



ULTRA SAFE NUCLEAR

USNC MMR

Small Reactor, Big Potential

SwRI: Industrial Processes Emissions Reduction (IPER) Technology
Workshop March 1 – 2, 2023

RELIABLE ZERO-CARBON ENERGY ANYWHERE



March 23

Classic Civilizations



Ancient Egyptians



Classic Greek



Roman Empire



Vikings



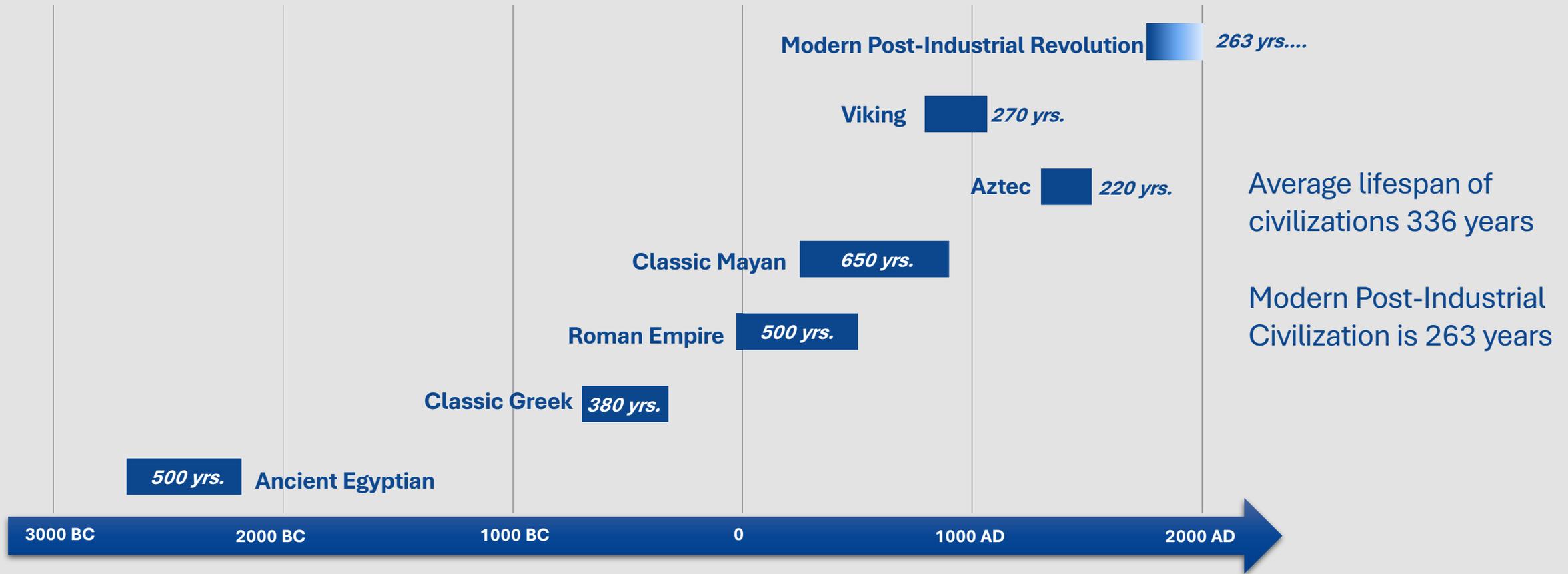
Classic Mayan



Aztecs



Classic Civilizations & Societal Collapse

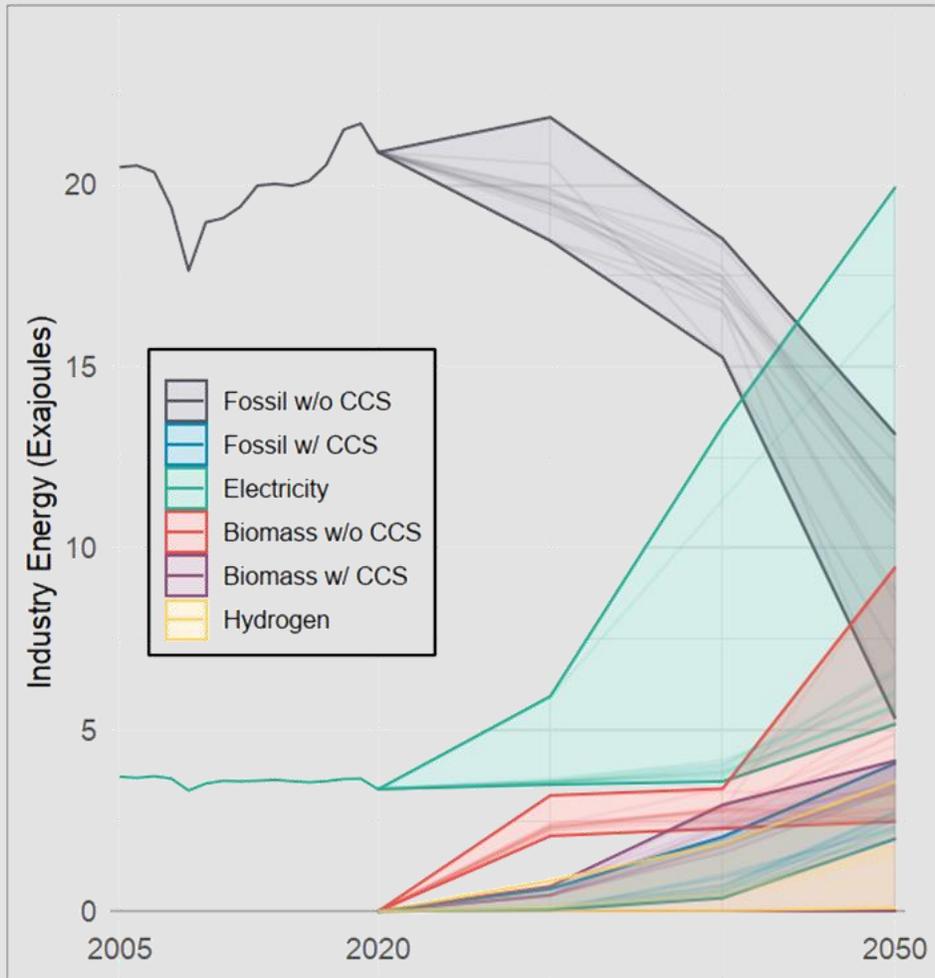


Societal collapse is a choice.

What will our modern global society choose?



US Long Term Strategy on Industrial Emission Reductions



INDUSTRY

Migration to:

Electrification, Hydrogen, Biomass, Carbon Capture

Significant innovation required over the decisive decade

Nuclear technology can support the migration, in addition supply process heat

THE LONG-TERM STRATEGY OF THE UNITED STATES, Pathways to Net-Zero Greenhouse Gas Emissions by 2050, NOV 2021



USNC – Who we are



A privately held, investor financed US enterprise

Founded in 2011

Headquartered in Seattle, 250+ employees around the globe

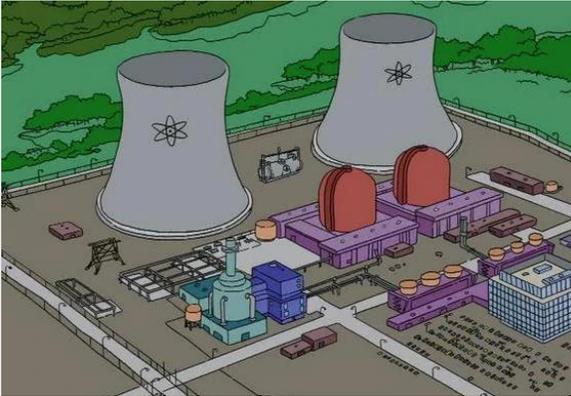
USNC develops and promotes its founding technology in three areas:

- Micro Modular Reactor (MMR[®]) – a subclass of Small Modular Reactors that utilizes high temperature inert gas cooled technology
- Fully Ceramic Micro-encapsulated (FCM[®]) nuclear fuel
- Advanced Systems - Space Nuclear Power, Propulsion and Batteries



Traditional Large Scale Nuclear

US Nuclear Power Industry: Generation II Light Water Reactor Technology



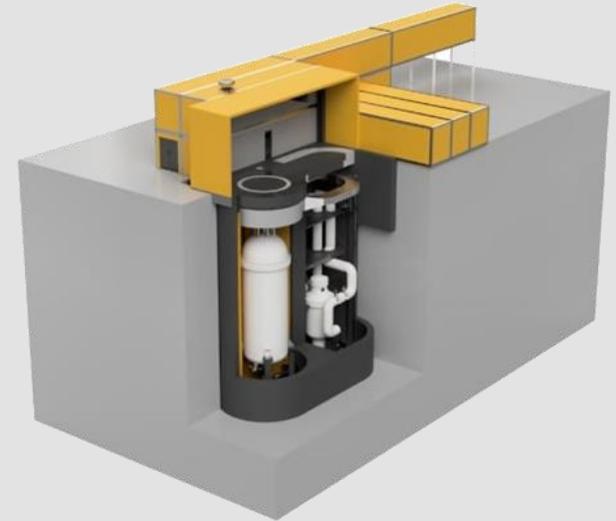
- Very Large Power Plants (700 MW+ electric)
- Capital intensive
- Long duration, stick-build construction
- Complex Operation
- Active safety systems to mitigate melt-down risks
- Frequent refueling required, increasing nuclear proliferation risks
- Low nuclear fuel burn-up (larger amount of waste)
- Low Temperature heat ($\sim 300^{\circ}\text{C}$ / 570 F)



What are Small Modular Reactors

Small Modular Reactors – Advanced Gen IV Reactors

- Power limited to a maximum of 300 MWe
- Modular, factory fabricated, road transportable designs
- Improved fuel performance & safety
- Simplified operations including autonomous control
- Passive safety systems & inherent safety reactor characteristics
- In-frequent, and in some cases no refueling (minimizing high level waste)
- High nuclear fuel burn-up (minimizing the amount of waste)
- High temperature heat (~500°C / 930 F to 950°C / 1740 F)



USNC Fuel

Built on solid foundation of TRI-Structural ISOtropic(TRISO) Particle Fuel

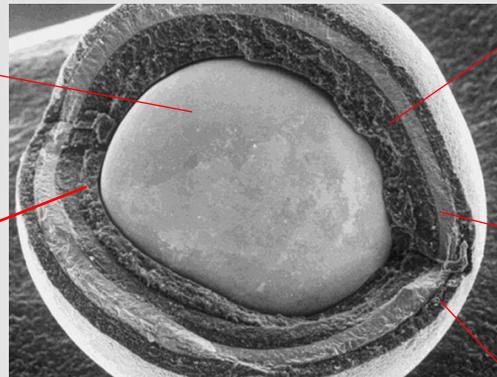
- Dates back to 1960's
- TRISO fuel is fundamental to the safety case for high-temperature gas reactors (HTGRs)
- Radionuclides are retained within the multiple barriers and provide for retention at source
- TRISO fuel has successfully survived 300+ hour safety tests at 1800°C (INL AGR)

Fuel Kernel

- Provides fission energy
- Retains fission products

Buffer layer (porous carbon layer)

- Attenuate fission recoils
- Void volume for fission gases
- Accommodates kernel swelling



Inner Pyrocarbon (IPyC)

- Prevent attack of kernel during manufacture
- Provides structural support for SiC
- Retains gaseous fission products

Silicon Carbide (SiC)

- Primary load bearing member
- Retain gas and metal fission products

Outer Pyrocarbon (OPyC)

- Provides structural support for SiC
- Retains gaseous fission products

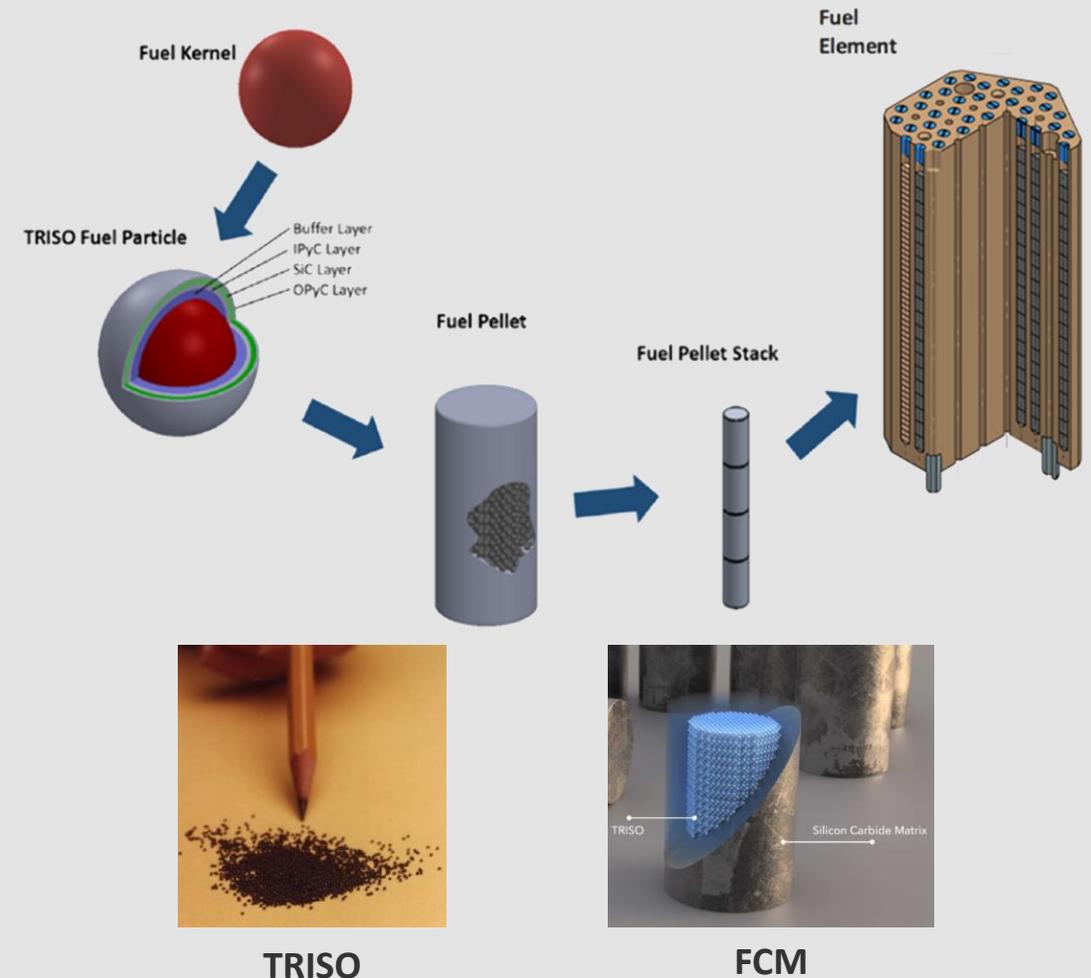
The TRISO Fuel Particle is a Mini Pressure Vessel that retains fission products



USNC Fuel Technology

Fully Ceramic Micro-encapsulated (FCM[®]) fuel

- Manufactured with TRISO coated fuel particles + compacted in specially sintered silicon carbide (SiC) pellets instead of a carbonaceous matrix
- The SiC provides another layer of containment of fission products during operations and accident conditions
- Enhances non-proliferation goals
- Provides another layer of protection during interim storage and in a permanent repository after operations



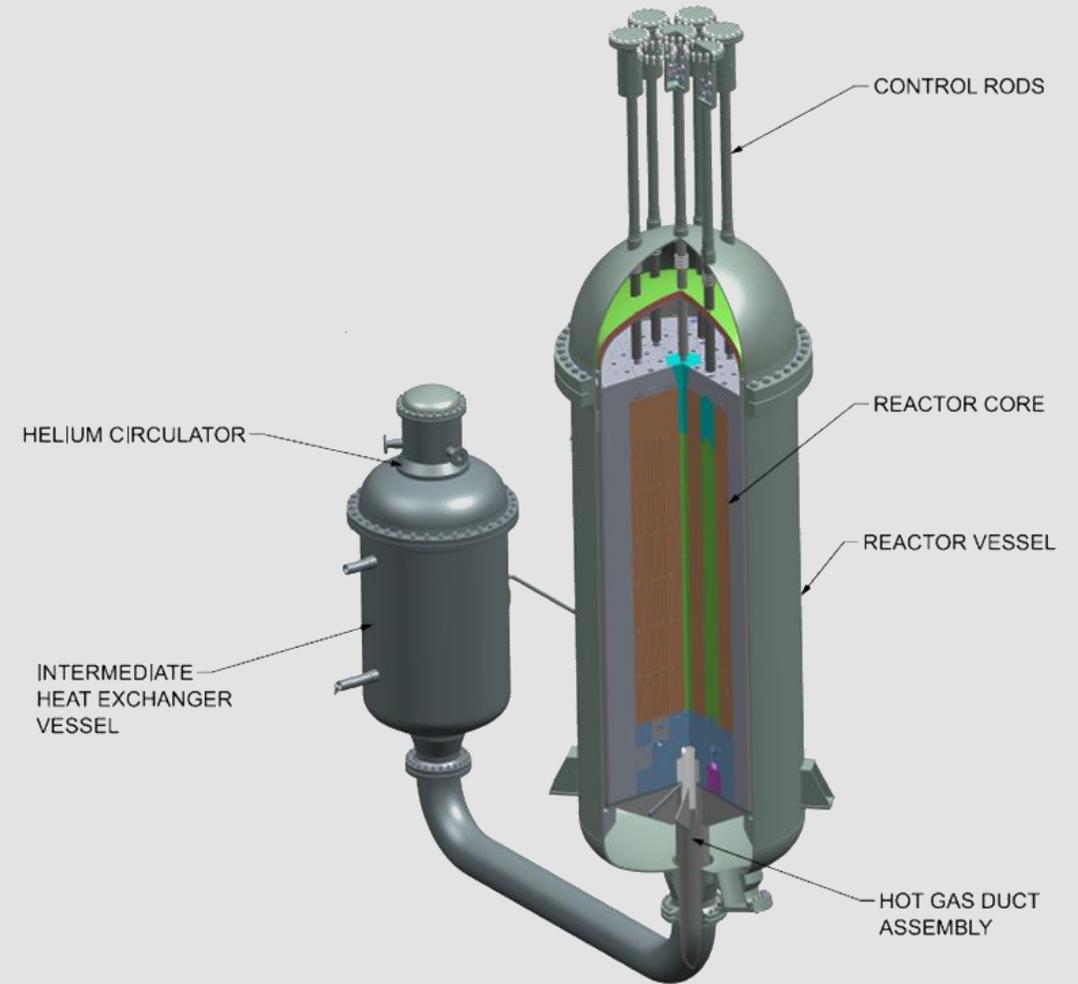
The USNC Micro Modular Reactor MMR®

Reactor: 15 MW thermal / 5MW electric

- Generation-IV Reactor Technology
- Graphite moderator
- Inert material (helium) for coolant
- Proven TRISO fuel in FCM matrix
- No refueling for 20-year operational life (HALEU)

Safety:

- Passive safety features, with no requirement for cooling water, electricity or operator action to keep reactor safe.
- Under all accident scenarios heat dissipates passively into the environment without moving parts or fluids
- Located underground (buried) reactor provides excellent protection against physical hazards
- Negative Fuel Reactivity Temperature Coefficient, as the core heats up the fuel becomes less reactive



MMR design benefits from significant operational experience



1965

DRAGON
20 MWt, UK



1968

AVR
46 MWt – 15 MWe,
GERMANY



1985

THTR
750 MWt – 300 MWe,
GERMANY



2000

HTR-10
10 MWt, CHINA



1966

Peach Bottom
115 MWt - 40 MWe
Pennsylvania, USA



1976

Fort St. Vrain
842 MWt – 330 MWe
Colorado, USA



1998

HTTR
30 MWt, JAPAN

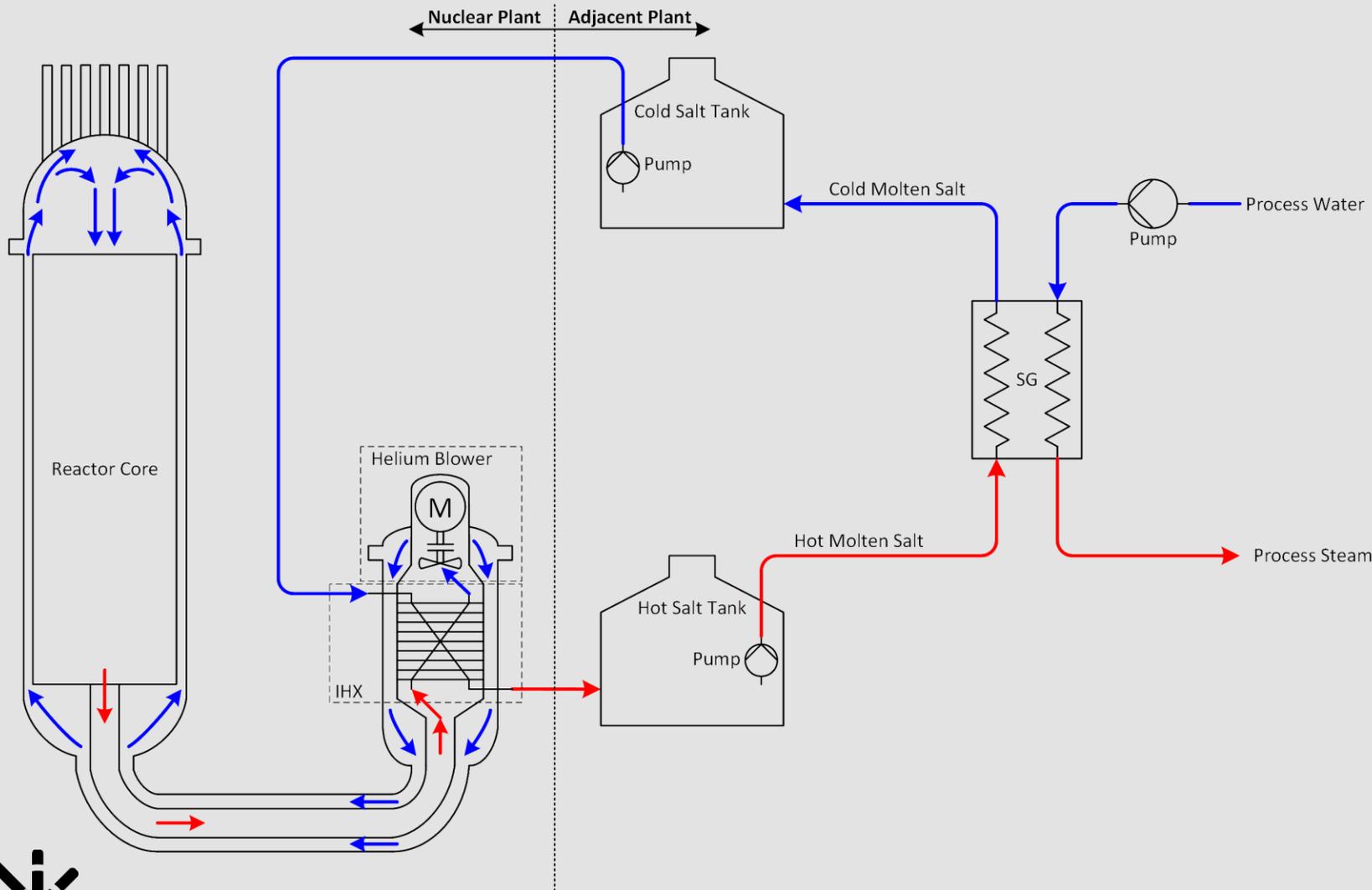


2021

HTR-PM
250 MWt, CHINA



MMR: Basis Process Flow



Helium

Inlet: 300°C

Outlet: 630°C

Molten Salt

Inlet: 275°C

Outlet: 575°C

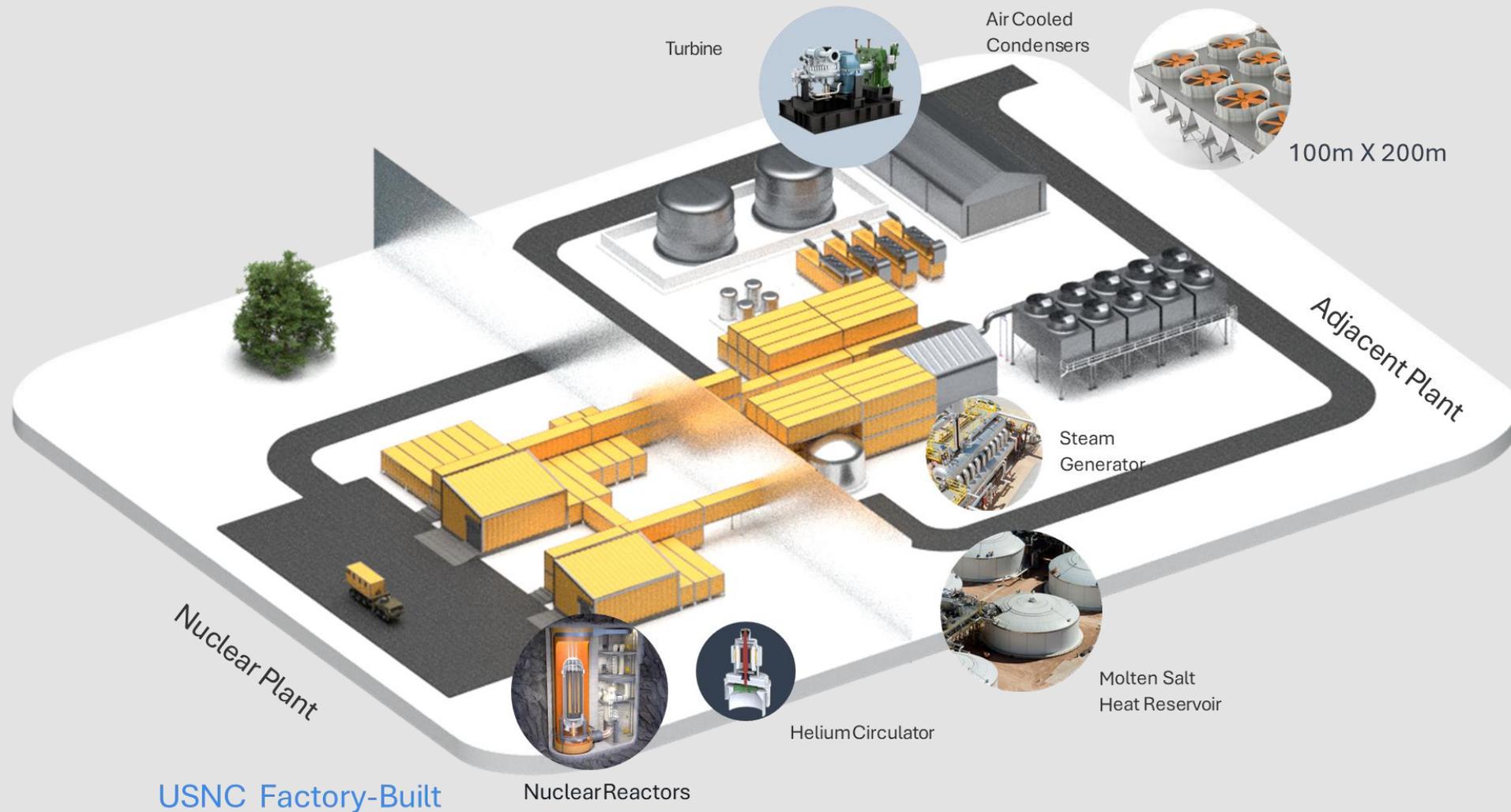
Molten Salt storage (CSP technology)

Sodium/ Potassium salt mixture

Allows for separation of nuclear plant from industrial application



MMR – Two Reactor Unit (30 MW thermal)



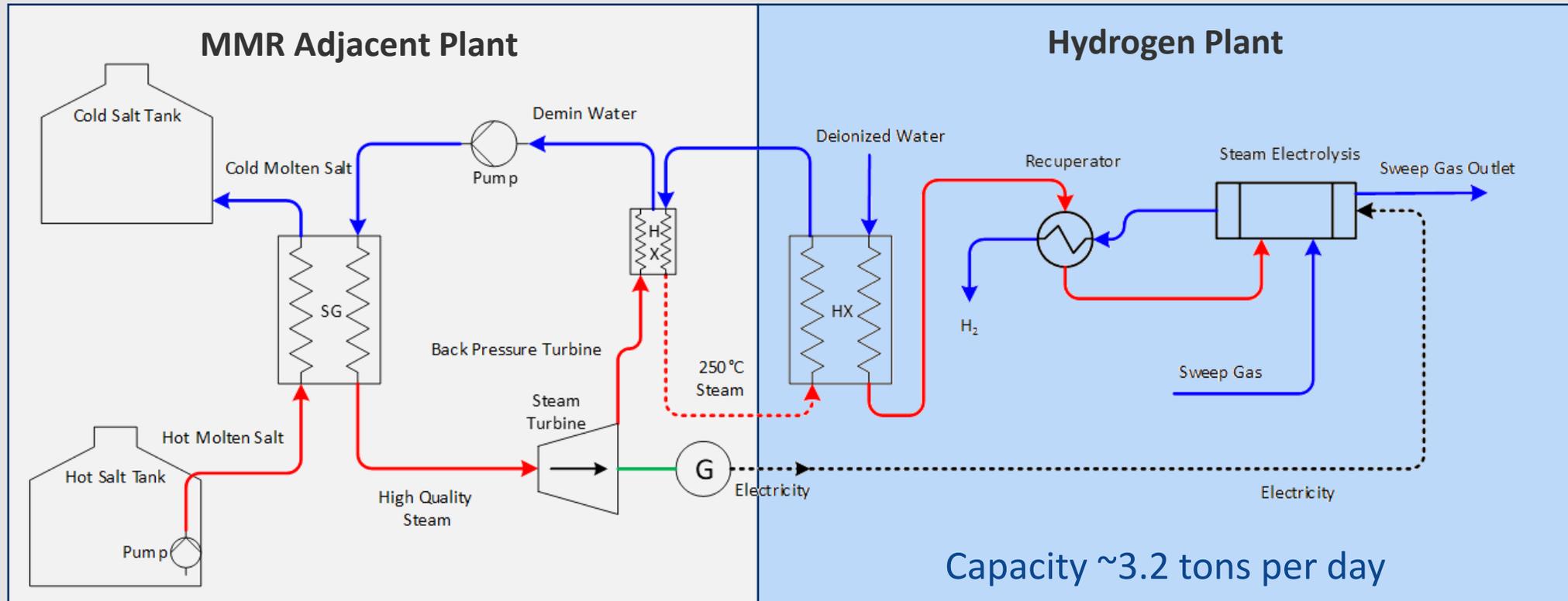
Progress to date – Chalk River (Canada), University of Illinois (UIUC)



MMR Application - Industry

15 MW thermal MMR with Hydrogen Production (High Temperature Steam Electrolysis)

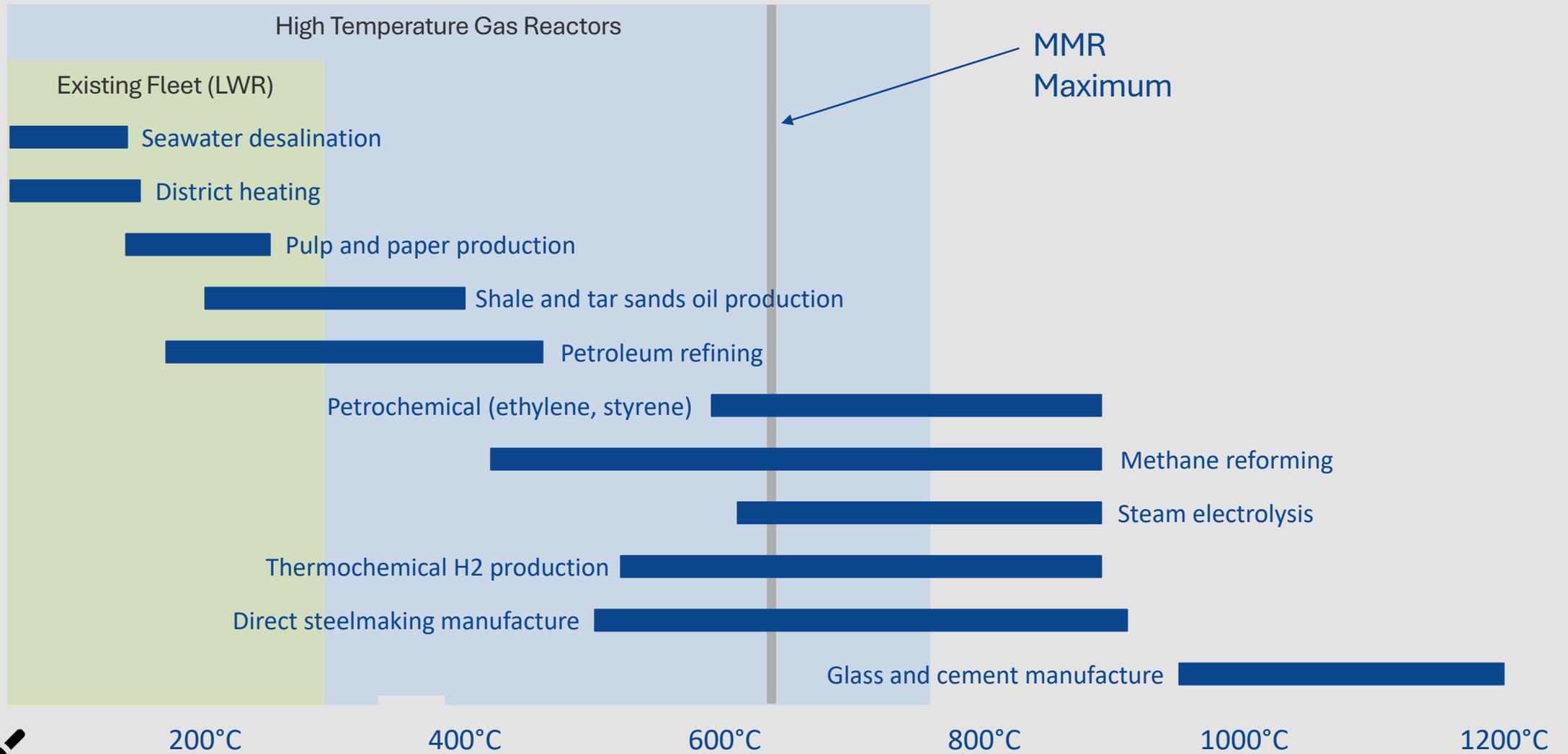
Pink Hydrogen



- Supports distributed hydrogen generation
- 15-20% energy from process heat and 80-85% energy from electricity
- Temperature required ranges from $\sim 600^{\circ}\text{C}$ to 800°C , supplied by recuperated heat, and topping heaters
- Hydrogen yield efficiency of $\sim 36\%$



Industrial Processes - Temperature Range



A US led Nuclear Renaissance

Asian domination of renewable supply chain

Stagnant nuclear development in the West & rampant development in the Far East

A US nuclear renaissance?

- Public sector spending for de-risking & scaling
- Aggressive innovation to unlock future export of zero-carbon energy technology
- Create suitable licensing framework for SMRs

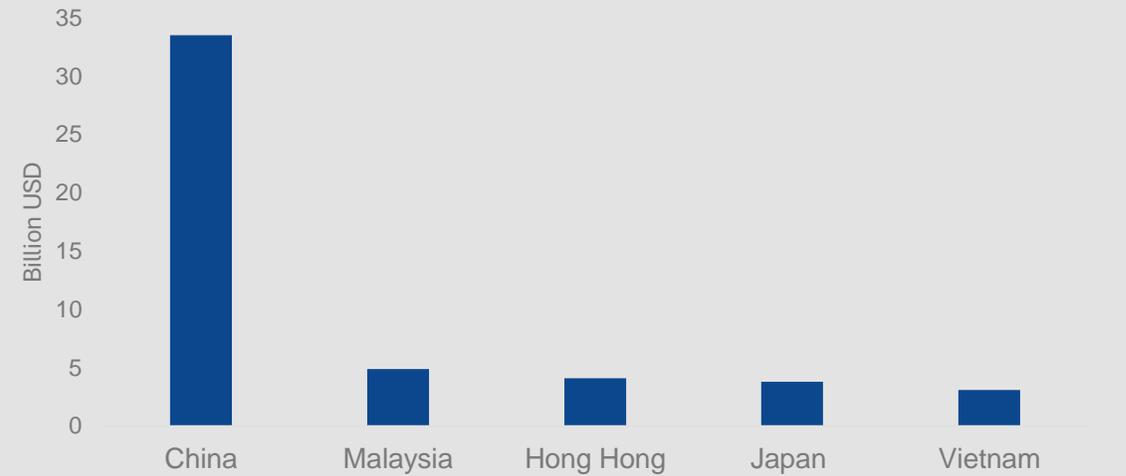
The US must acknowledge lessons learnt from the late start in renewables and avoid the same outcome for new nuclear



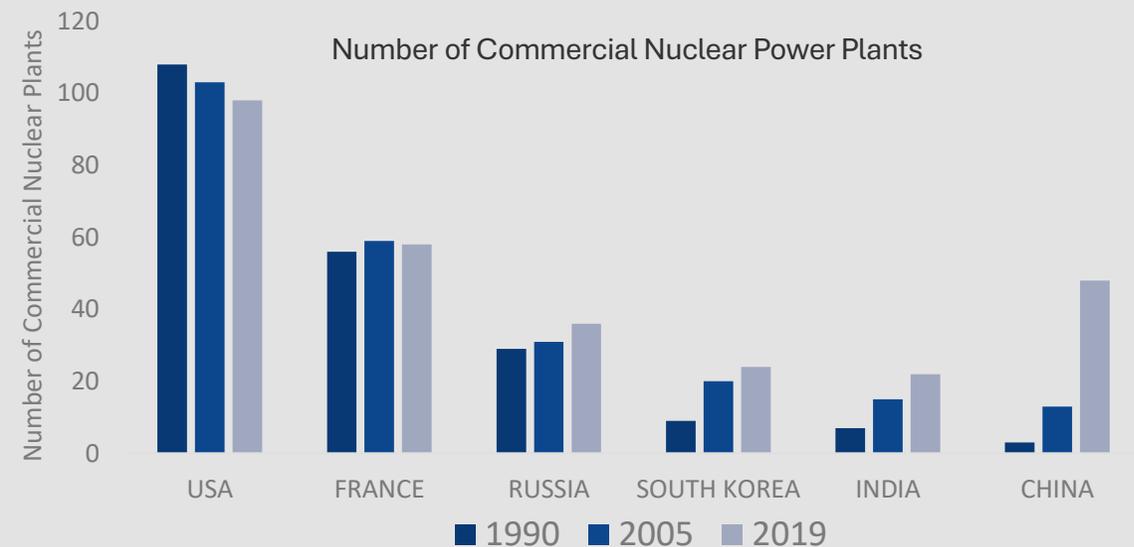
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Top Solar Power and Wind Power Equipment Exports by Country



Number of Commercial Nuclear Power Plants



17

Concluding Remarks

Climate Change driven social collapse is indeed a choice...



*“We are the **first generation** to feel the effect of climate change and the **last generation** who can do something about it.”*

Barack Obama, Former US President





ULTRA SAFE NUCLEAR

Thank You

Questions?

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