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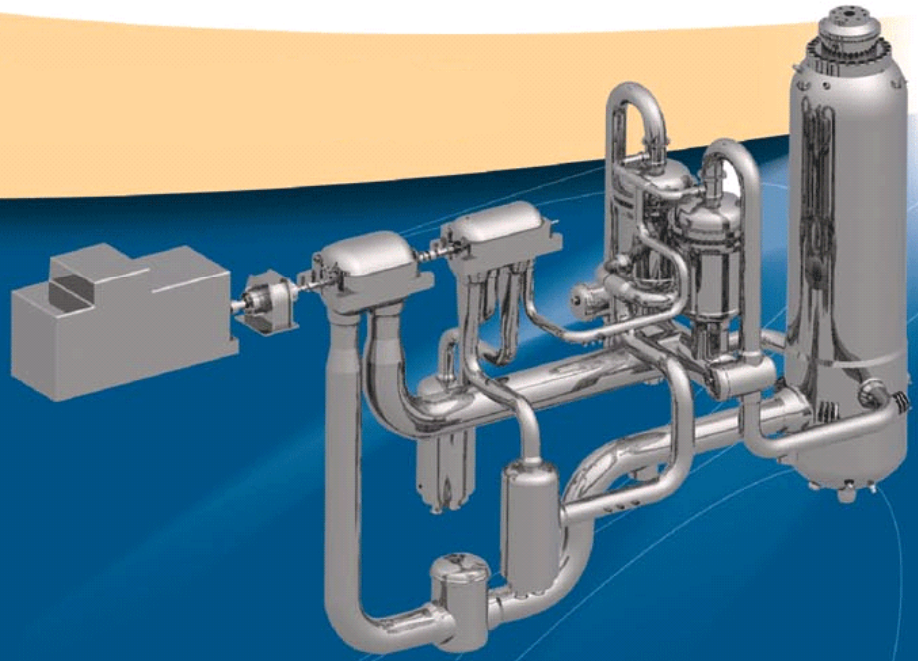
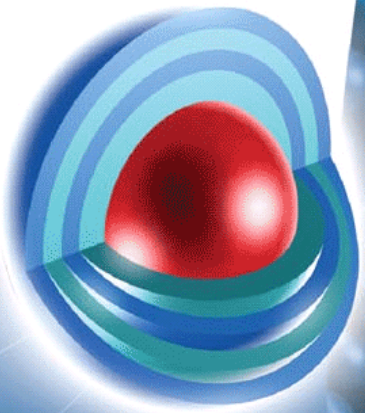
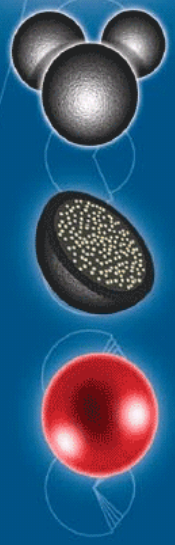






Status of PBMR Process Heat Plant Project

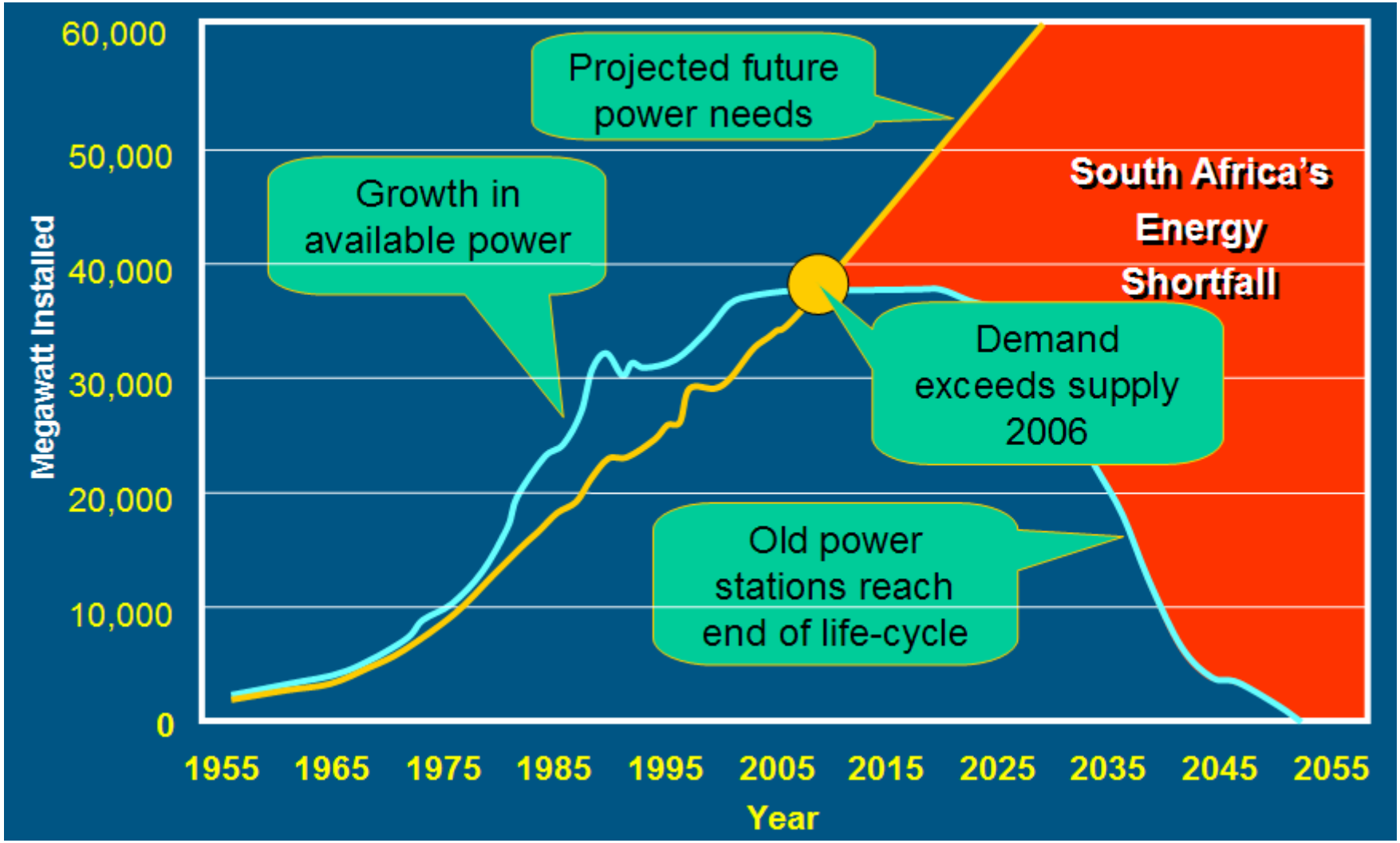
Presented by Mr. Willem Kriel - PBMR (Pty) Ltd.

Expert Opinions

"The South African PBMR technology will become the world's first successful commercial Generation IV reactor. It offers an enormous potential to expand the use of nuclear energy both in the electrical generation sector and the process heat sector".

Africa Needs Energy

SA Needs Energy Now



A Perfect Fit

The challenges facing the energy industry in Africa & internationally are to find sources that are ***accessible, reliable, affordable, proliferation resistant, safe and environmentally friendly****.*

The PBMR adheres to all these requirements.

Window of Opportunity

A **Window of Opportunity** for South Africa arose with the decision in Germany to discontinue the HTR development work in 1989.

Although there are other HTR designs, PBMR is regarded as the **most advanced** High Temperature Reactor in the world.

PBMR will be the first commercial scale **Generation IV reactor** to be deployed – 10 years ahead of the anticipated development period.

Beyond Electricity

- Electricity generation
  - where smaller incremental market conditions prevail, including limited financing, transmission or cooling water resources
- Process heat applications
  - for a range of applications needing process temperatures up to 950°C, with options for co-generation

Government Support

"The South African Government is treating the very ambitious, but very important Pebble Bed Modular reactor project with a great deal of seriousness"

Phumzile Mlambo-Ngcuka
Deputy President of South Africa

RSA Government Commitment

"Government wants to produce between **4 000MW – 5 000MW** of power from pebble bed reactors in South Africa. We firmly believe that the PBMR will place the country at the forefront of energy technology."

Alec Erwin,
South Africa's Minister of Public Enterprises

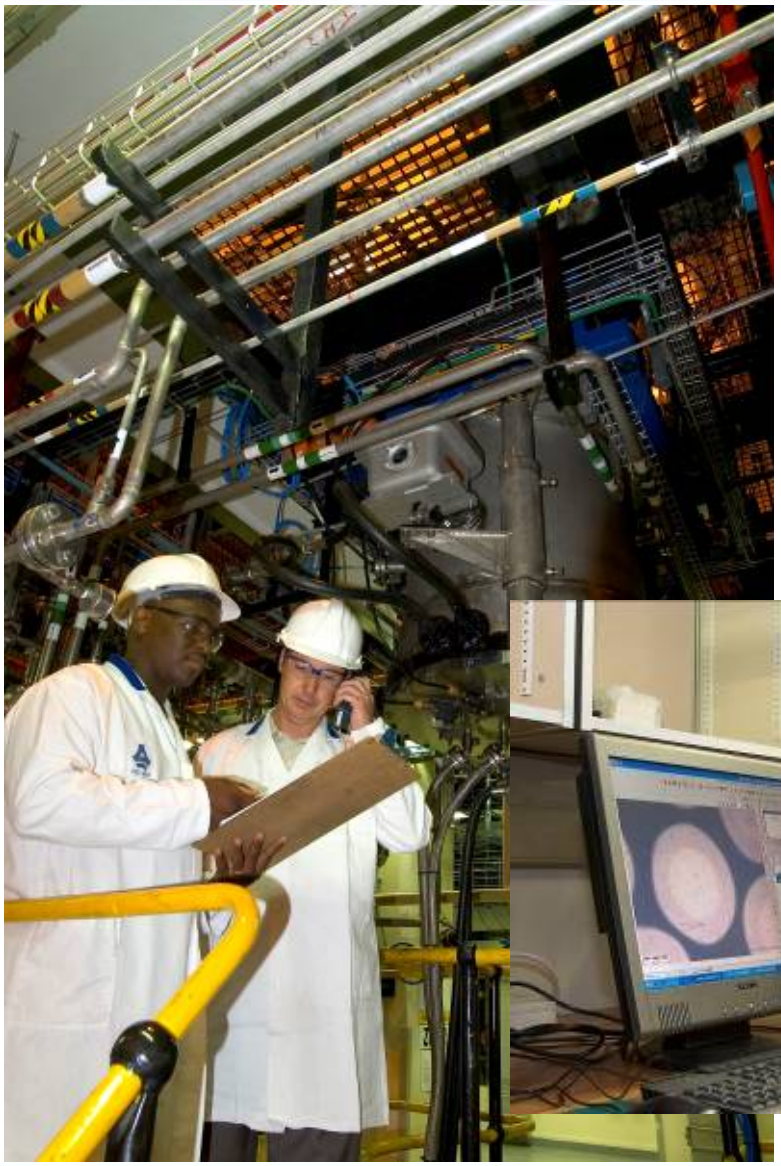
Demonstration Power Plant

PBMR identified as a **National Strategic Project** during Finance Minister's Budget speech

Personnel

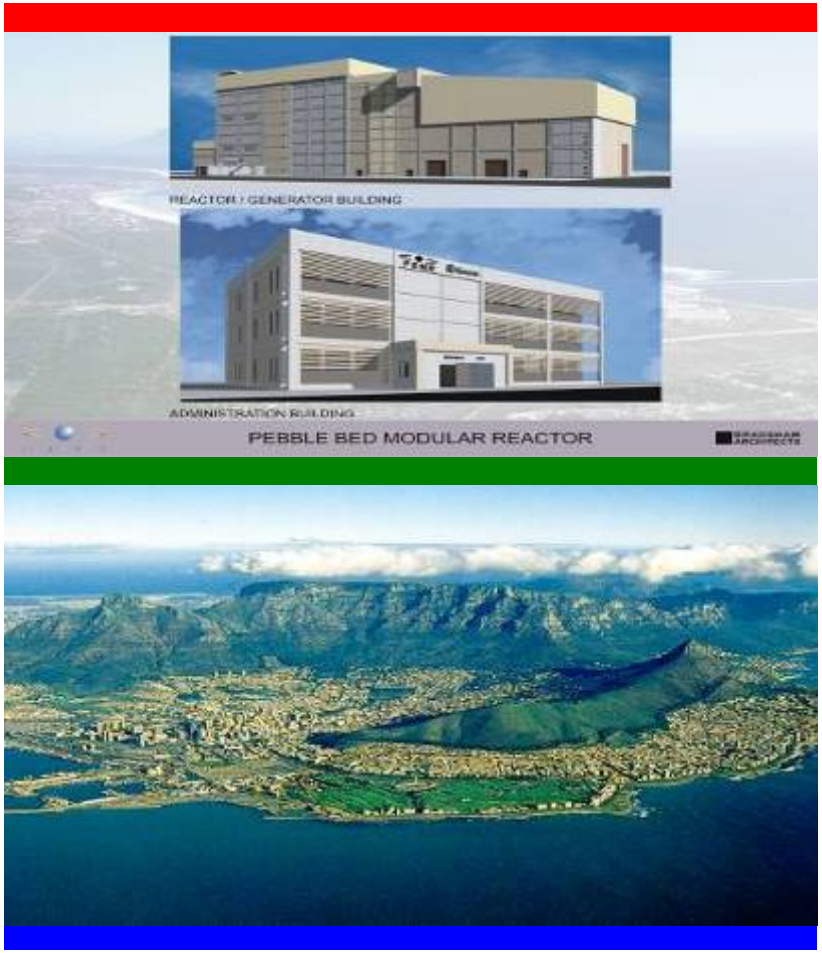
Staff of over 700.

~ 2000 people involved in project



PBMR Koeberg Site

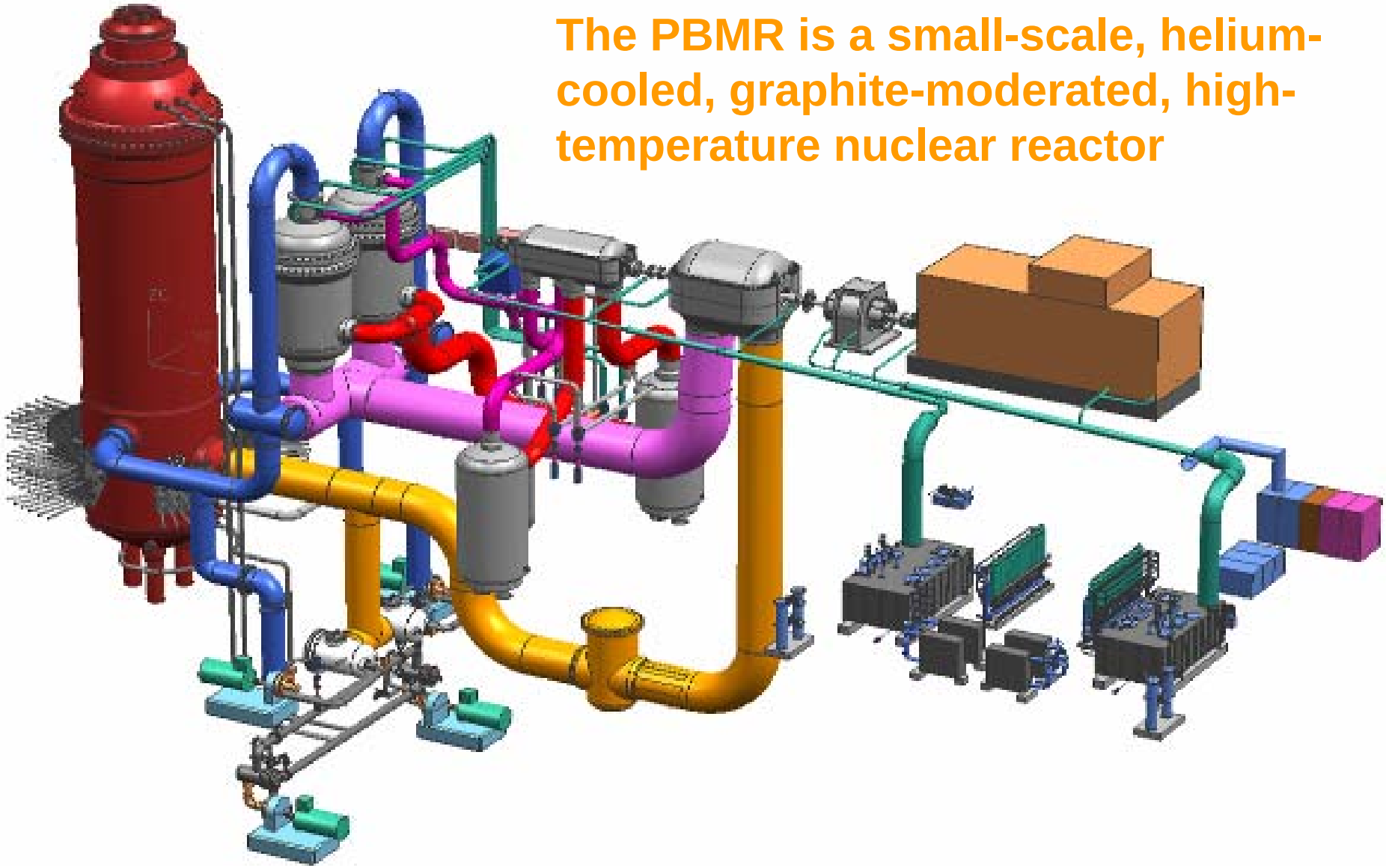
- **Mission**
  - To build a commercial size (165 MWe) Demonstration Power Plant near Cape Town by 2012
  - To build a Pilot Fuel Plant near Pretoria



This project has been identified as a National Strategic Project **by the South African Government**

What is the PBMR?

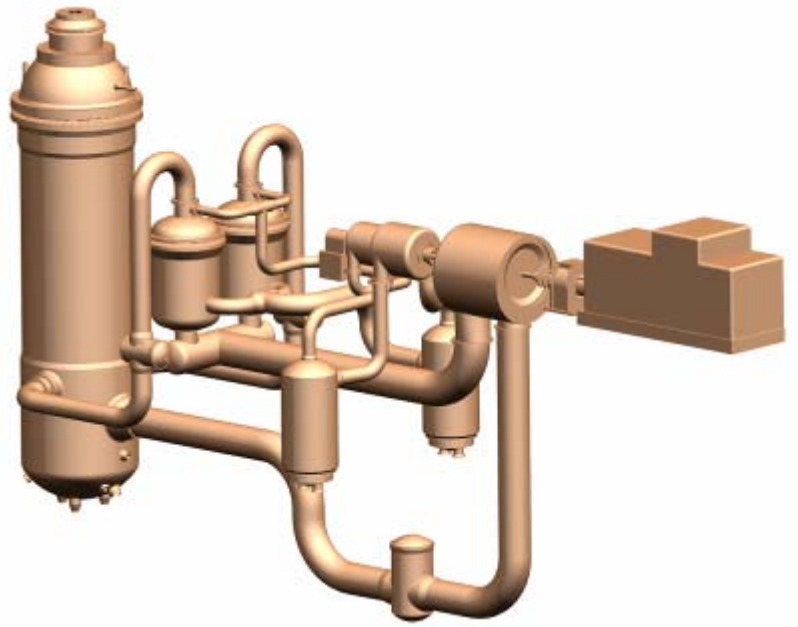
The PBMR is a small-scale, helium-cooled, graphite-moderated, high-temperature nuclear reactor




REACTOR / GENERATOR BUILDING
ADMINISTRATION BUILDING
PEBBLE BED MODULAR REACTOR
BRADSHAW ARCHITECTS

Demonstration Power Plant Status

- Detailed design and procurement underway with international supply team
- Extensive test programs underway
- Construction scheduled 2009; with operation 2013
- South African utility Eskom issued a Letter of Intent for follow-on electric plants
- Dedicated PBMR organization and support for process heat market



Investors in PBMR (Pty) Ltd.

- South African Government
- Industrial Development Corporation (IDC) of South Africa
- Eskom (National Utility)
- Westinghouse

Advantages for South Africa

- Skills development and job creation (56 000 local jobs)
- Locally controlled technology
- Limiting foreign exchange exposure
- Potentially adding value to own uranium
- Power stations sited close to demand
- Industrial development and localization
- Contribution to clean and safe energy
- Security of energy supply

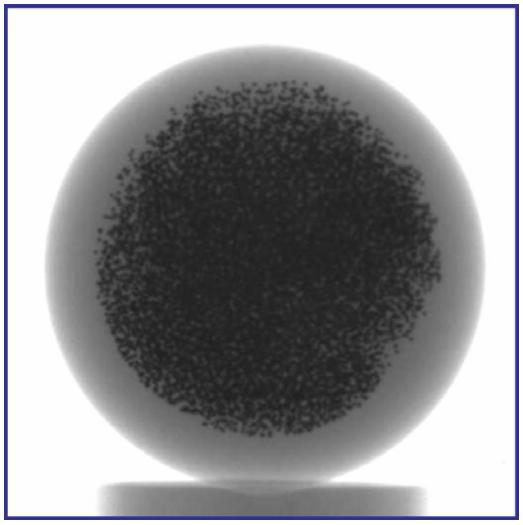
PBMR Fuel

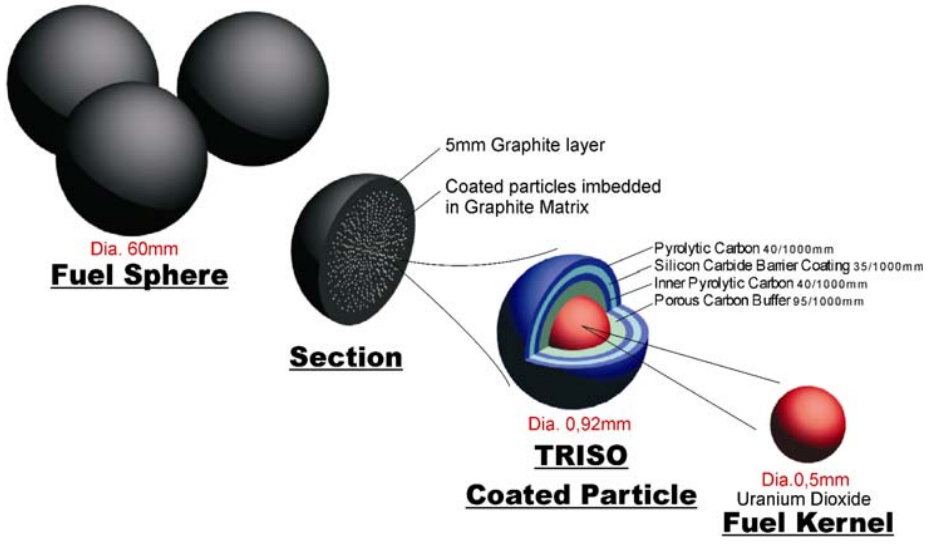
Safest nuclear fuel in the world

Cast **Aged** **Dried** **Calcined** **Sintered**

Passive Safety

- Ceramic-coated fuel particles provide primary radionuclide barrier
- Helium gas is a single phase coolant and both chemically and radiologically inert
- Radionuclide retention within fuel assured through passive safety design with inherent characteristics
- Low power density and large thermal capacity ensures slow core transient behavior





Fuel Manufacturing at Pelindaba

The Power of the Pebble

1 pebble

(9g of 9.6% enriched uranium)

5.76 tons of coal

1.5 to 2.5 tons of ash

21 tons of CO^2

The Power of the Pebble

- One Pebble (11.5MWh) can:
  - Power 115 000x100W light bulbs for 1 hour
  - Power one 60W light bulbs, burning 12 hours per day, for 43 years

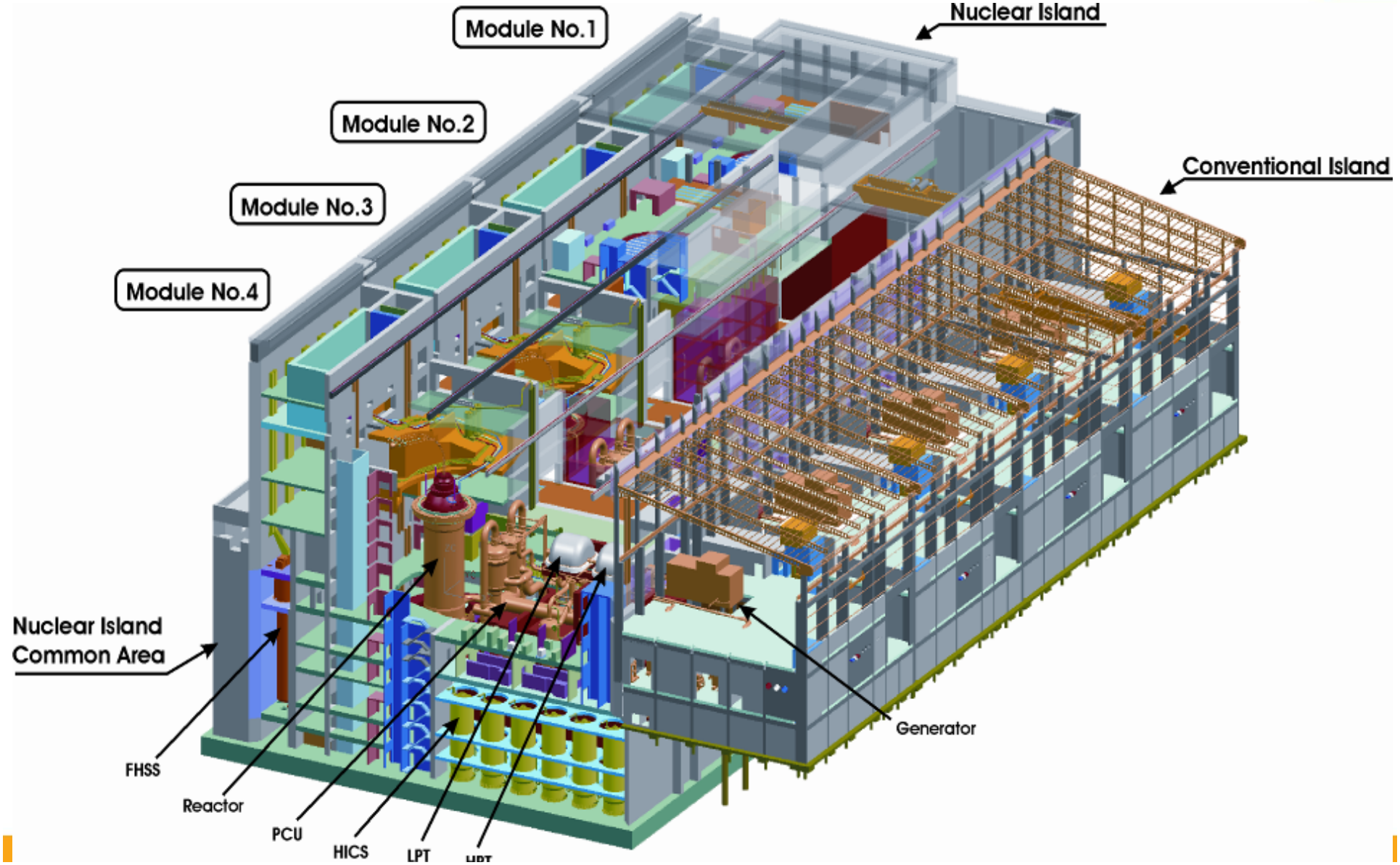
PBMR Features

- Inherent Safety (design rules out a core melt)
- Distributed generation due to small size
- Modularity (additional modules can be added)
- Low impact on the environment
- Lower capital cost during construction
- Smaller capital cost increments
- Small emergency planning zone
- High efficiency (> 41%)
- Short construction times
- Load following
- On-load refueling
- Low proliferation risk

Safety Features

- Inherent safety features proven during public tests
- New Generation IV “safe design” technology
- System shuts itself down
- No need for off-site emergency plans
- Minimal 400 meter safety zone
- No need for safety grade backup systems
- Helium coolant is chemically inert
- Coated particle provides excellent containment for the fission product activity

Multi Module Concept



Manufacturing of Components

Gas Blowers

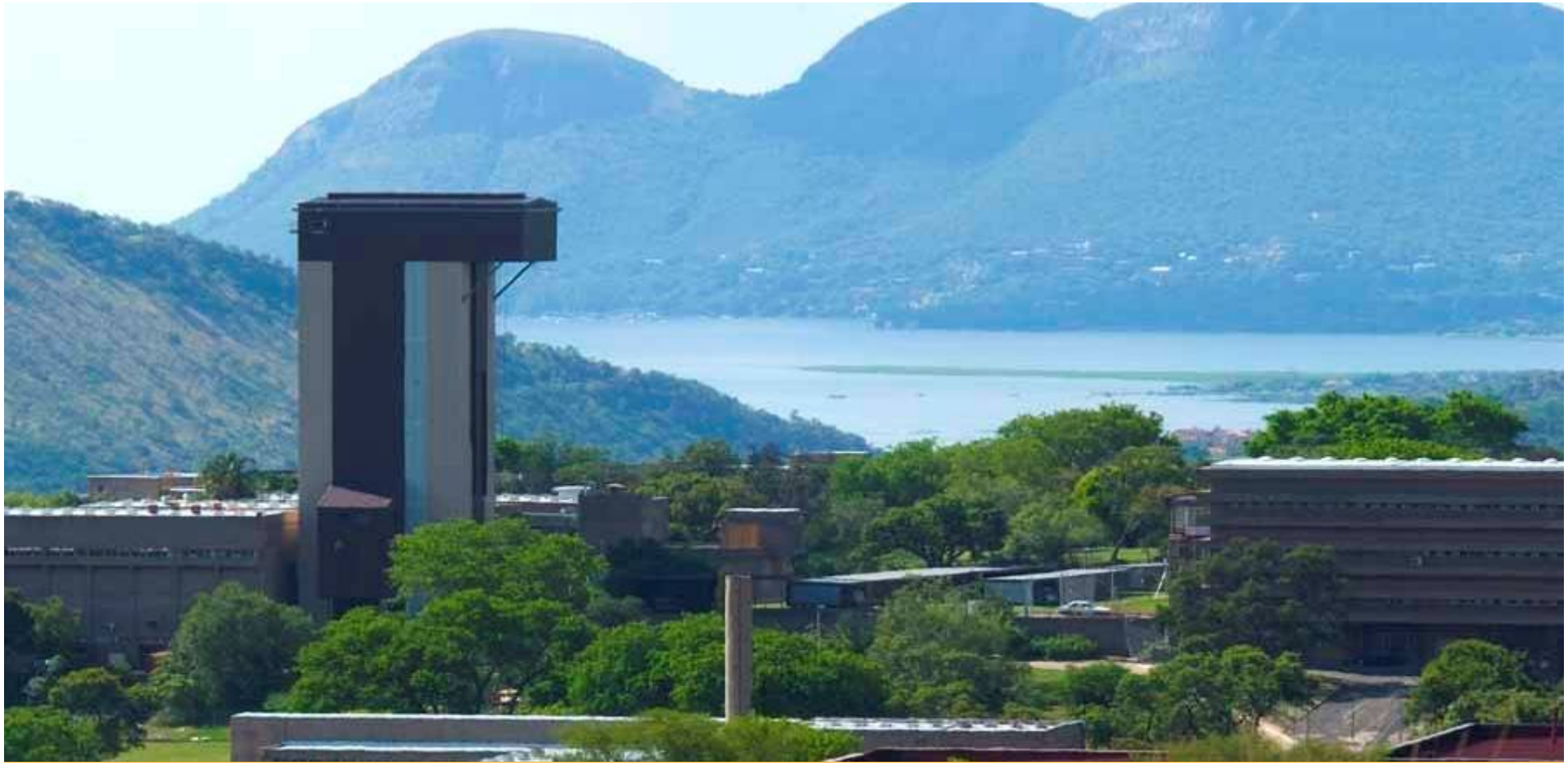
Gas Cycle Valves

Graphite Structures

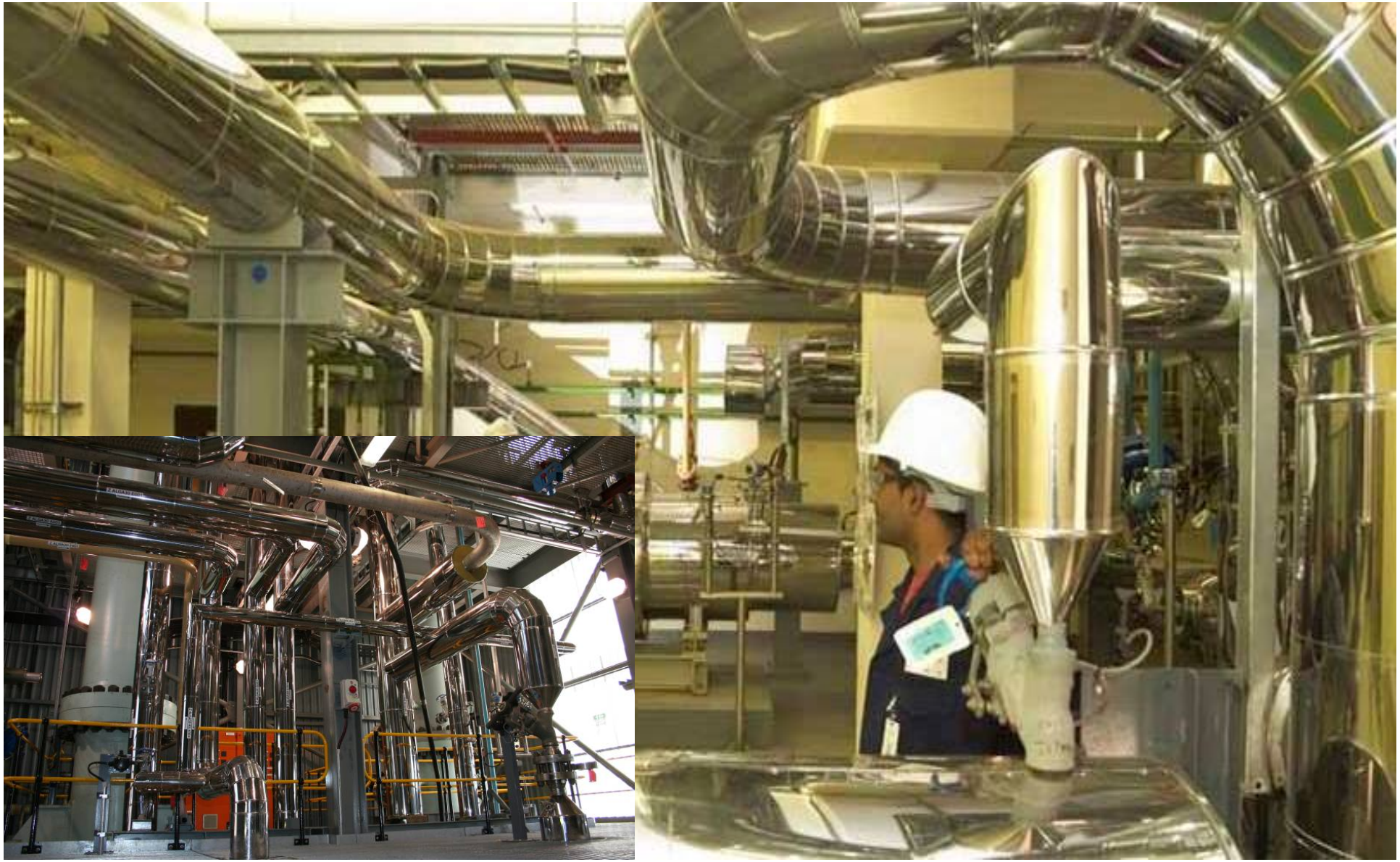
Reactor Pressure Vessel

Extensive Test Programs: Helium Test Facility at Pelindaba

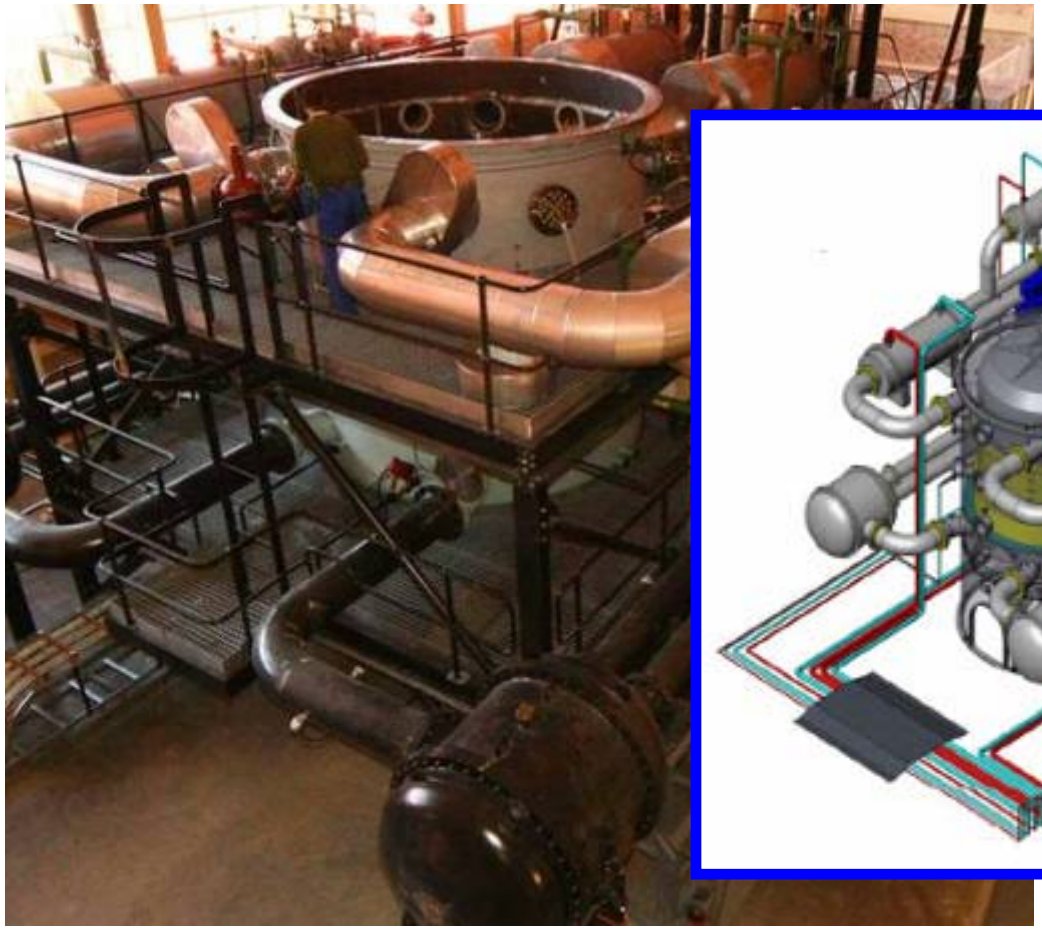
Helium blower, valves, heaters, coolers, recuperator and other components to be tested at pressures up to 95 bar & 1200 °C

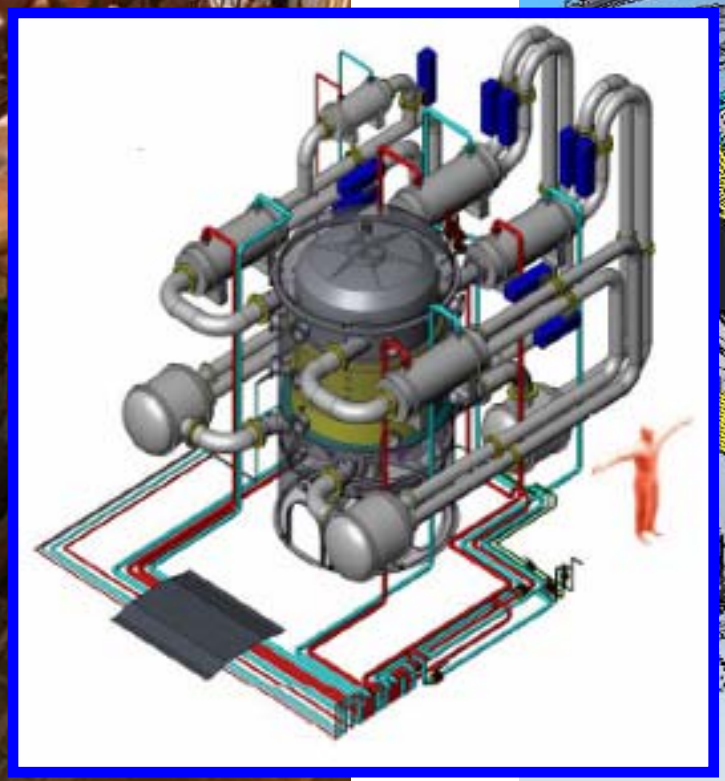


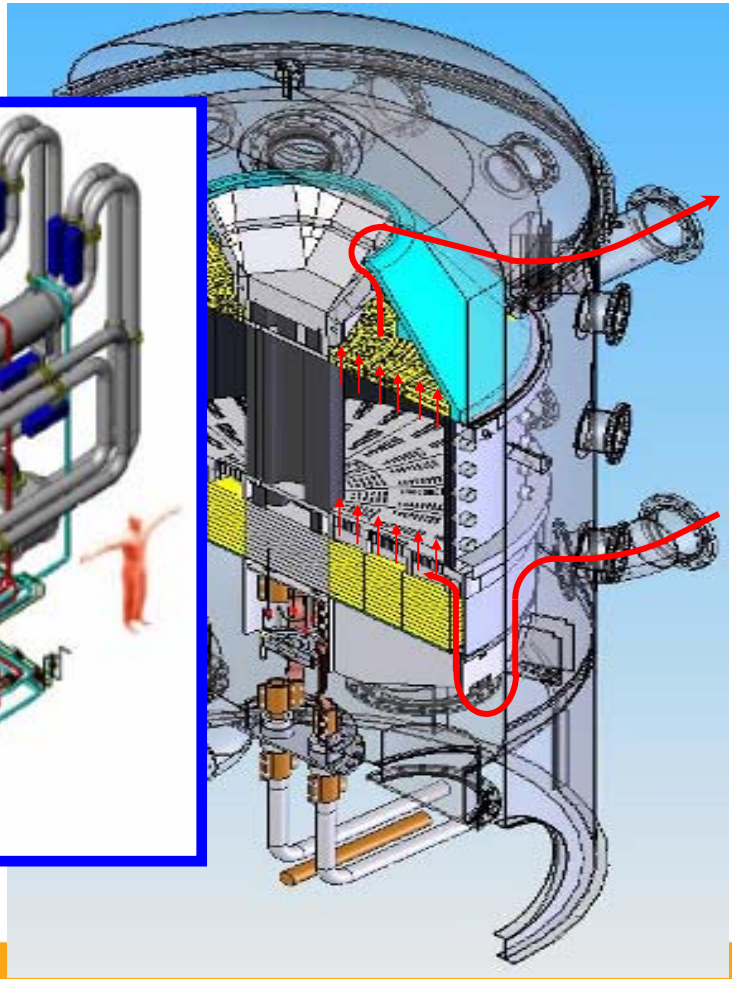
Extensive Test Programs: Helium Test Facility at Pelindaba



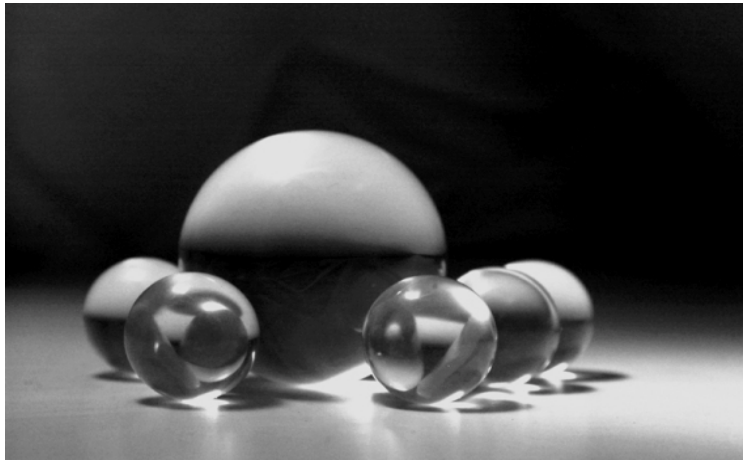
Extensive Test Programs:
Heat Transfer Test Facility, HTTU



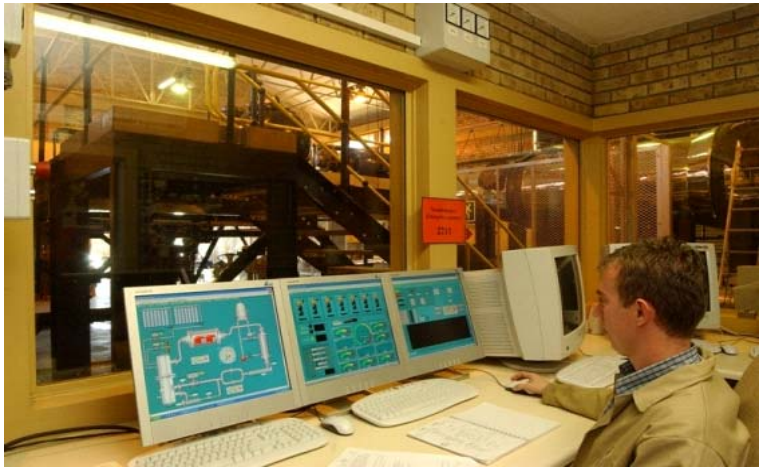




HTTF-High Pressure Test Unit



Pebbles used in the HPTU test sections – 60 mm and 30mm acrylic spheres



HPTU Control room

From Left to right: HPTU Main test vessel, Blower vessel, Water cooler

Construction of the test sections.

Extensive PBMR Test Programs

PBMR is Set for Success

Opportunity in new global energy markets will be driven by:

- Diversification of energy supply
- Shortage of and increasing cost of natural gas
- Increasing cost of petroleum
- Incentives to reduce CO_2 and other emissions

PBMR will be a CO_2 free economic option for providing large amounts of process heat in the 900 °C temperature range

Why PBMR for Process Heat?

- **Right Temperatures**
- **Right Size**
- **Soon**
- **Safe**
- **Economic**

PHP Partners

- PBMR
- Shaw Group
- Westinghouse
- Technology Insights
- M-Tech Industrial

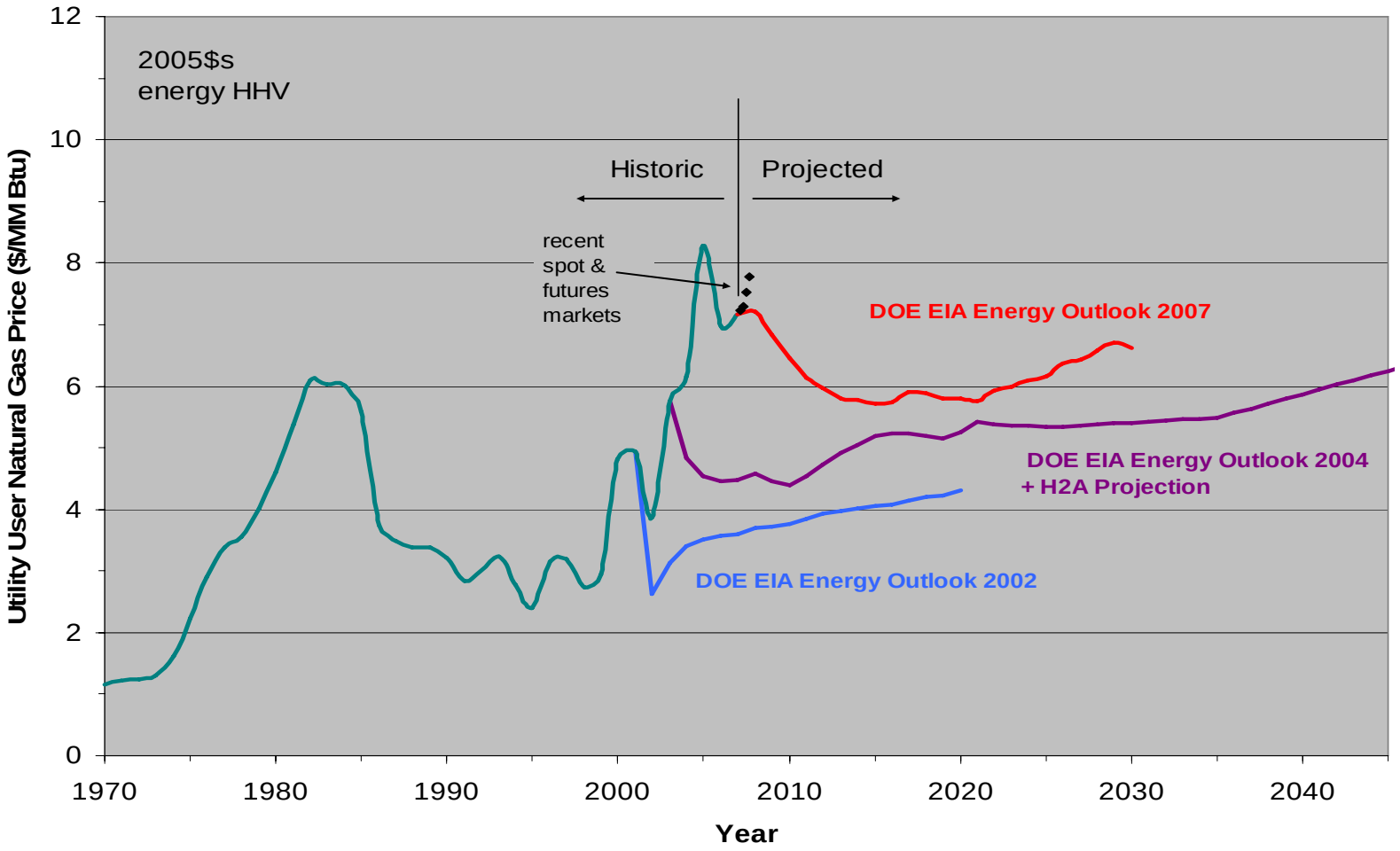
PHP Markets

- Syngas from natural gas
  - Chemical feed (captive and remote H_2 plants, ammonia, methanol)
- Cogeneration
  - Refinery & petrochemical
  - Heavy industrial
  - District heating and desalination
- H_2 production
  - Refinery applications
  - Pipeline hydrogen
- Oil sands recovery and processing
  - Steam and power production
  - Hydrogen for bitumen processing
- Coal to liquids without CO_2 emission
- Water scarcity countries provide desalination potential

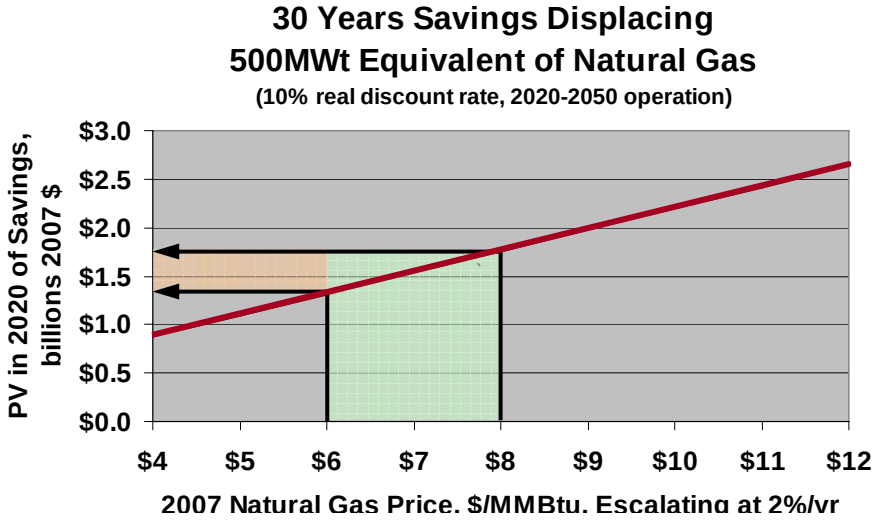
Process Heat Applications

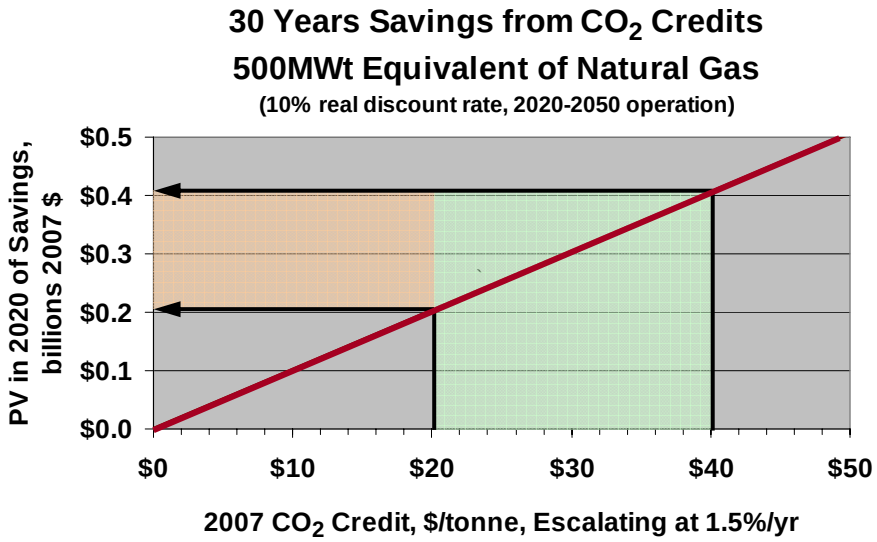
- Steam Generation
  - Heavy Oil Recovery
  - Oil Sands
  - Cogeneration
- Steam Methane Reforming
  - Hydrogen
  - Ammonia
  - Methanol
- Water-Splitting (H_2 & O_2)
  - Bulk Hydrogen
  - Coal-to-liquids
  - Coal-to-methane
- Desalination

Natural Gas Price Actuals and Forecasts per EIA



Present Value of Replacing Natural Gas

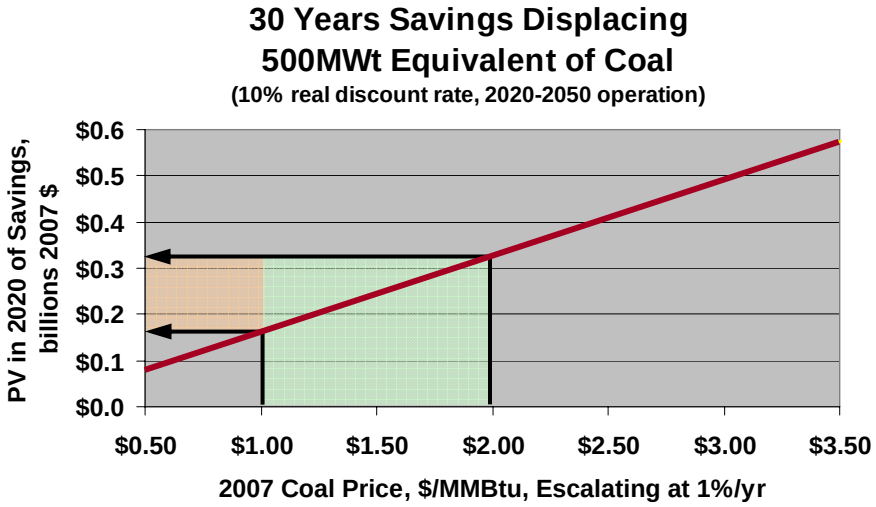


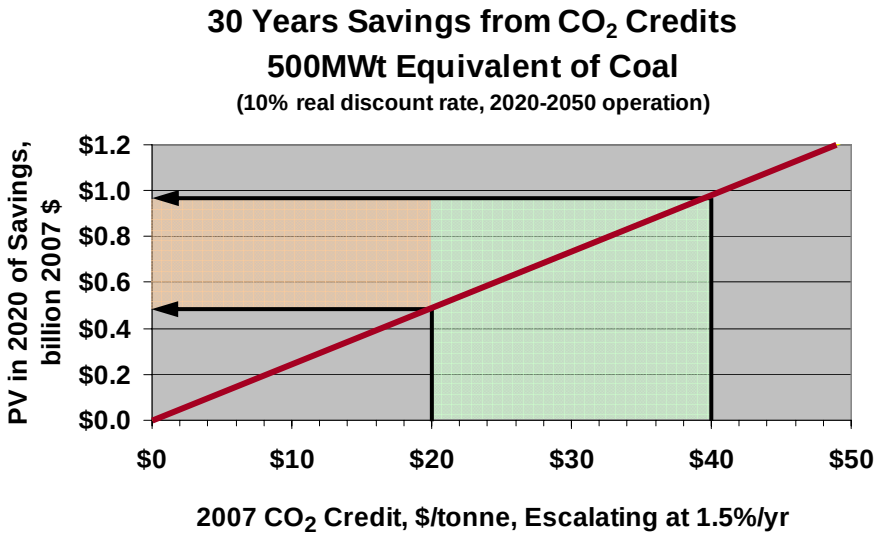


- At $7.00/MMBtu gas in 2007, the PV of the gas alone for process heat is $1.55Billion

- If gas as a heat source is displaced, the PV of the CO_2 credits @ $30/tonne are worth another $300M

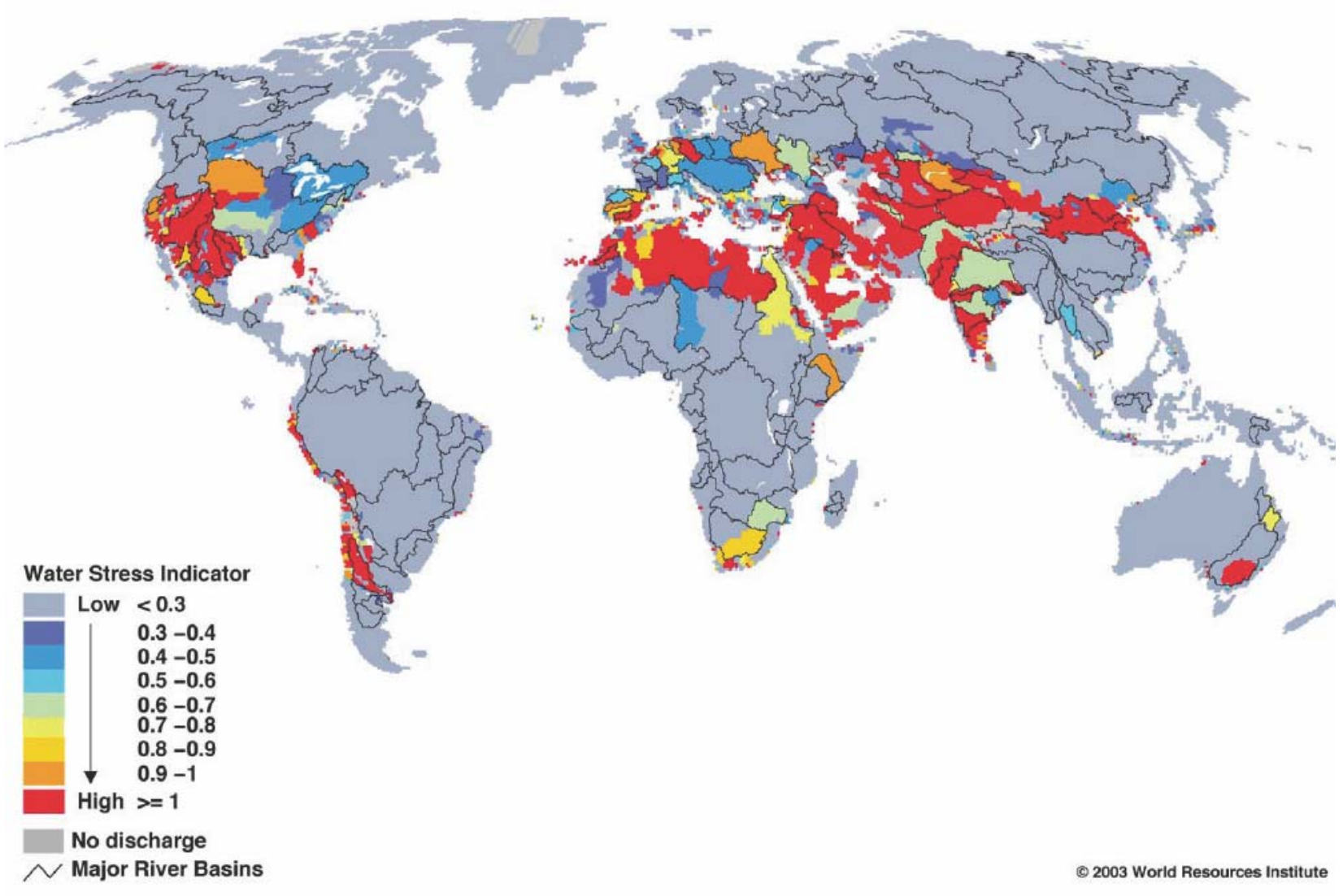
Present Value of Replacing Coal





- At $1.50/MMBtu Coal in 2007, the PV of the coal alone for process heat is $245Million
- The PV of the CO_2 credits @ $30/tonne are worth another $735M

Environmental Water Scarcity Index by Basin

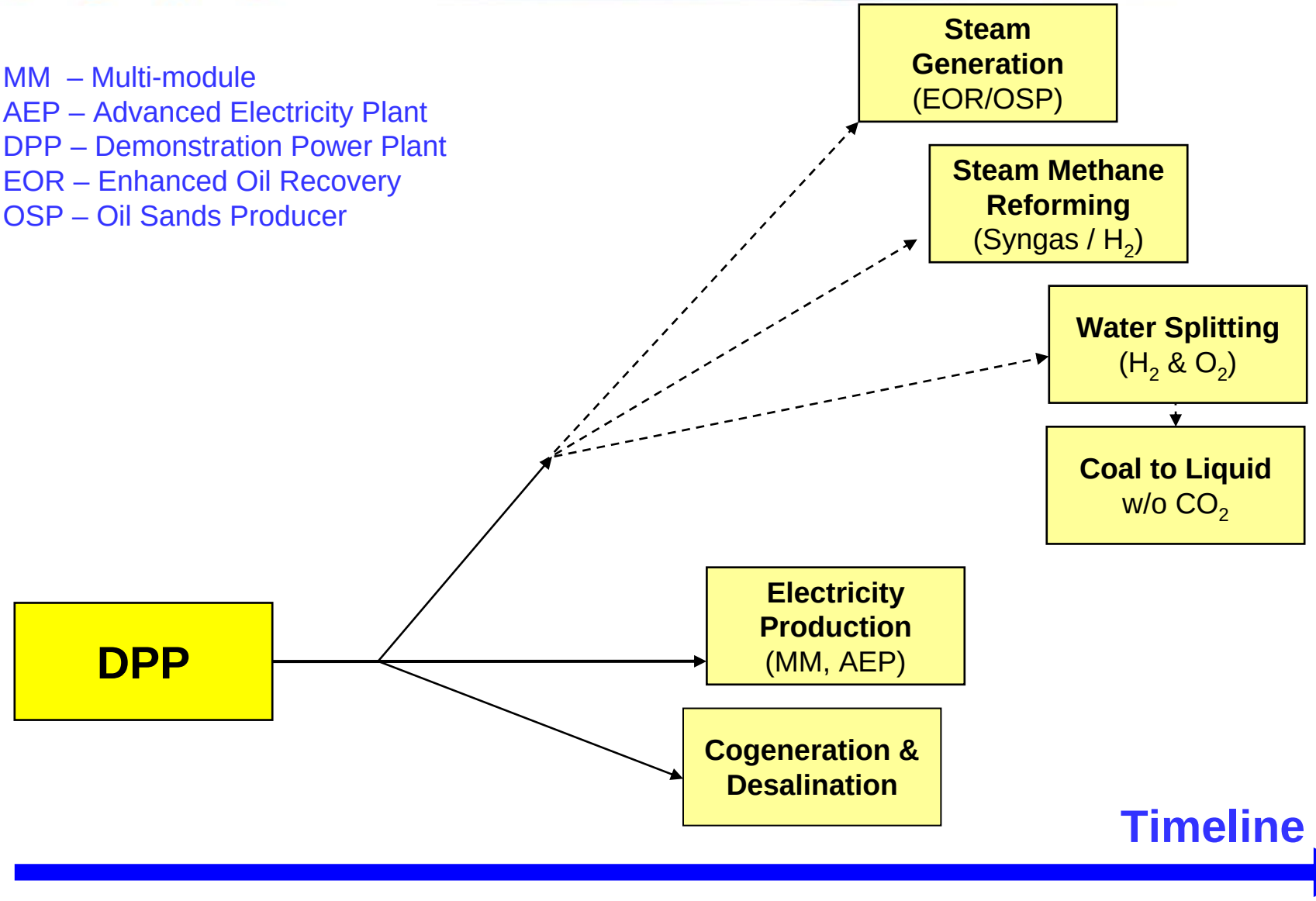


PHP Timeline

- **2005 - 06** Phase I: Evaluate Candidate Applications
- **2006 - 07** Phase II: Engage Clients in Business Cases
- **2007 - 08** Phase III: Finalize Feasibility Studies & Consortia
- **2007 - 08** Project Development & Planning through Consortia
- **2007 - 12** Technology Development & Design
- **2008 - 12** Regulatory Prerequisites
- **2010 - 16** Project Implementation
- **2016+** Commercial PBMR PHP Projects

Product Development Path

MM – Multi-module
AEP – Advanced Electricity Plant
DPP – Demonstration Power Plant
EOR – Enhanced Oil Recovery
OSP – Oil Sands Producer



Strategy

- Build on DPP
- Early market entry (fast-track off DPP)
- Commercially driven (focus on early user requirements)
- Establish a development team with process experience
- Develop multiple demonstration projects
- Early identification and implementation of prerequisites
- Early consortium development
- Leverage government opportunities (such as NGNP)

Strategy for Participation in NGNP

- Accelerate US licensing
- Leverage funded research and development
- Demonstrate PBMR as most advanced HTR project in the world

NGNP Status and Team

- The Westinghouse-led consortium was awarded the principal contract for the initial phase of pre-conceptual engineering services and planning for the Next Generation Nuclear Plant (NGNP) by the U.S. Department of Energy (DOE). This initial 12-month phase of the NGNP is the U.S. government's first step in deploying a commercial scale HTGR prototype plant for the generation of hydrogen and/or electricity.

- Majority of the first phase (pre-conceptual design) work to be completed by May 2007 with a single major deliverable:
  - Pre-conceptual Design Report to be approved & accepted by INL

- NGNP Team
  - Westinghouse Electric Company LLC (Prime)
  - Pebble Bed Modular Reactor (Pty) Ltd. (Republic of South Africa)
  - Shaw Stone & Webster
  - Air Products and Chemicals Inc.
  - Technology Insights
  - M-Tech Industrial (Pty) Ltd. (Republic of South Africa)
  - Nuclear Fuel Services
  - Kadak Associates

Water-Splitting Status

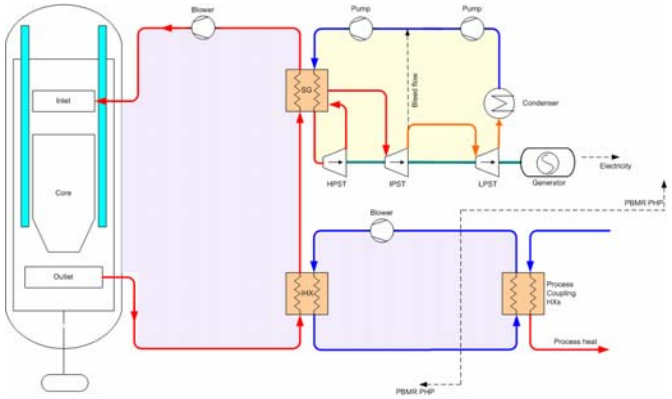
- Process Design
  - Westinghouse flowsheet
  - Conceptual economics
- Hybrid Sulfur Working Group (R&D collaboration)
  - Shaw Group
  - PBMR team
  - Savannah River National Laboratories
  - M-Tech Industrial
  - University of South Carolina
  - University of Sheffield
- Industrial clients

Water-Splitting Plan

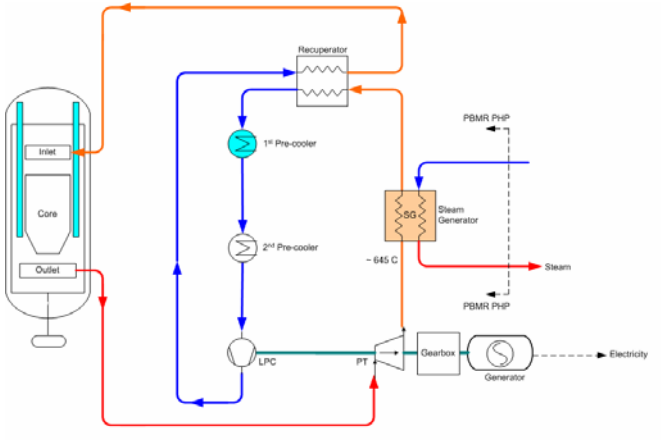
- Consolidate common flowsheet and conceptual estimates
- Develop a coordinated R&D plan
- Develop project definitions
- Leveraging government programs
  - US DOE – NGNP, NHI
  - RSA DST- Hydrogen based program expected to be funded next year

Heat Delivery Configurations

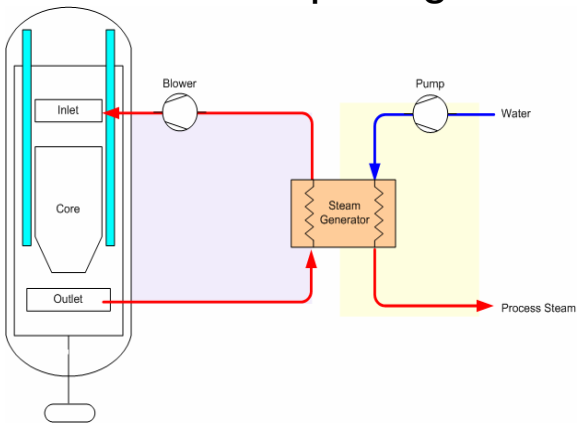
- **Depends on specific process heat application**
- **Options include:**



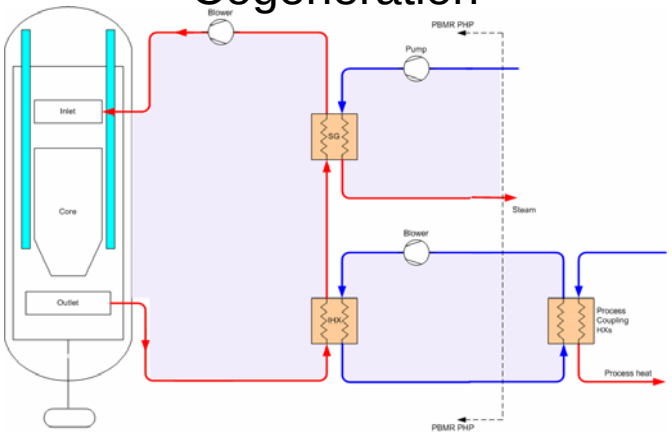
Water-Splitting



Cogeneration



Steam Generation



Steam-Methane-Reforming

Technology Development

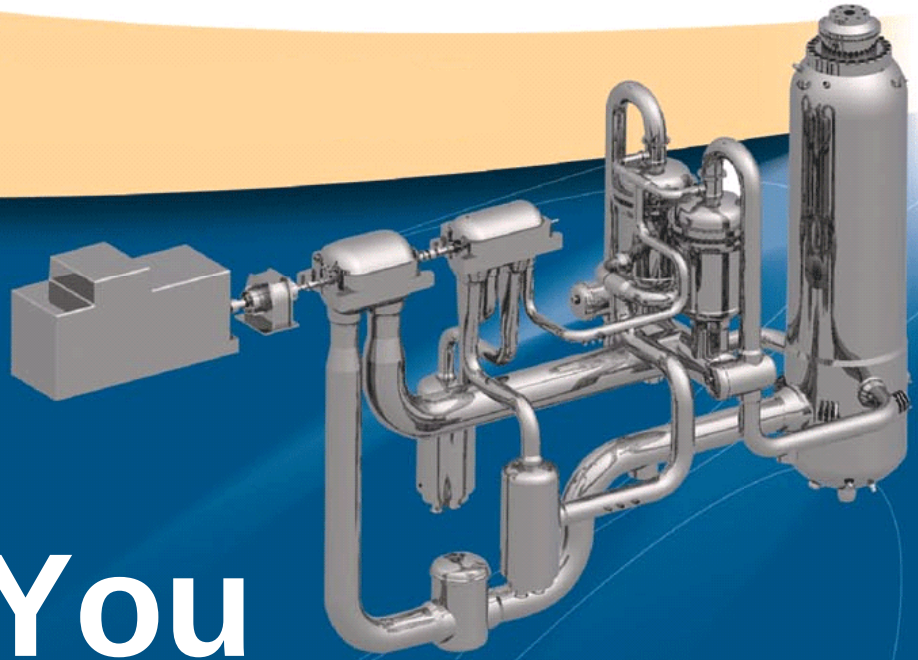
- **Key Parameters**
  - Primary: 950C/9MPa
  - Secondary: 900C/[TBD]MPa*
- **Significant technology challenges**
  - Metals marginal at these temperatures
    - Pressure balancing likely required
  - Ceramic materials being evaluated
  - Design rules must be updated and/or developed
    - Extension for metals
    - Development for ceramics
  - Licensing basis for IHX pressure boundary needs evaluation

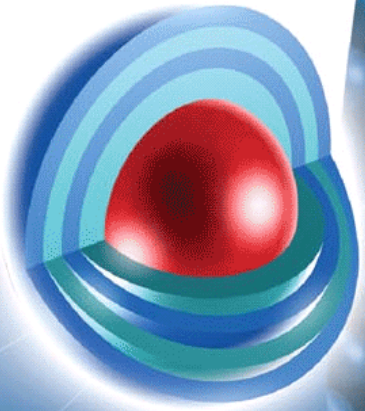
***Requires tradeoffs between process and IHX issues**

Conclusion

- Large process heat markets
- DPP valuable stepping stone to process heat markets
- Several promising process heat applications
- Collaborations have been formed with interested parties

P B M R





Thank You

P B M R

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TECHNOLOGY INSIGHTS

M-Tech industrial