VTT TECHNICAL RESEARCH CENTRE OF FINLAND LTD

GENXFIN – Advanced nuclear energy for near-term future

SAFIR2018 Interim Seminar
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Gen IV

Timeline of Adoption

Safety

Economics

Licenciability in Finland

Sodium-cooled fast reactor (SFR)

- EBR-I (1951-1964), Sodium Reactor Experiment (1957-1964), Fermi 1 (1963-1966), EBR-II (1965-1994), Rapsodie (1967-1983), BN-350 (1973-1999), Phénix (1973-2009), PNR (1974-1994), Jōyō (1977-2007), BN-600 (1980-), Fast Flux Test Facility (1980-1992),FBTR (1985-1998), Superphénix (1980-), Monju (1994-1995, 2010-2010), BN-800 (2016-), China Experimental Fast Reactor (2011-)

Lead-cooled fast reactor (LFR)

- BM-40A, OK-550

High temperature gas-cooled reactor (HTGR)

- Dragon (1965-1976), Peach Bottom 1 (1966-1974), Fort Strain Vain (1979-1989), AVR (1967-1988), THTR-300 (1983-1989), HTTR (1999-), HTR-10 (2003-)

Molten-salt reactor (MSR)

- ARE (1954-1954), MSRE (1965-1969)

IAEA SMR Timeline

Immediate Deployable

Under Construction

CAREM-25
CNEA, Argentina

KLT-40S
OKBM Afrikantov, Russian Federation

HTR-PM
INET, People's Republic of China

Near-term deployable

Certified or at Advanced Design Stage

SMART
KAERI, Republic of Korea

RITM-200
OKBM , Russian Federation

PRISM
GE-Hitachi, USA

PBMR-400
PBMR, South Africa

BREST300-OD
NIKIET, Russian Federation

4S
Toshiba, Japan

ACP100
CNNC, People's Republic of China

NuScale
NuScale Power, USA

mPower
B&W, USA

GTHTR300
JAEA, Japan

SVBR-100
AKME Engineering, Russian Federation

ABV-6M
KMBM, Russian Federation

Mid to Longer-term Deployable

Conceptual Design for Future Deployment

AHWR300
BARC, India

Flexblue
DCNS, France

IRIS
IRIS International Consortium

DMS
Hitachi-GE, Japan

IMR
MHI, Japan

VVER-300
OKB Gidropress, Russian Federation

Westinghouse SMR
Westinghouse, USA

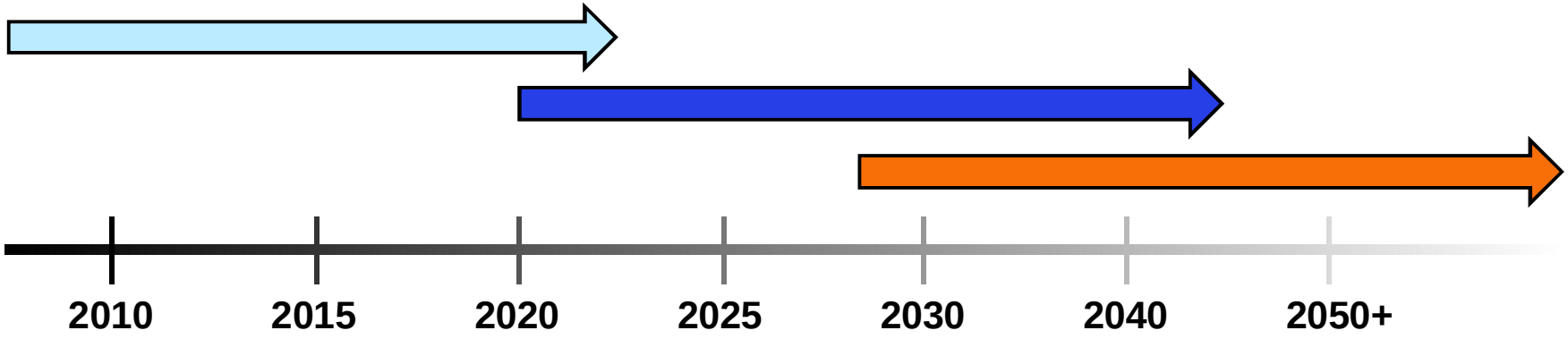
SMR160
Holtec, USA

VK-300
Nikiet, Russian Federation

TH-100
STL, South Africa

SC-HTGR
Areva, France

G4M
Gen4 Energy, USA

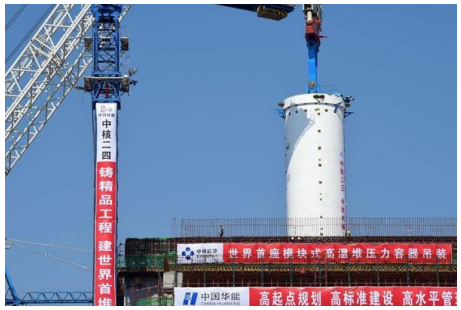


Source: IAEA SMRs Estimated Timeline of Deployment, "Small Modular Reactors, Update on International Technology Development Activities", October 2016
https://www.iaea.org/INPRO/13th_Dialogue_Forum/007_Advances_in_Small_Modular_Reactor_Technology_developments.pdf [17.3.2017]

HTR-PM

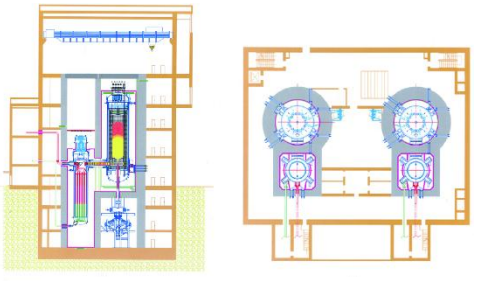
HTR-PM is a twin-reactor modular pebble bed HTGR demonstration plant.

It is under construction at Huaneng Shidao Bay site, People's Republic of China and will connect to grid within a year.



Design highlights:

- 420.000 fuel elements in one reactor core
- 250 MWth / 100 MWe per reactor unit **(40 % efficiency)**
- **567 ºC** secondary circuit steam output at 13.25 Mpa
  - primary circuit helium at 750 ºC at core outlet
- **Modular** on the scale of the power plant
  - Multiple reactor units for single turbine
- Passive safety: fully passive capacity for decay heat removal
  - Heat is conducted to structure: no need for natural circulation
- No central graphite column, no helium turbine, small core size
  - Avoids several problems otherwise associated with such designs



Source: "The Shandong Shidao Bay 200 MW_e High-Temperature Gas-Cooled Reactor Pebble-Bed Module (HTR-PM) Demonstration Power Plant: An Engineering and Technological Innovation", Engineering, Vol 2, Issue 1, pages 112-118, http://dx.doi.org/10.1016/J.ENG.2016.01.020 [17.3.2017] and *The State Council, People's Republic of China*

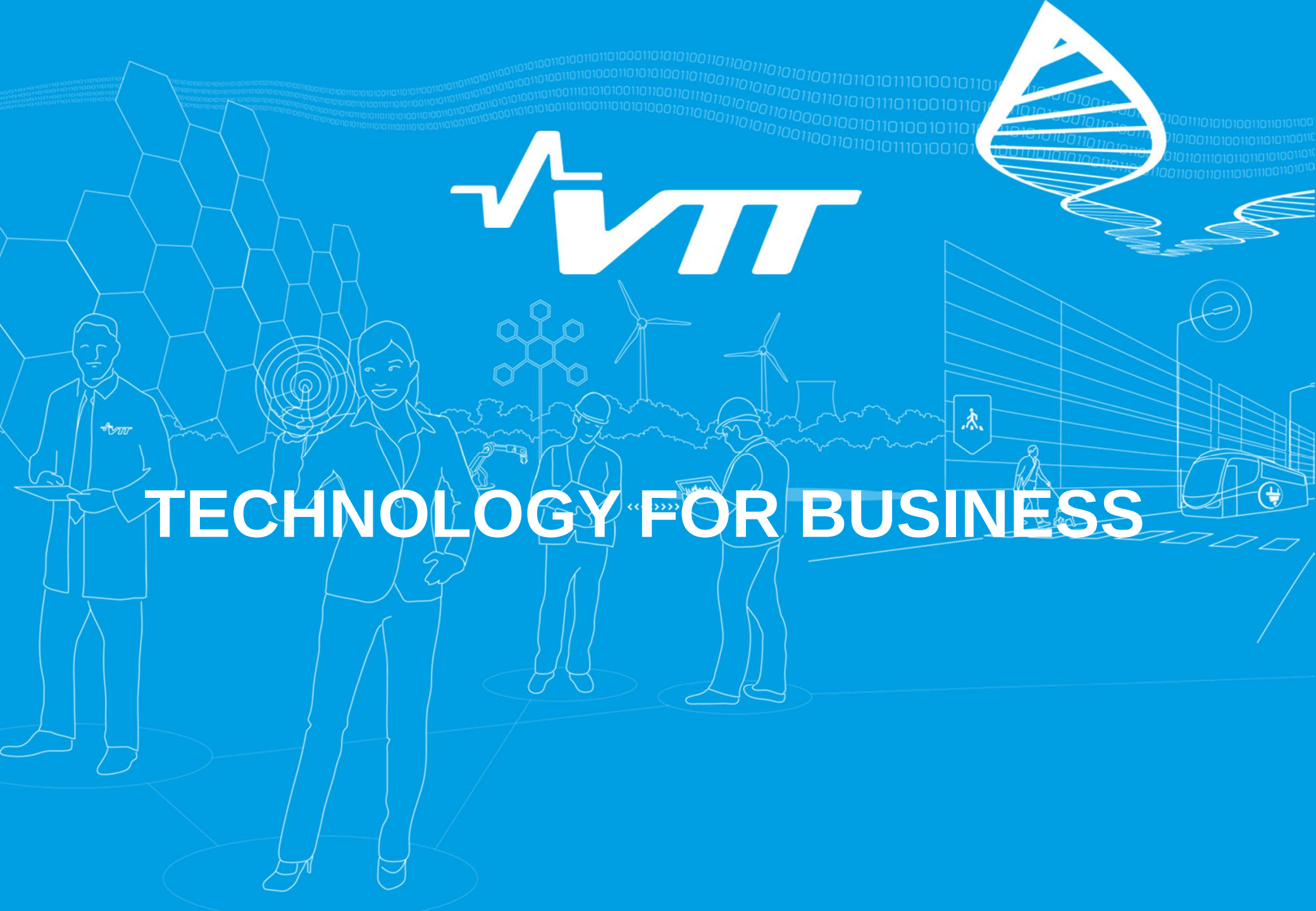
HTR-PM

Prototype HTR-10 reactor was used to demonstrate the reactor behavior by **initiating several ATWS events.** The reactor shut itself down safely with no damage in all cases**.**

Similar tests with HTR-PM are expected this year to prove the design's inherent safety.

HTR-PM is a first-of-a-kind demonstration plant. Its **actualized costs** per MWe exceed corresponding traditional LWR costs by **10-20%** before cost reductions from mass production or establishment of HTGR industry.

Source: "The Shandong Shidao Bay 200 MW_e High-Temperature Gas-Cooled Reactor Pebble-Bed Module (HTR-PM) Demonstration Power Plant: An Engineering and Technological Innovation", Engineering, Vol 2, Issue 1, pages 112-118, http://dx.doi.org/10.1016/J.ENG.2016.01.020 [17.3.2017] and *The State Council, People's Republic of China*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