar/PV, wind, and biomass.
5. Includes industrial combined -heat-and-power (CHP) and industrial electricity -only plants.
6. Includes commercial combined -heat-and-power (CHP) and commercial electricity -only plants.
7. Includes commercial electricity -only and combined -heat-and-power (CHP) plants whose primary business is to sell electricity, or electricity and heat, to the public.

Vulnerabilities of fossil fuel consumption (83% of today’s energy consumption in US)

- Price volatility
- Reliance on imports
- GHG emissions
- Use of natural resources
Industrial Applications – the Principal Market

The Opportunity — Providing High Temperature Process Heat and Electricity without Burning Hydrocarbon Fuels

- Petrochemical (170 plants in U.S. – 6.7 quads*)
- Petroleum Refining (137 plant in U.S. – 3.7 quads)
- Fertilizers/Ammonia (23 plants in U.S. – 0.3 quads NH3 production)
- Coal-to-Liquids (24 – 100,000 bpd new plants) Project 250 GWth HTGR application
- Hydrogen Production (60 – 600 MWe HTGR Modules)
- Oil Sands/Shale (43 – 600 MWe HTGR Modules)

* Quad = $10^{15}$ Btu (293 MM MWth) annual energy consumption
Thermal Power Requirements for Postulated Market

Scoping evaluations performed for HTGR technology in industrial sector

- 75,000 MWth Co-Generation Supply of Process Heat to Industrial Processes
  (25% of Process Heat & Power, including electricity)

- 36,000 MWth for Production of Hydrogen
  (25% of growth in the merchant market)

- 25,800 MWth for Oil Sands Bitumen Recovery
  (25% of projected growth in energy required to extract & upgrade bitumen)

- 249,000 MWth for Coal to Transportation Fuels
  (Reduces imports by 25% of 2009 imports of crude oil – 9.1 MMBPD)

- 110,400 MWth for Electricity Production
  (10% of the nuclear electrical supply increase required to achieve pending Government objectives for emissions reductions by 2050)
Postulated Deployment of HTGR Results in Stable Energy Prices, Secure Source and Reduced Emissions

Natural Gas and Crude Oil Prices exhibit high volatility

HTGR Energy Prices affected only by normal inflationary factors, (e.g., wages, material)
Emissions Reductions

CO2 emissions are reduced by ~400 million metric tons by 2050; ~7% of pending Government objective

Natural Gas Conservation

Reduce Oil Imports by 25% of 2009 Rate

Reduces the need to import oil by ~2.5 million barrels per day (on an energy equivalent basis). Outflow of US dollars reduced by $150 million per day (based on an average $60/BBL price)

Natural gas combustion is reduced by ~7 trillion scf by 2050; ~30% of U.S. consumption in 2009
Evaluations of HTGR Integration with Industrial Processes

- Co-Generation Supply of Steam, Electricity and High Temperature Gas
- Ammonia and Ammonia Derivatives Production
- Hydrogen Production
- Conversion of Coal and Natural Gas to Transportation Fuels
- Oil Recovery from Oil Sands and Oil Shale
- Electricity Production
Possible Business Model

Contract with Regional Grid for purchase of excess electrical power

Long term purchase energy agreement

Energy
60 year lifetime Minimal GHG emissions Stable price Secure supply

Owner

HTGR Plant

Owner

Industrial Facility

Potentially more than one facility, owner & agreement
Electricity and Steam Production

Electricity Production Price Versus Price of Natural Gas, $/Mwhe, and Carbon Credits, $/metric ton CO₂ eq
Comparison of Production Pricing for HTGR and CCGT Plants

Comparing Price of Steam Generated by an HTGR and a CCGT versus Price of Natural Gas and Cost of GHG Emissions

Economic Factors

- **HTGR Plant Capital Cost**: $1,700/KWt
- **CCGT Capital Cost**: $625/KWt
- **Debt**: 80%
- **Internal Rate of Return**: 15%
- **Financing Interest**: 8%
- **Financing Term**: 20 years
- **Tax Rate**: 38.9%
Conversion of Coal to Gasoline (MTG Process)

Gasoline Production Price versus Crude Oil Price
Conventional Crude Oil Refining versus Coal to MTG using Conventional and HTGR Integrated Processes

Comparison of Gasoline Pricing for Conventional versus HTGR Integrated Coal to Gasoline Conversion

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Ammonia Production

Comparison of Ammonia Pricing for Conventional and HTGR Integrated Processes

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Conclusions

• A large and viable potential market has been identified
• The economics of each application have been scoped
• The economic viability of applications is mixed & dependent on assumptions, (e.g., policy for CO₂ emissions)
• There is large uncertainty in the results of the economic evaluations:
  – Capital costs
  – Operating costs
  – Financing
• Design work is needed to improve cost estimates
• Market evaluations to date were to establish end-user technical requirements – detailed market study is required