International Partnership For A Near-Term Advanced Reactor Deployment: Process Heat, Electric Power, Hydrogen Production

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An International Team Is Being Formed for Near-Term Advanced Reactor Integrated Energy System Deployment

- Why?
- What?
- Who?
- How?
- Where?
- Some things to consider

Why Advanced Reactors?

- Better safety, efficiency, versatility, etc.
- Even greater potential to reduce carbon emissions
- But costs, time frames and current market conditions make deploying even “ready to go” advanced reactors VERY HARD

Crowded Advanced Reactor Landscape

- Several types of advanced reactors including:
  - Gas-Cooled Fast Reactor
  - Molten Salt Reactor
  - Sodium-Cooled Fast Reactor
  - Lead-Cooled Fast Reactor
  - Supercritical Water-Cooled Reactor
  - High Temperature Gas Cooled Reactor (HTGR)
- All have attractive characteristics with potentially very significant advantages over today's LWRs
- Large pent up demand for RD&D

NGNP Industry Alliance Is Focused on Having HTGR Demonstration Plant Built

- Alliance promotes the development and commercialization of the HTGR
- Created in response to Energy Policy Act of 2005 authorization of NGNP Project
- Alliance currently executing projects to:
  - Update HTGR Business Plan & evaluate US sites for Advanced Reactors
  - Quantify conservatism in analysis of HTGR depressurization event
  - Catalyze a near-term International HTGR Initiative

SOUTHERN COMPANY

TECHNOLOGY INSIGHTS

AREVA forward-looking energy

Southern Ohio Asset Recovery LLC

TOYO TANSO Inspiration for Innovation

SGL GROUP THE CARBON COMPANY

EXCEL SERVICES CORPORATION NUCLEAR ENGINEERING CONSULTING

High Expectations INTERNATIONAL LLC

US ULTRA SAFE NUCLEAR

UTPB

Manufacturing Excellence Consulting, Inc.

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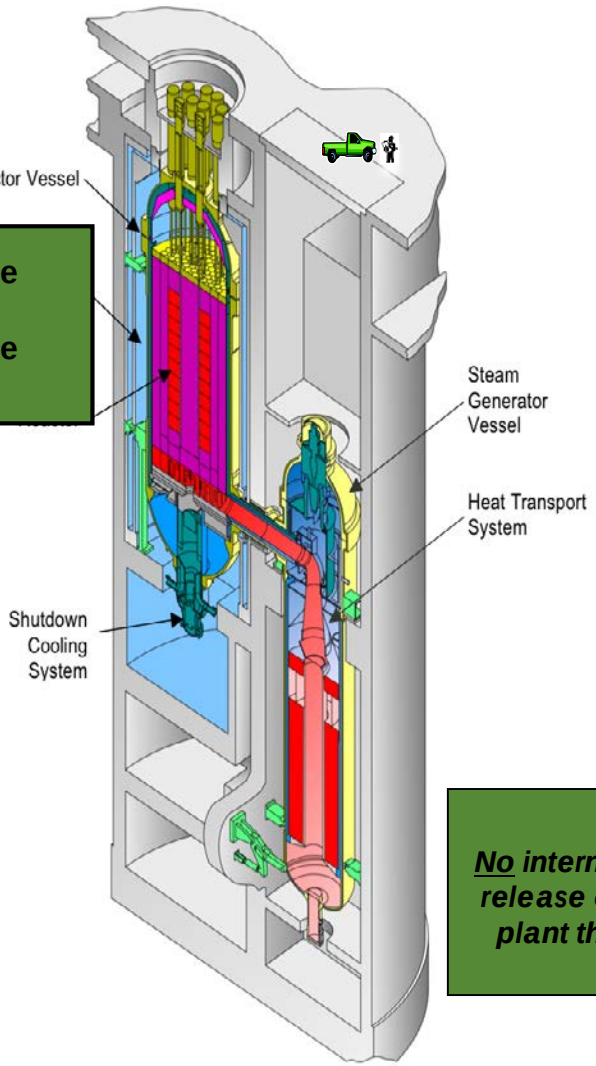
The HTGR

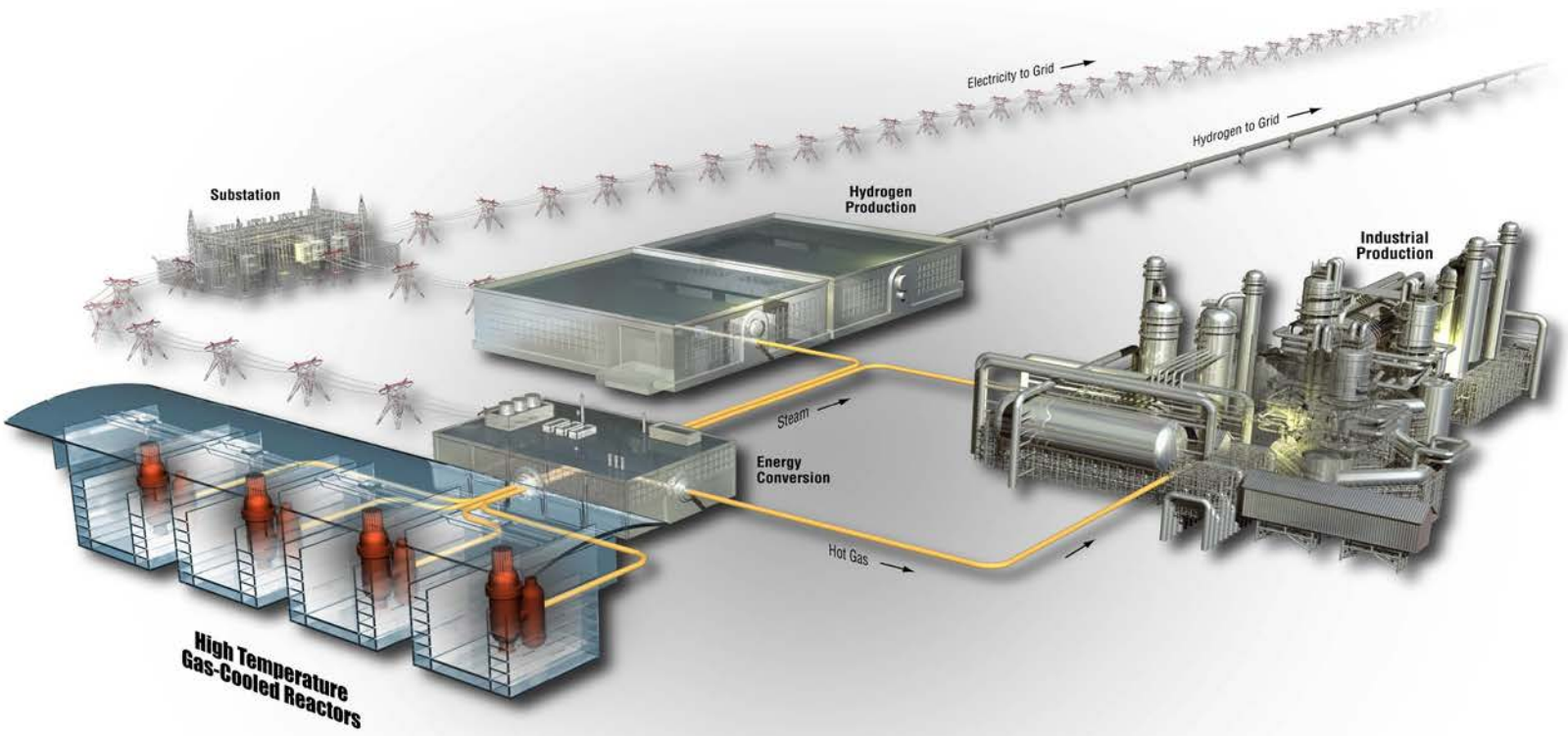


325°C Core Inlet
750°C Core Outlet

Intrinsically Safe –
***No* internal or external event can lead to release of radioactive material from the plant that endangers the safety of the public**

- **Intrinsic safety features**
  - The intrinsic safety allows collocation or proximate location with major industrial facilities
    - Requires no operator intervention to be safe
    - Requires no active or passive safety systems
    - Spent fuel is air cooled
- **Carbon free process heat can be be applied to large number of industrial processes:**
  - Substitute for the combustion of fossil fuels such as natural gas in production of process heat and electricity
  - Process heat and electricity in conversion of indigenous carbon resources to liquid transportation fuels and chemicals
  - Use of the HTGR technology for a process heat source results in:
    - Long term stable energy prices
    - Long term secure and independent source of energy (direct and through conversion)
    - Minimal greenhouse gas and other emissions

HTGR-Centered Integrated Energy System



North American Electrical & Process Heat Markets and Potential Emission Reductions Are Huge

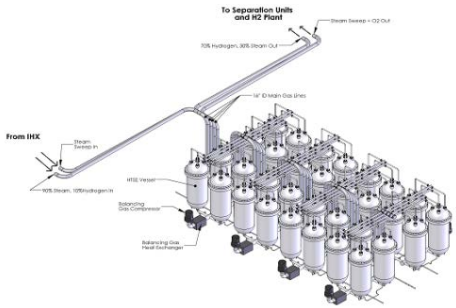
Existing Plants – Assuming 25% penetration of process heat & power market - - - 2.7 quads*

Fertilizers/Ammonia
(23 plants in U.S.–NH3 production)

Petrochemical
(170 plants in U.S.)

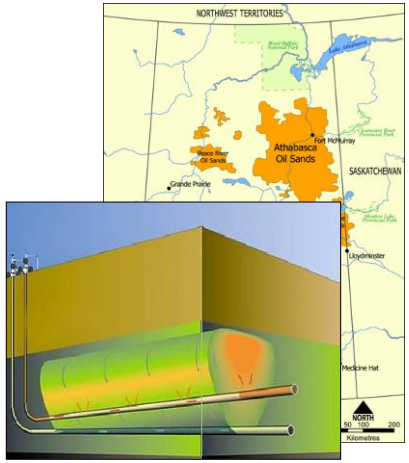
Petroleum Refining
(137 plants in U.S.)

Growing and New Markets – Potential for 9.3 quads of HTGR Process Heat & Power



Hydrogen Production

Coal-to-Liquids (24 – 100,000 bpd new plants)



Oil Sands/Shale

** Quad = 1x10^{15} Btu (293 x 10^{6} MW$_{th}$) annual energy consumption*

International: Why?

- Previous lack of U.S. success in completing domestic advanced reactor projects.
- "Going international" makes sense:
  - Sharing of costs
  - More compelling case for Congress and Executive Branch – strategic partners and national security
  - Helps maintain and stabilize required long-term (10-15 years) government funding
  - Decreases risks / increases technical expertise and available test facilities and technology
  - Increases markets
- Partner countries have similar incentives
- Pave way for other advanced reactor types – Success Begets Success

The Time Is Right

- International need for emissions reductions
- Modern HTGRs are technically mature – ready to deploy
- HTGR programs in multiple countries
- Japanese, Korean, EU and U.S. interest in similar design
- FOAK commercial demo costs exceed what any one country is currently willing to do
- In U.S. – early HTGR can ”exercise” a modernized licensing regime for all advanced reactors & other nations can benefit from this experience

The Four Parties

NGNP Industry Alliance
Industry group created to move HTGRs forward in the U.S. Considerable U.S. HTGR experience and recent R&D

Japan Atomic Energy Agency
Substantial historic and current HTGR and H2 experience including the HTTR Test Reactor

Korean Atomic Energy Research Institute
Substantial historic and current HTGR and H2 experience

Poland and EU's Nuclear Cogeneration Industrial Initiative
Both with strong interest in nuclear industrial process heat. Considerable EU HTGR historic experience

Fundamentals of International HTGR Project / Enterprise

- **Four nations participate in a near-term FOAK prismatic block 750 degree C steam cycle HTGR deployment:**
  - **U.S. and Poland siting**
  - **Japan and Korea participate as precursor to higher temps and H2 production**
- **Government-led four nation development program for more advanced HTGR (and advanced reactor) technologies**
- Open and collaborative process amongst the government and non-government parties to define, structure and solidify support
- Very successful, well attended first plenary meeting this past March (2016) with ongoing follow up by all parties.

HTGR Based IES Siting: U.S. and Poland

- Current U.S. sites being evaluated:
  - **Piketon / Portsmouth, Ohio** – possible focus on CTL, H2, process heat
  - **Odessa/Midland, Texas** – integration with Texas Clean Energy program or enhanced oil recovery / desalination
  - **Southeastern U.S.** – specific site TBD
  - **Idaho Falls** – possible focus on CTL, H2

- Poland focus on chemical site

Some General Issues

- "Actor mismatch": all partners will need substantial government support, but government is much more the "first mover" with EU, Japan and Korea
- U.S. government complexity and "fear of commitment"
- Ensuring effective project management structure
- Avoiding, if possible, years of negotiations on treaty-like intergovernmental agreements
- Ensuring that cost savings aren't eroded by potential inefficiencies of an international project itself
- Negotiating the details: work scopes, cost shares, IP, etc.

But, the will and interest is there: these things will be addressed.

Actions and Milestones

- Agreement on draft Terms of Reference in coming weeks
- Private investment sources being sought
- Partners working with respective governments
- 2nd Plenary meeting in fall, 2016
- Signing of MOU or TOR document in fall, 2016
- Begin early project funding in 2017

Recap: International HTGR Based Integrated Energy System

- Why?
  - Reduces costs and should increase government interest, funding stability and markets
  - HTGRs mature with strong international alignment
- What / Where?
  - Near term 750C degree international HTGR demos in U.S. and Poland
  - Longer-term government enterprise for higher temperatures and H2 production
- Who? U.S., Japan, Korea and EU
- How? Common purpose, open ongoing communications, flexibility, industry/government balance and responsiveness

Thank You

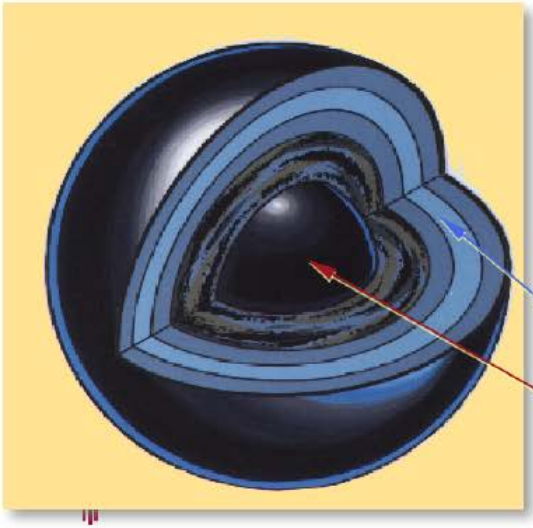
For more information:

www.ngnpalliance.org

Search under "Resources"

Backup Slides

Prismatic Reactor Core



TRISO Coated Fuel Particles:

- ***Lots of cladding - extremely strong***
- ***Little fuel - fully encapsulated***

Each fuel particle forms a separate pressure containment vessel for the kernel (to 1000 atm)

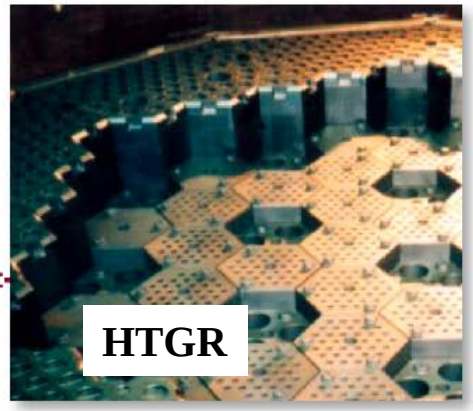
Ceramic Coatings

Fuel Kernel (U, Pu, Th, TRU)

PARTICLES

COMPACTS

FUEL BLOCK



MHR CORE

Prismatic concept illustrated - Pebble Bed variant also possible

Generic U.S. Licensing Modernization and the HTGR

- Strong industry, DOE and Congressional support for licensing modernization for advanced reactors
- Southern Company proposes:
  - To lead an effort to modernize U.S. licensing structure for advanced reactors building on previous and on-going efforts for last 30 years (e.g., MHTGR, PRISM, etc.)
  - ”Exercising” the modernized structure by enabling submittal of an advanced reactor license application to the NRC in the next three years
  - Prismatic Block HTGR is the best candidate for this purpose because of the design maturity, credible supply chain, licensable fuel, and extensive previous licensing work
- This aligns perfectly with the international HTGR deployment effort

*** Southern is the 4th largest utility in the U.S.. Currently operates 6 nuclear plants and is building 2 new AP1000 units in Georgia. Is also the leading U.S. utility supporting advanced nuclear plants.*