USNC Perspective and Strategy for Deployment and Commercialization of Micro-Scale and Modular-Scale HTGRs

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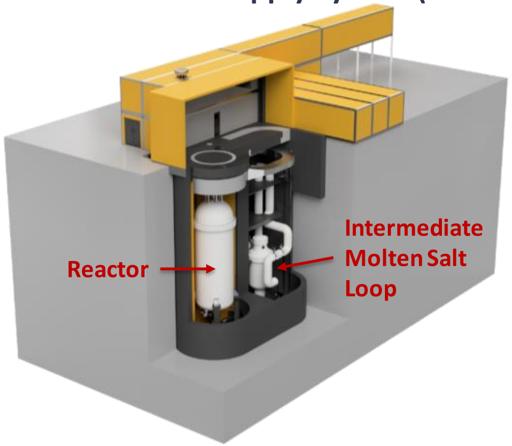
International Atomic Energy Agency
Vienna, Austria
September 18, 2019

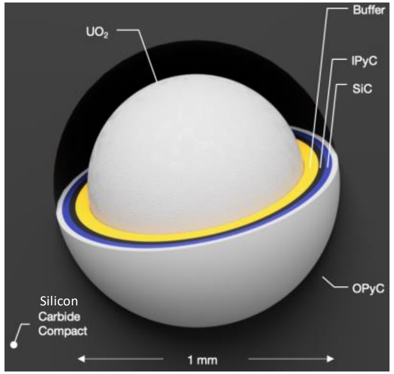
About Ultra Safe Nuclear Corporation (USNC.COM)

- **USNC is a private U.S. company with Headquarters in Seattle, WA**
  - Founded by CEO Dr. Francesco Venneri in 2011
  - Approximately 50 total employees located in 6 countries
- **USNC funding is mostly private investments for its two key focus areas:**
  - **Micro Modular Reactor (MMR®)** energy system for remote, off-grid industrial applications and communities
    - Remote mining operations in Canada
  - **Fully Ceramic Micro-Encapsulated (FCM™)** TRISO fuel
    - TRISO coated-particle fuel consolidated in a SiC matrix compact
    - Reduces or eliminates reliance on primary coolant pressure boundary and reactor building during accident scenarios
- **USNC has also been funded by government contracts**
  - Funding from NASA for nuclear space power concepts
  - U.S. Department of Energy
    - Enhanced Technical and Financial Evaluation of Opportunities for International Collaboration on HTGRs
    - Siting studies for modular HTGRs and other advanced reactor concepts
    - Experimental and analytical assessment of modular HTGR building response during depressurization accidents
  - Participation in UK Advanced Modular Reactor (AMR) solicitations
- **Business plan focused on addressing the barriers to private investment for advanced reactor deployment**
  - Start with a micro-HTGR design not requiring technology development and high capital costs
  - Focus on remote, but significant markets where competing fossil costs are very high
  - Leverage the MMR design to support more advanced concepts for less remote applications and hydrogen production/process heat applications

MMR Nuclear Heat Supply System (15 MWt)



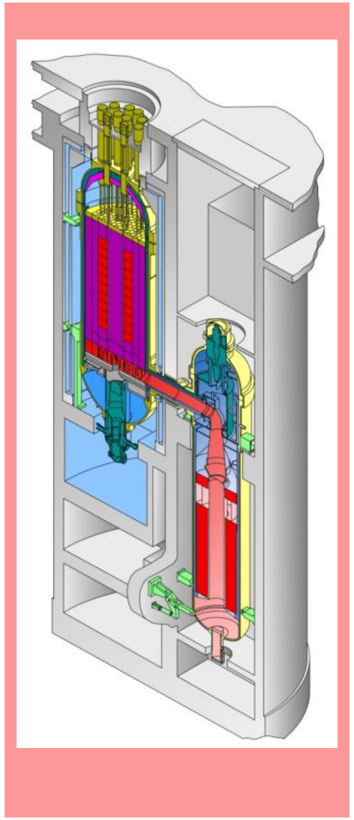
FCM Fuel



HTGR Development/Deployment Activity in the U.S.

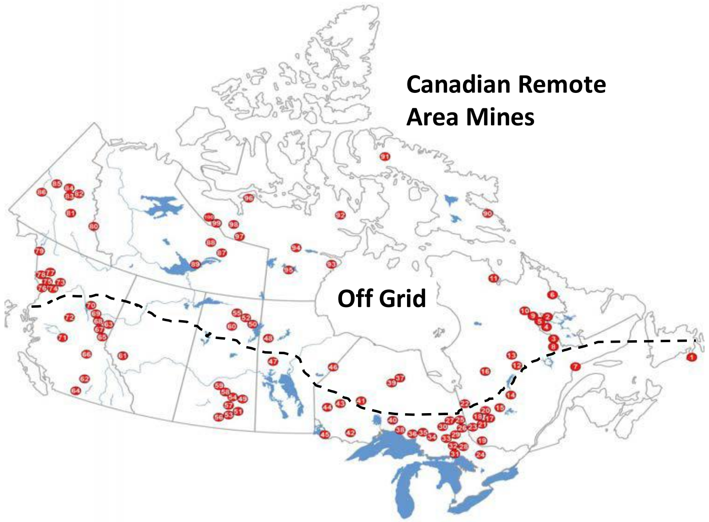
- **The U.S. is not currently engaged in deployment of HTGRs or any non-LWR advanced reactor technologies**
- **Most recent advances on Modular HTGRs came under the U.S. DOE Next Generation Nuclear Plant (NGNP) Project**
  - Authorized by Energy Policy Act of 2005 (EPACT)
  - EPACT directed DOE to seek international cooperation, participation, and financial contributions for the Project
  - Pre-Conceptual Design (2007) focused on VHTR conditions for electricity and hydrogen production
  - Conceptual Design (2011) focused on HTGR conditions for electricity and process heat/steam applications
  - **Final design and construction was not approved**
- **HTGR R&D has continued under the DOE Advanced Reactor Technologies (ART) program**
  - TRISO fuel manufacturing, irradiation testing, and post-irradiation examinations
  - Nuclear-grade graphite development and qualification
  - High-temperature materials development
  - Methods development
- **In 2015, X-Energy was awarded a contract under a DOE Funding Opportunity Announcement**
  - DE-FOA-0001313, Advanced Reactor Industry Competition for Concept Development
  - Supports advancing the design of the X-Energy X-100 modular pebble-bed HTGR
  - Approximately \$40M - \$50M total over 5 years
  - Additional award to support design of a commercial TRISO fuel manufacturing plant
  - However, low natural gas prices and other barriers prevent market penetration

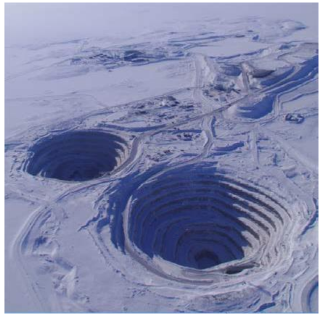
NGNP Conceptual Design



USNC Activities in Canada

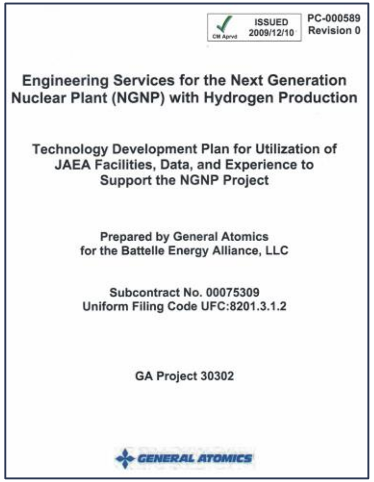
- **Why remote mining markets in Canada?**
    - High transportation costs and transportation safety issues for diesel fuel
    - Compared to remote diesel, MMR can cut electricity costs by 50% or more
    - MMR can operate 20 years without refueling
    - Current accessible market is 200 mines/communities (1,900 MWe)
    - Existing nuclear infrastructure in Canada
    - Public acceptance and government support of nuclear energy
- **Present status**
    - Completed Phase 1 Vendor Design Review (VDR) with Canadian Nuclear Safety Commission (CNSC)
    - Completed Conceptual Design
    - Completed Level 4 Costing
    - Submitted Stage 3 Site License for Chalk River Site
    - Ontario Power Generation selected as operating partner for first site
    - Applications started for government loan guarantee and infrastructure grant
    - Selection of Engineering, Procurement and Construction (EPC) company in progress
    - Supplier selection in progress





Japan's Capabilities to Support HTGR Development and Deployment

- **The HTTR has unique capabilities to support HTGR/VHTR development**
  - Operating data
  - Design data
  - Data for code/methods validation
  - Data to support licensing by regulatory agencies
  - Demonstration of inherent safety to enhance public confidence
- **Technology Development Plan was prepared for utilization of the HTTR and other JAEA facilities to support NGNP Project**
  - Plan identified test programs that could support NGNP Design Data Needs (DDNs) for HTGR and VHTR conditions
- **JAEA successfully completed test program for Tritium Permeation and Mass Balances in the HTTR**
  - Test performed during 50-day operation of HTTR at 950°C outlet temperature
  - Data used to validate Idaho National Laboratory Tritium Permeation and Analysis Code (TPAC)
  - JAEA audited and qualified to ASME NQA-1 standards
- **JAEA has made significant advances on development of nuclear hydrogen production**
  - Thermochemical water splitting using Iodine-Sulfur process
  - Can support USNC advanced MMR concepts for hydrogen production
- **Japan industry can support international collaboration on HTGRs/VHTRs**
  - Fuji Electric and Toshiba Corporation were subcontractors to General Atomics on NGNP
  - Potential collaboration with Japan industry on the MMR, with support from JAEA and Japan Government



ISSUED 2009/12/10 PC-000589 Revision 0

Engineering Services for the Next Generation Nuclear Plant (NGNP) with Hydrogen Production

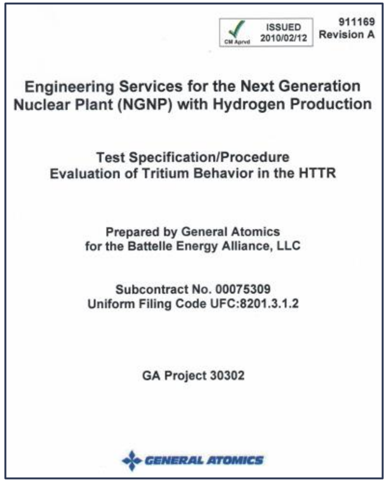
Technology Development Plan for Utilization of JAEA Facilities, Data, and Experience to Support the NGNP Project

Prepared by General Atomics for the Battelle Energy Alliance, LLC

Subcontract No. 00075309
Uniform Filing Code UFC:8201.3.1.2

GA Project 30302

GENERAL ATOMICS



ISSUED 2010/02/12 911169 Revision A

Engineering Services for the Next Generation Nuclear Plant (NGNP) with Hydrogen Production

Test Specification/Procedure
Evaluation of Tritium Behavior in the HTTR

Prepared by General Atomics for the Battelle Energy Alliance, LLC

Subcontract No. 00075309
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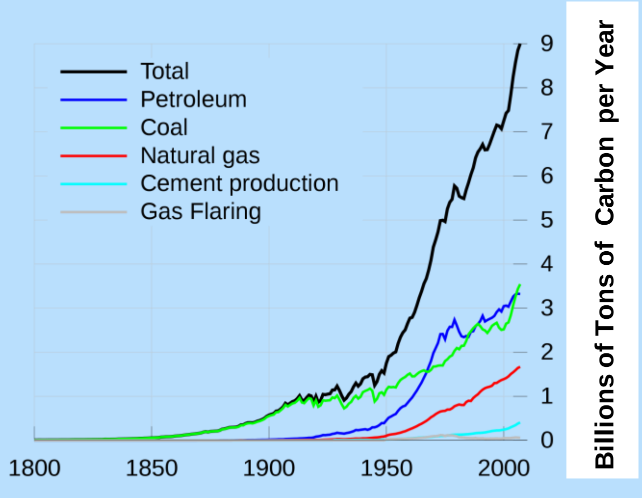
GA Project 30302

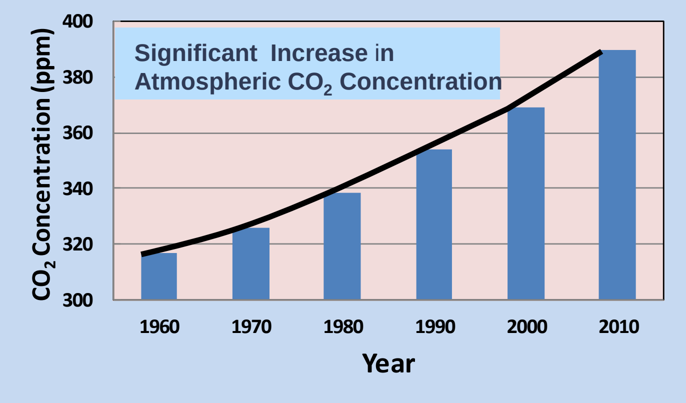
GENERAL ATOMICS

Presentation Slides to Support Panel Discussion

Why Develop HTGRs/VHTRs?

- **Increasing use of fossil fuels has impacted the global carbon cycle**
  - Future impact on climate unknown at best
- **Globally, nearly 80% of the world's energy demand is consumed outside the electricity sector**
  - Energy is supplied from burning fossil fuels
  - HTGRs/VHTRs are the only current concepts that can provide the high temperatures required for these applications
- **Inherent safety allows HTGRs/VHTRs to be co-located with industrial facilities to provide process heat and steam**
- **HTGRs/VHTRs also operate with high thermal efficiency**
  - **Enables location in areas with very limited supply of cooling water**

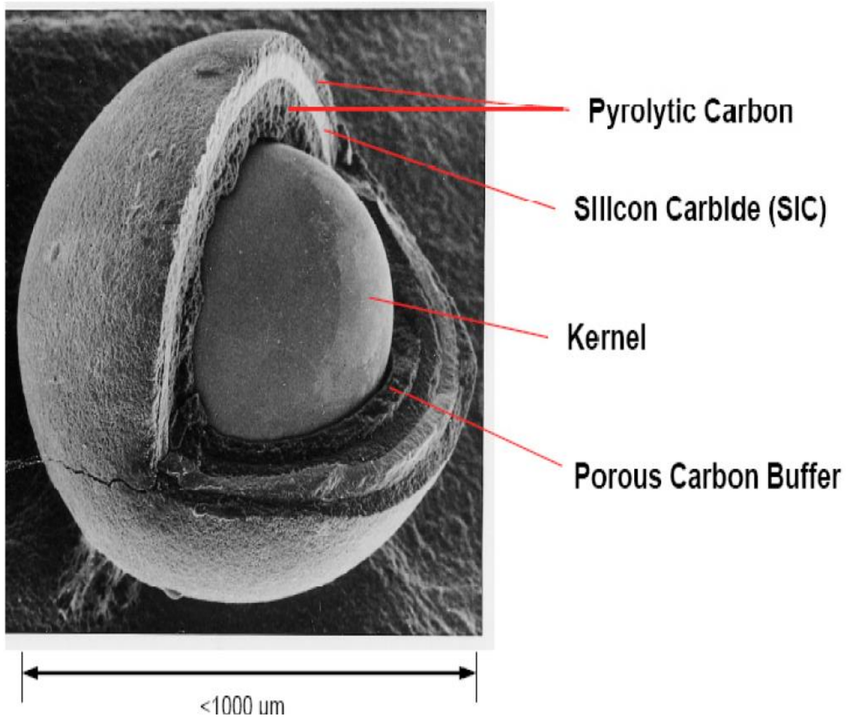




HTGR Design Approach to Safety

- **Inherent safety features include**
  - High temperature, ceramic coated particle fuel
  - Relatively low power density
  - Inert helium coolant, which reduces circulating and plateout activity
  - Negative temperature coefficients of reactivity
  - Multiple barriers to the release of radionuclides, starting with the coated particle fuel
- **High consequence events, including core meltdowns are eliminated**

TRISO Coated-Particle Fuel

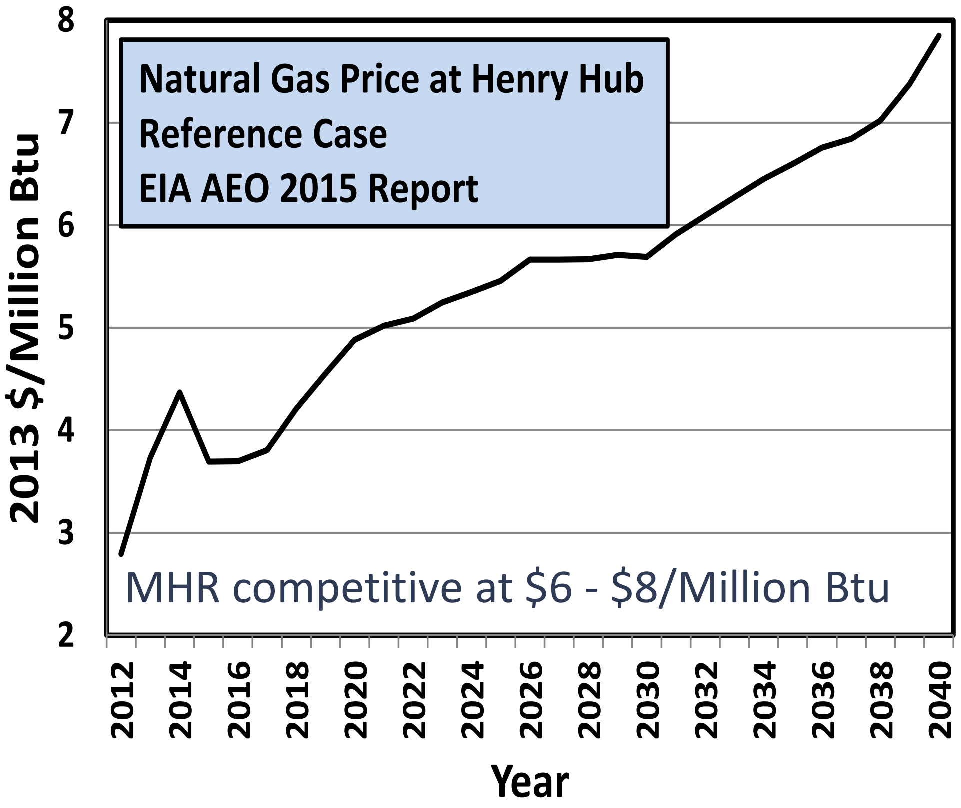


Barriers to Commercial-Scale Advanced Reactor Deployment

- Too much risk for private industry alone
- Reality: Commercial-scale advanced reactor deployment dependent on strong and lasting government support
  - HTR-PM is an example of this support

Low Fossil Fuel Prices Remain a Barrier in the U.S.

- No current carbon subsidizes for nuclear energy
- Fossil fuel prices significantly higher outside of U.S.
  - Importing LNG adds significant cost
- International markets can be initial focus for commercial deployment



How Micro-Scale HTGRs Can Address Key Deployment Barriers

Barrier	Solution
Low fossil fuel prices prevent market penetration	Identify viable markets where fossil prices are high
Nuclear plant capital costs are very high	Micro-scale significantly reduces capital costs
Licensing/regulatory risks	Inherently safe design with TRISO fuel significantly reduces risks
Identifying suitable sites for nuclear plant deployment	Micro-scale = low source term Inherently safe design = no public safety concert High thermal efficiency = less cooling water

International Collaboration to Overcome Deployment Barriers

- Adds geopolitical justification for deployment of demonstration plant
- International collaboration can save funding for individual countries
    - Common design and shared technology development
    - Requires political support to get it started and to keep it going
- Common interest in design concepts, industrial process heat, and H_2 production
- International collaboration should be crafted to properly manage any potential complexities
    - Requirements for work share
    - Access to intellectual property
    - Deployment rights in their respective countries/regions
    - Project governance

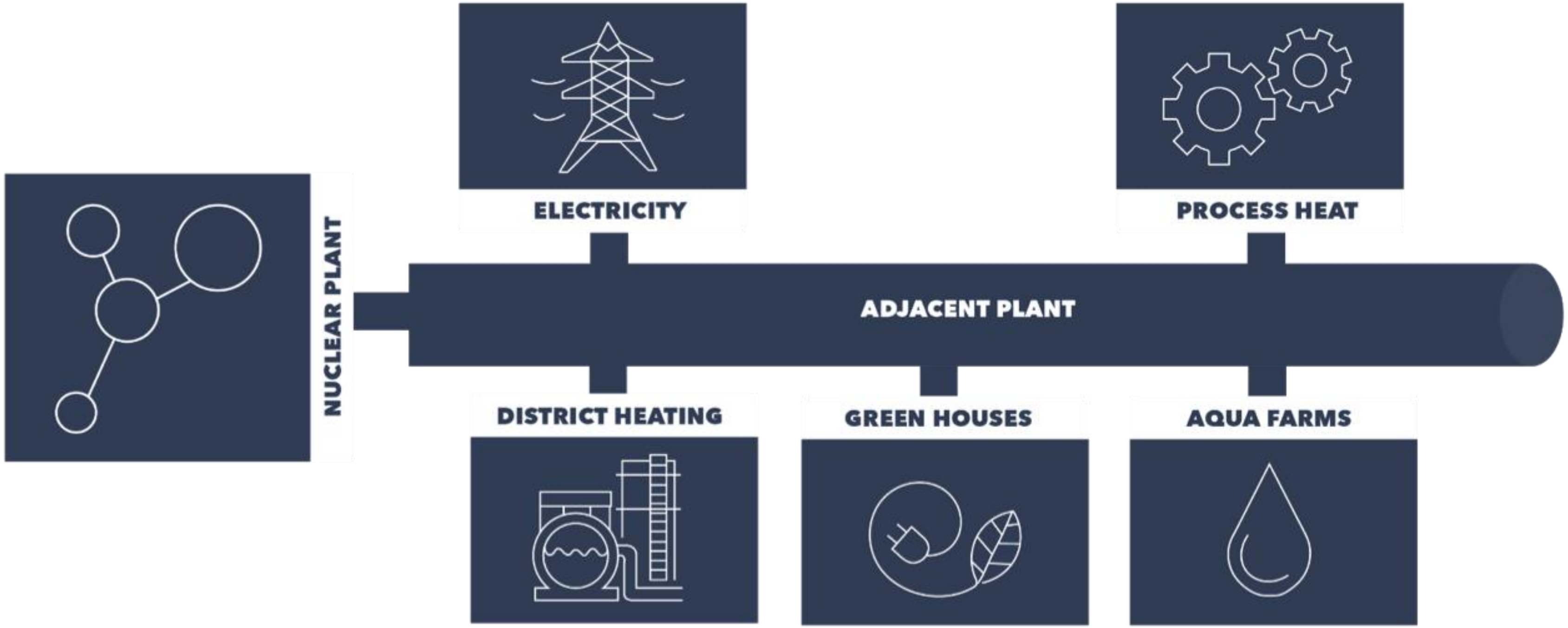
Collaboration with Japan

- **Under the U.S. DOE NGNP Project, a successful precedent was established for utilizing the HTTR to support VHTR technology development**
  - This model can be used to support future collaboration with JAEA
  - Advanced MMR for process heat and hydrogen production aligns very well with JAEA R&D programs
  - Advanced TRISO fuel R&D (e.g., FCM fuel, deep-burn fuels)
- **MMR Chalk River demonstration project can provide additional areas for collaboration**
  - JAEA independent review of MMR safety assessment deliverables to support the MMR Chalk River site licensing application
  - Potential collaboration with Japan industry
    - The MMR is an inherently-safe, micro-scale reactor with a viable business case that overcomes barriers to private investment
- **Collaboration on advanced micro-reactor concepts for process heat, hydrogen, and economical on-grid electricity consistent with smart-grid integration with renewable energy**
  - MMR provides a viable foundation for advanced concepts operating at higher temperatures and power levels

MMR Canada Market Assessment

1,900 MWe 380 Units	98 Units	35 Units 4 Plants	7 Plants (42 units) in feasibility study stage
Size of the market we are tracking	Size of our current sales pipeline where we are actively engaging clients	LOI level commitment	We are working on and planning to start feasibility studies on 7 plants, both in mines and remote settlements

MMR Applications



Advanced MMR Market Assessment for Process Heat

- **Design approach**
  - Increase power level to 45 MWt
  - Refuel every 6 years
  - Full-core cartridge replacement
- **Build up production capacity to access larger markets**
- **Competitive with natural gas process heat in Europe and other markets**

MMR Addresses Process Heat Market Needs

It is big	It is small	It is diverse	It is dispersed
MMR can scale through mass production	MMR is right-sized for the market	MMR technology can match many / multiple applications	MMR is designed for distributed applications
• Addressable Market: the global plug-in process heat market is 3,000 – 5,000 TWh/year [370-630GWth] • Extended Market: at 11,000 – 16,000 TWh/y [1,200 – 1,800GWth], may be partially addressable in future	• Very few (<10% of the plant are over 150MWth) • 50% of the plug-in market is at a unit size below 30MWth	• The market comprises many individual users with different requirements (Temperature / process streams) • Often several requirements on a single small site	• The users are geographically dispersed, not necessarily collocated in a single geographic location • One cannot serve them from a central point