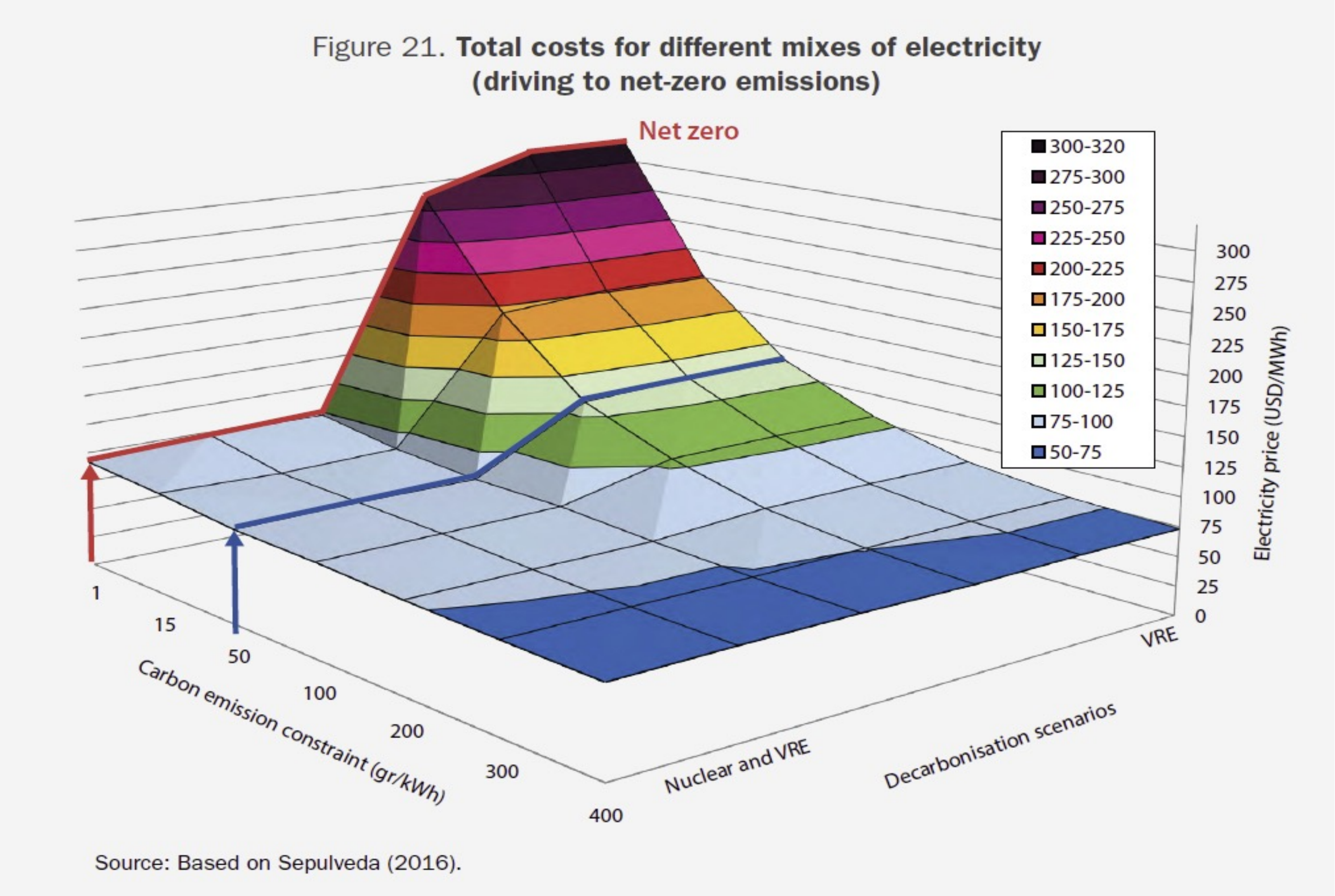
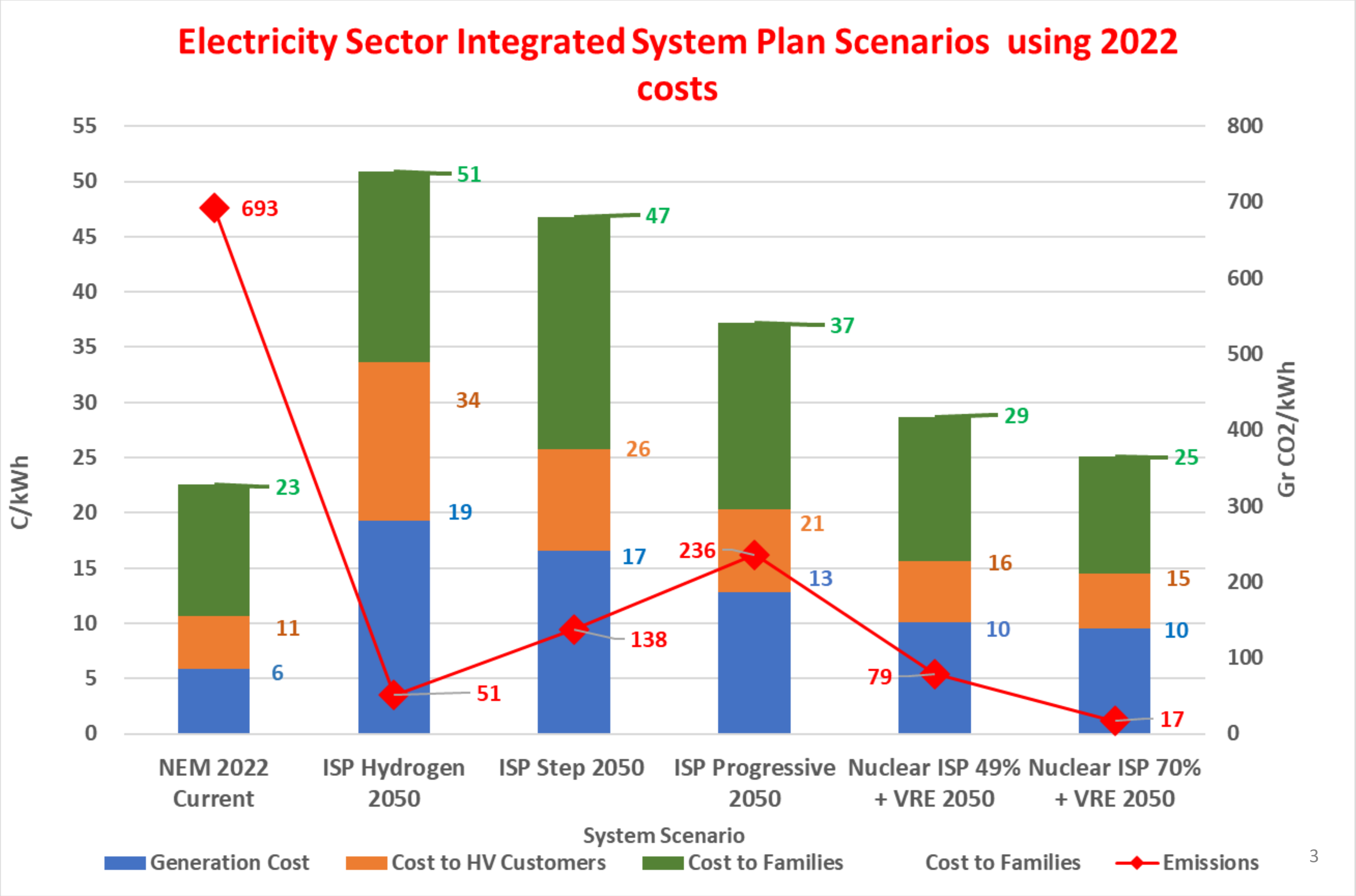
Opportunities for Clean Energy Adoption

1. **Brief statement on the energy problem**
2. **Nuclear Power Plant Options**
   - **Grid Connected**
   - **Industrials use**
   - **Micro Modular**

Emissions target vs Gen Mix vs Energy cost



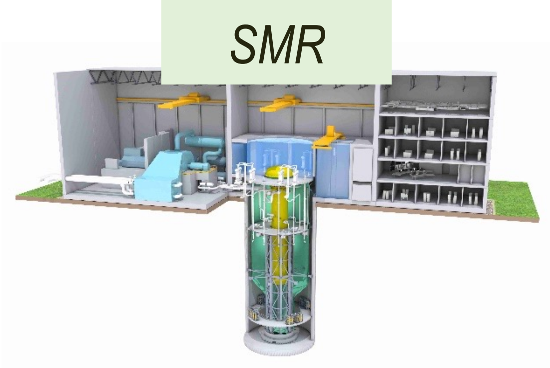


Electricity Sector Integrated System Plan Scenarios using 2022 costs
C/kWh
Gr CO2/kWh
55
50
45
40
35
30
25
20
15
10
5
0
800
700
600
500
400
300
200
100
0
693
51
138
236
79
17
23
11
6
51
34
19
47
26
17
37
21
13
29
16
10
25
15
10
NEM 2022 Current
ISP Hydrogen 2050
ISP Step 2050
ISP Progressive 2050
Nuclear ISP 49% + VRE 2050
Nuclear ISP 70% + VRE 2050
System Scenario
Generation Cost
Cost to HV Customers
Cost to Families
Cost to Families
Emissions

SMALLER MACHINES WITH REDUCED NUMBER AND COMPLEXITY OF NUCLEAR SSCs:

- Reduce the cost and time for design and engineering
- Dramatically reduce the cost and schedule of demo or FOAK unit

~1000 MW_e
~$10B
5-10 yrs



~100 MW_e
~$1B
3-5 yrs

~10 MW_e
<$0.1B
<1 yrs

Recently completed four unit Barakah project in UAE with 5,600 MWe South Korean Plants

Darlington Nuclear Power Plant in Ontario
4 units of 878MWe = 3,512MW

Small Modular Reactors

On-grid SMRs

- 150 to 300 Mwe
- Reliable, baseload power
- Displace coal-fired generation
- Near term deployment; by the end of this decade

▪ GE-Hitachi BWRX-300

Advanced Reactors

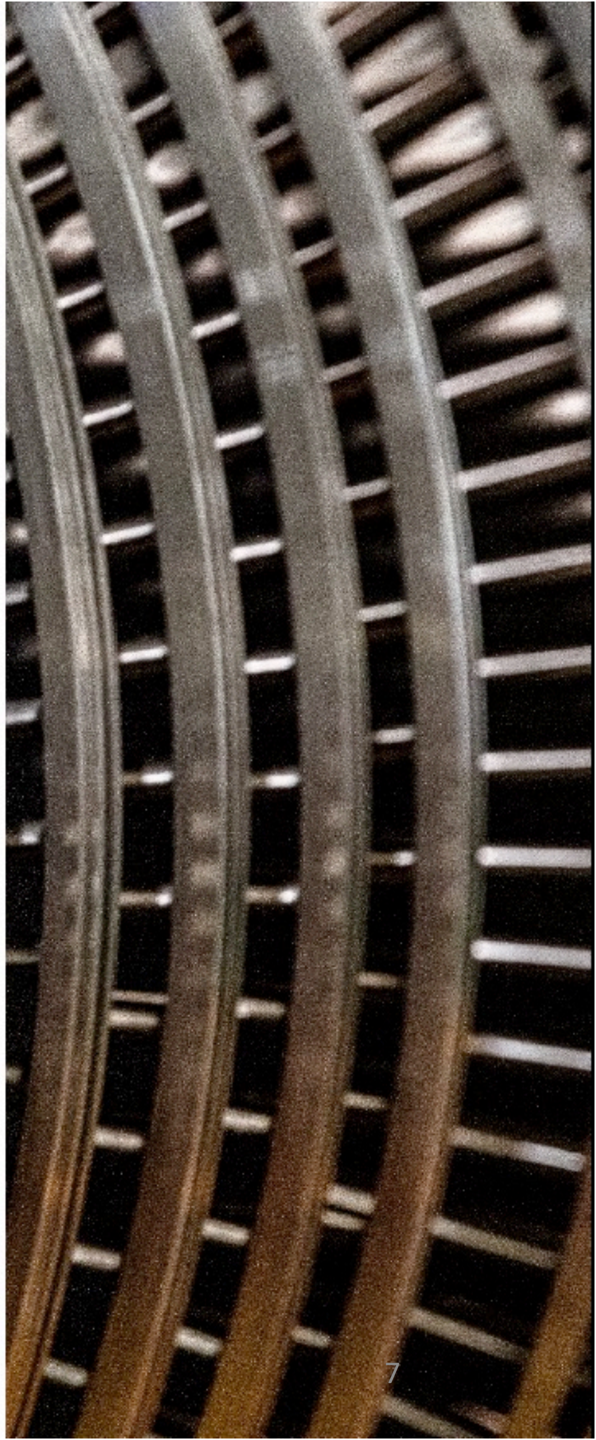
- 10 to 150 Mwe
- Advanced reactors
- Heavy industrial applications
- Expected to be deployed in mid-2030s

▪ ARC
▪ Moltex
▪ X-Energy

Off-grid SMRs

- 1 to 10 MWe
- Ideal for remote industrial and off-grid communities
- Commercial demonstration in the mid/late 2020s.

▪ Global First Power MMR
▪ Westinghouse eVinci



Darlington New Nuclear Project – Ontario Power Generation (OPG)

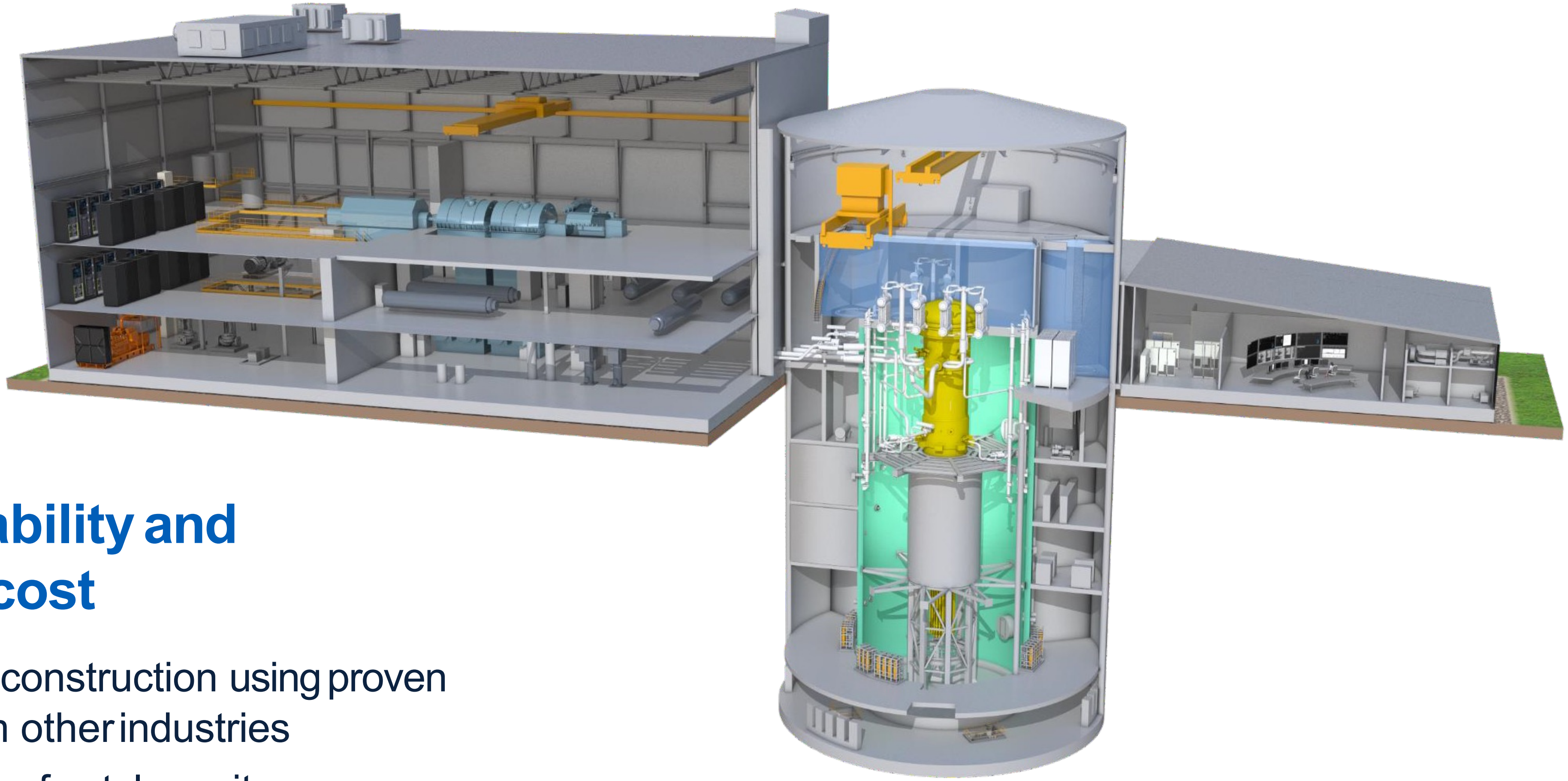
- Holds Licence to Prepare Site for new site in Clarington, Ontario
  - renewed in 2021 for another 10 years
- OPG has selected a SMR technology – GE Hitachi's BWRX-300
  - 300 MWe boiling water reactor
- OPG intends to apply for a licence to construct in fall 2022
  - Start construction of one BWRX-300 unit by early 2025 with an expected in-service date by 2028

https://www.opg.com/powering-ontario/our-generation/nuclear/darlington-nuclear/darlington-new-nuclear/

Small footprint and simple plant layout

Power Block dimensions: 140m x 70m
Secure or Protected Area: 2.7 Ha
Owner's Area: 13.8 Ha
EPZ: Expected to be site boundary

Optimized for cost and ease of construction

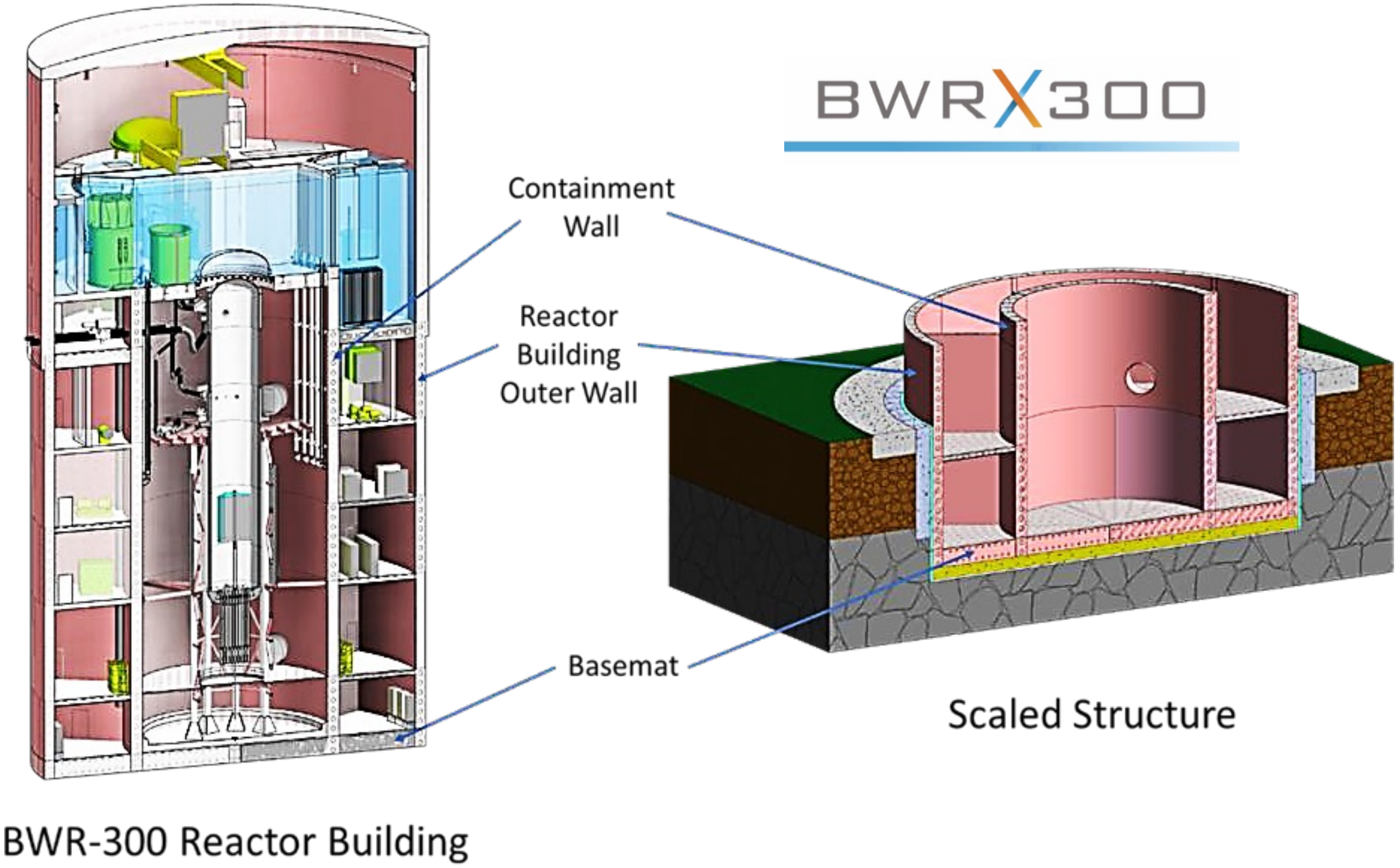


Constructability and Design-to-cost

- Underground construction using proven methods from other industries
- Maximum use of catalogue items
- “Off the shelf” turbine/generator

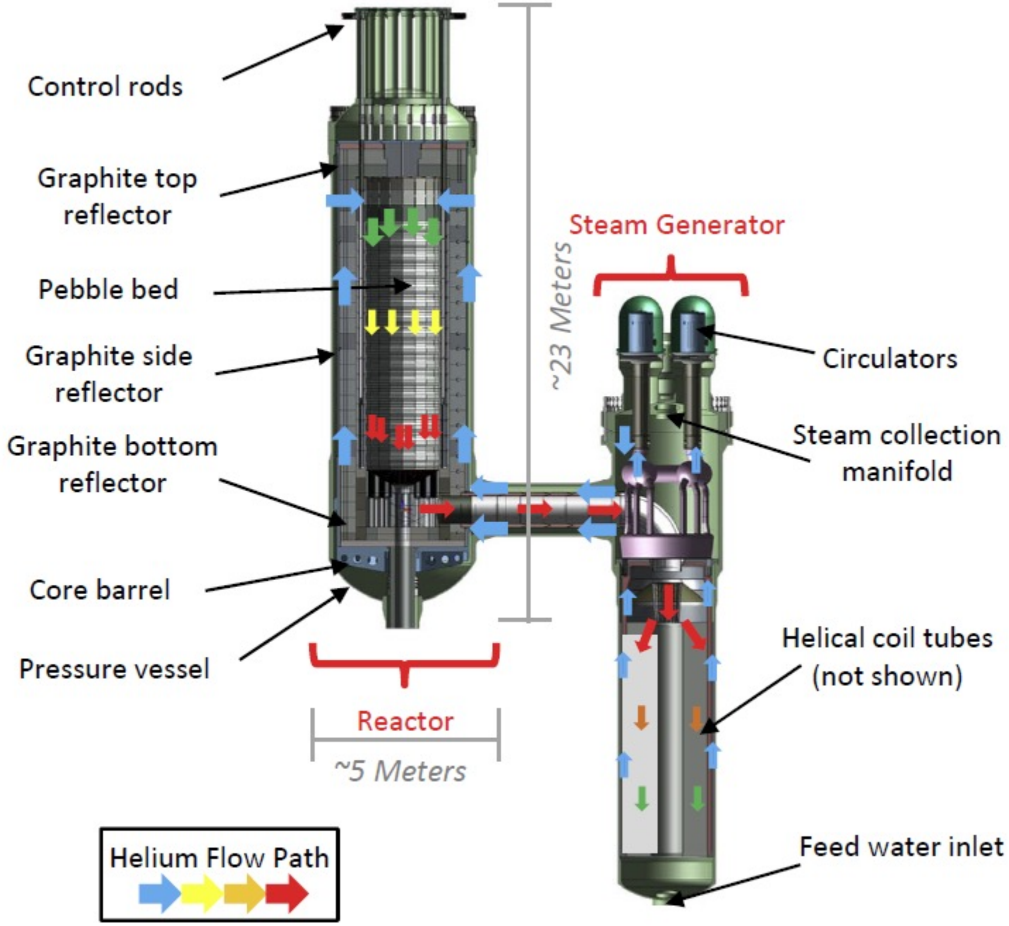
Improving Affordability & Scalability with Steel Bricks™

U.S. DOE taps GEH to lead research on lowering advanced nuclear construction costs including demonstration of Steel Bricks™ composite technology

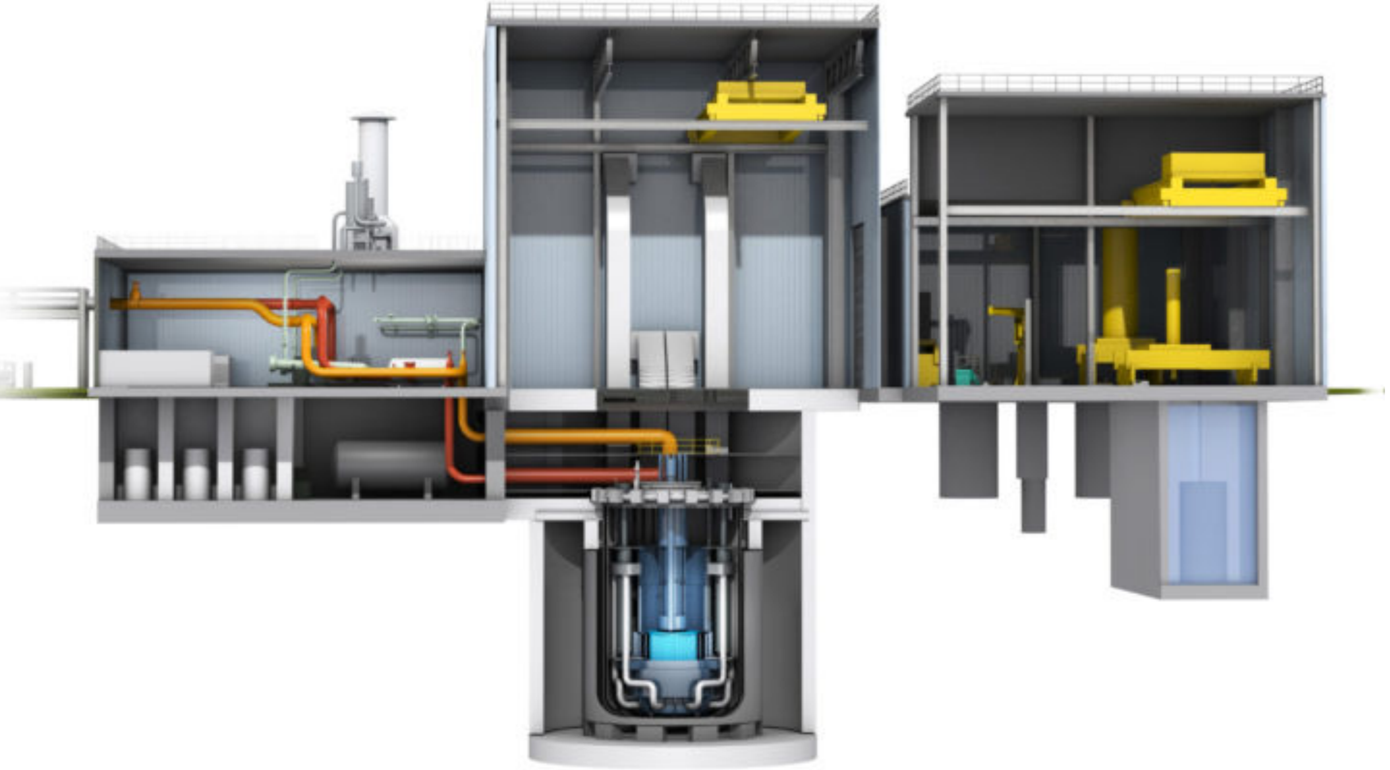


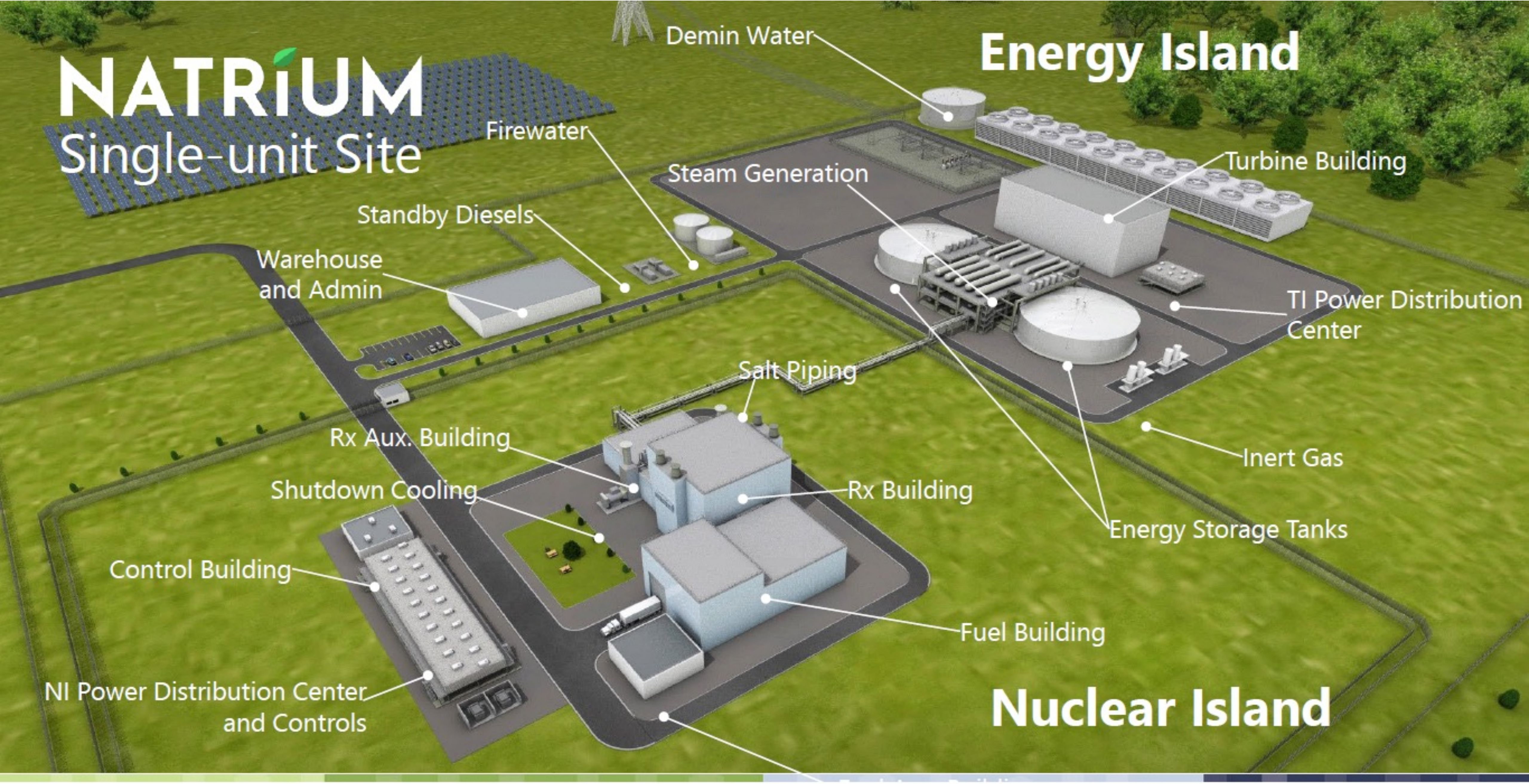
United States Nuclear Energy Gen IV Demonstration Projects

Xe – 100 Pebble Bed High Temperature Gas Reactor

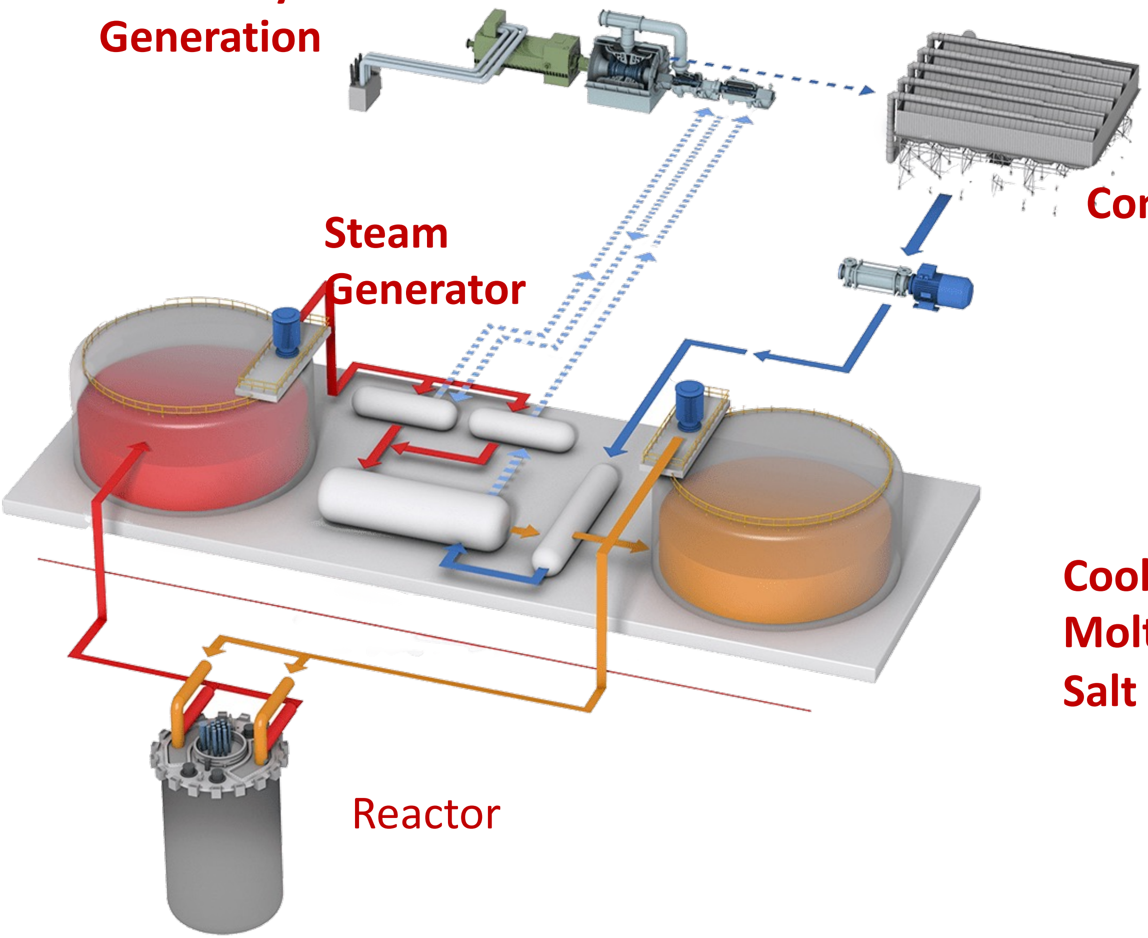


NATRIUM Sodium Cooled Fast Reactor with Molten Salt Storage




NATRIUM
Single-unit Site
Energy Island
Demin Water
Firewater
Steam Generation
Turbine Building
Standby Diesels
Warehouse and Admin
TI Power Distribution Center
Salt Piping
Rx Aux. Building
Inert Gas
Shutdown Cooling
Rx Building
Energy Storage Tanks
Control Building
Fuel Building
NI Power Distribution Center and Controls
Nuclear Island

The Natrium concept



The eventual 1000 MWe Natrium reactor should generate about 33 times more electrical energy per ton of mined uranium than present day light water reactors without the need for reprocessing.

China's HTR-PM HTGR at Shidaowan Bay

The HTR-PM features two small reactors (each of 250 MWt) that drive a single 210 MWe steam turbine

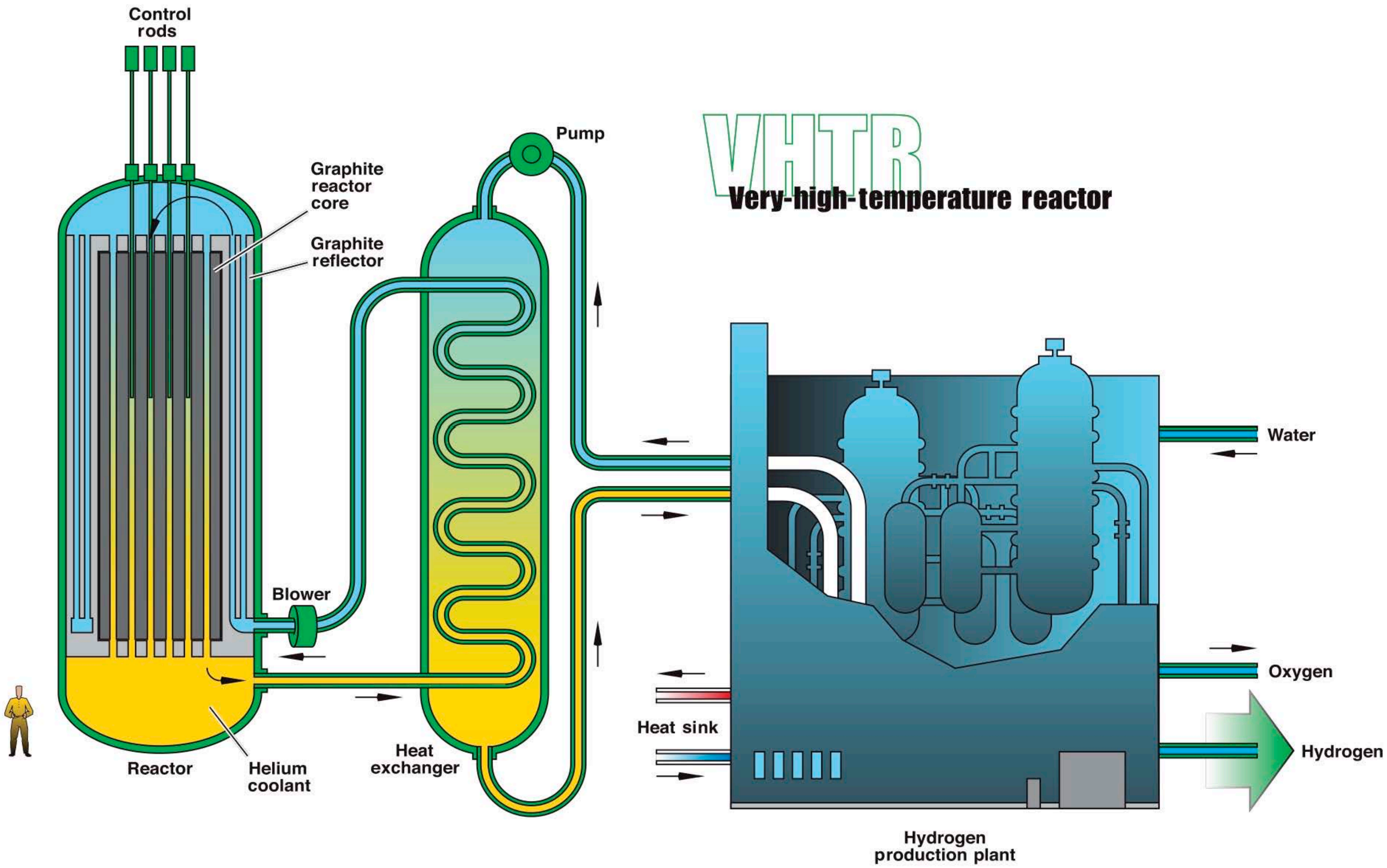
Very-High-Temperature Reactor (VHTR)

Characteristics

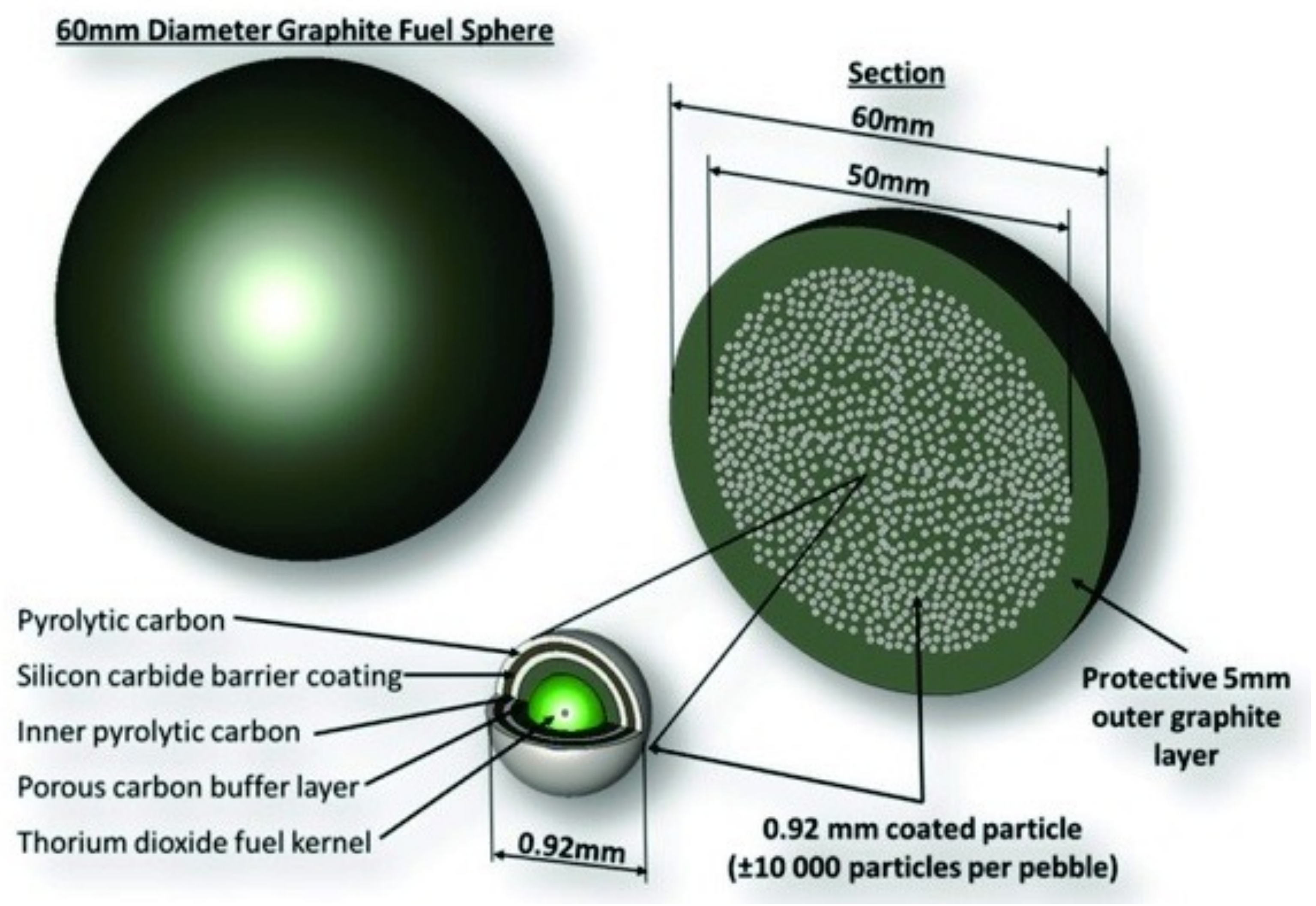
- He coolant
- >900C outlet temperature
- 250 MWe
- Coated particle fuel in either pebble bed or prismatic fuel
- Open fuel cycle

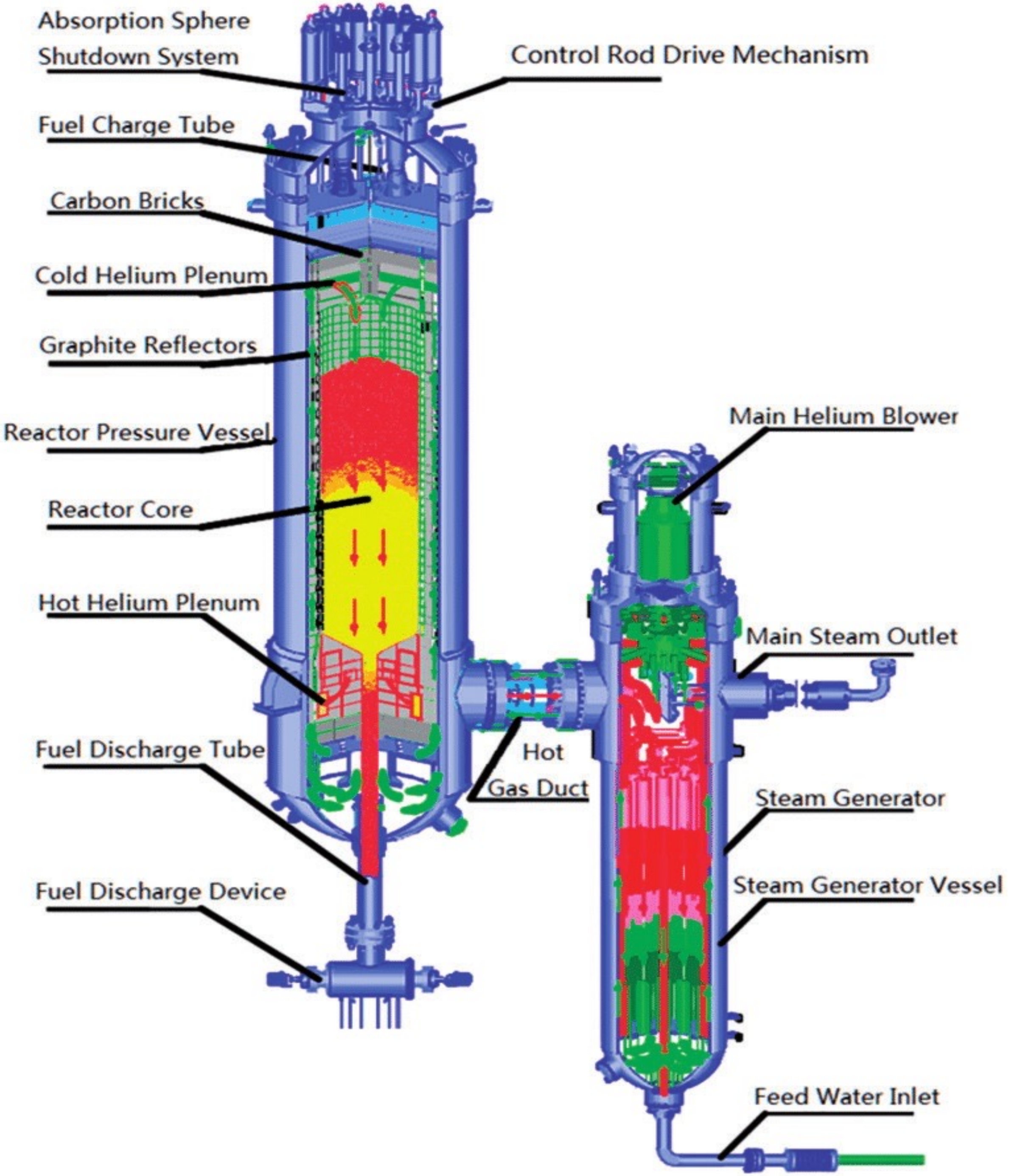
Benefits

- Hydrogen production
- Process heat applications
- High degree of passive safety
- High thermal efficiency option



TRISO Fuel


60mm Diameter Graphite Fuel Sphere
Section
60mm
50mm
Pyrolytic carbon
Silicon carbide barrier coating
Inner pyrolytic carbon
Porous carbon buffer layer
Thorium dioxide fuel kernel
0.92mm
0.92 mm coated particle
(±10 000 particles per pebble)
Protective 5mm
outer graphite
layer

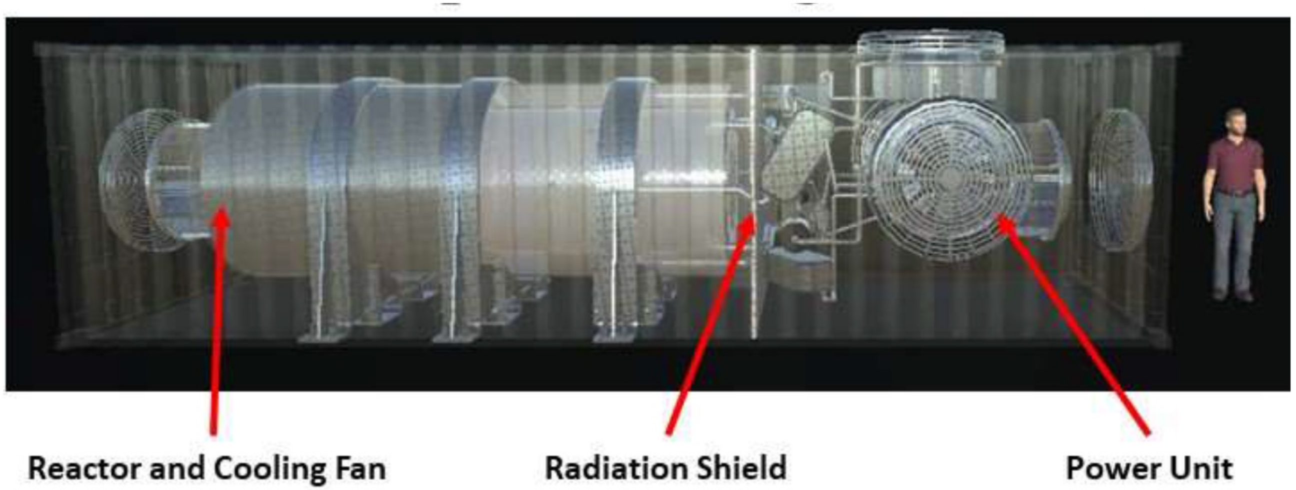


High Temperature Gas Cooled reactors

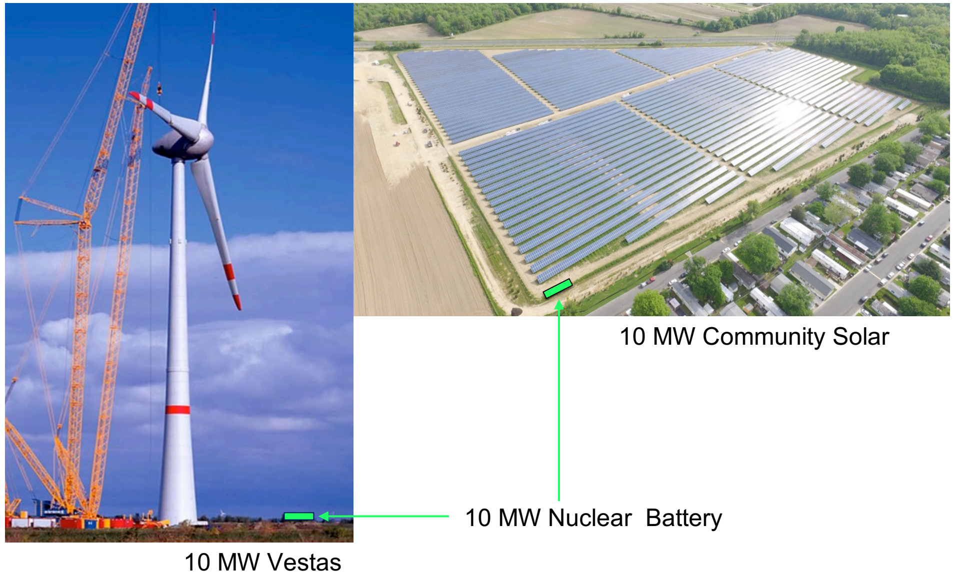
Xe – 100 Pebble Bed High Temperature Gas Reactor

Nuclear for CLIMATE AUSTRALIA

THE NUCLEAR BATTERY CONCEPT

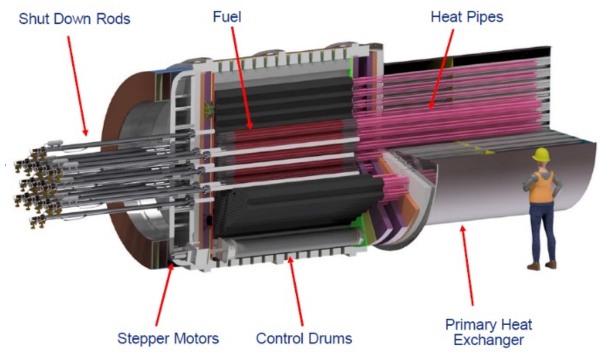


- 1-20 MW of heat and/or electricity
- Carbon free
- Dry cooling (no water needed)
- Standardized reactor design
- Factory built
- Transportable (ISO container)
- Plug-and-play connections
- Semi-autonomous operation
- Offsite refuelling every 5-10 years
- No onsite storage of radioactive material
- Very small footprint
- Western suppliers are leading (Westinghouse, BWXT, X-energy)



Nuclear for CLIMATE AUSTRALIA

NUCLEAR BATTERY EXAMPLES



[Westinghouse's eVinci]
5 MWe

[Core Power]
10 MWe

[Radiant]
1 MWe

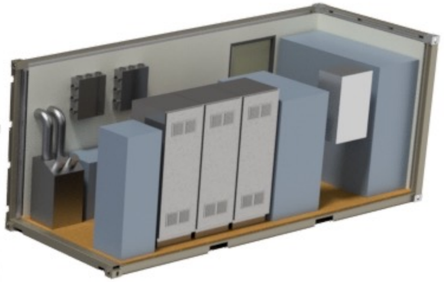
[NASA and LANL's Kilopower]
<100 kWe

[HolosGen]
13 MWe

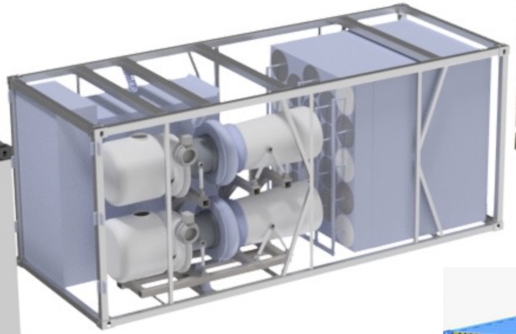
TRANSPORTABILITY

Entire plant delivered in four truckload size containers (40’ x 14’ x 14’)

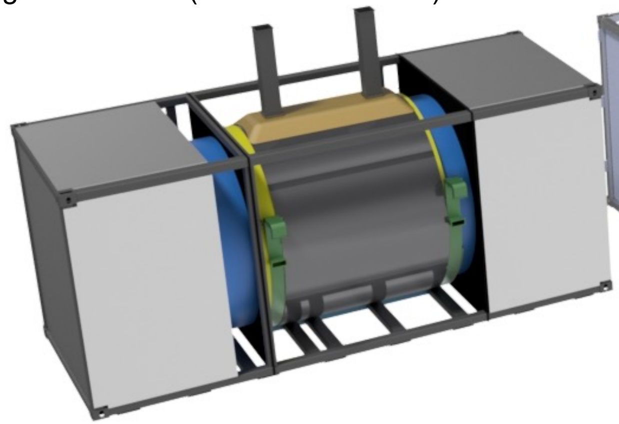
Shipping container #3 (the instrumentation and control module)



Shipping container #2 (the power conversion unit)



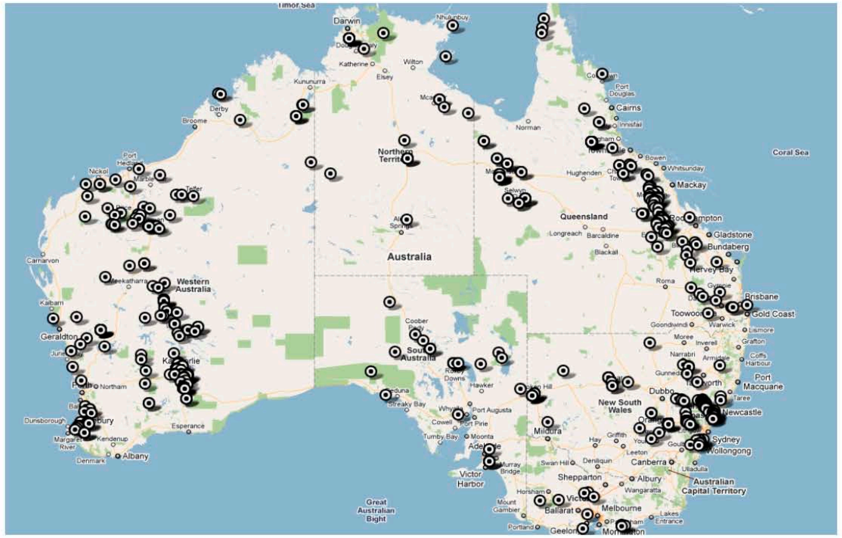
Shipping container #1 (the nuclear reactor)



Shipping container #4 (support equipment)

- Weights and sizes allow for deployment in remote areas (truck/rail/barge)
- Minimizes decommissioning and effort to return site to green field

Supply reliable, affordable and clean electricity to remote mining operations



- Requires nuclear reactors with dry cooling technology (available)
- Expansion of Olympic Dam alone could require an additional ~640 MW of electricity*

* https://www.bhp.com/-/media/bhp/regulatory-information-media/copper/olympic-dam/0000/information-sheets/olympic-dam-eis-energy-and-greenhouse-gases.pdf

Now for a Q&A

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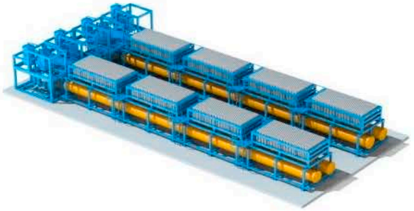
Nuclear for CLIMATE AUSTRALIA

NUCLEAR BATTERIES ARE IDEALLY SUITED TO SERVE EVERY SECTOR OF THE ECONOMY

Power

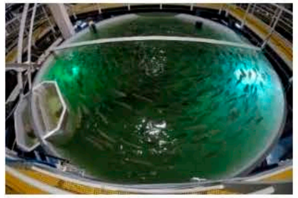

desalination

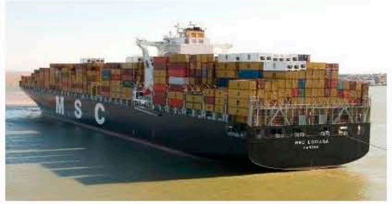

flood protection


hydrogen electrolyzers


data centers


e-vehicle charging stations


indoor aquaculture


freight ship propulsion


portable pharma

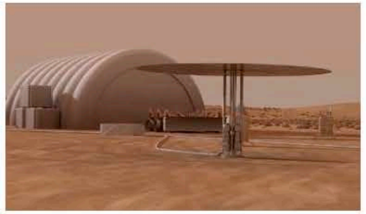
Combined Heat and Power


factories and chemical plants


district heating


microgrids (remote communities, islands)


indoor farming


space installations


military bases

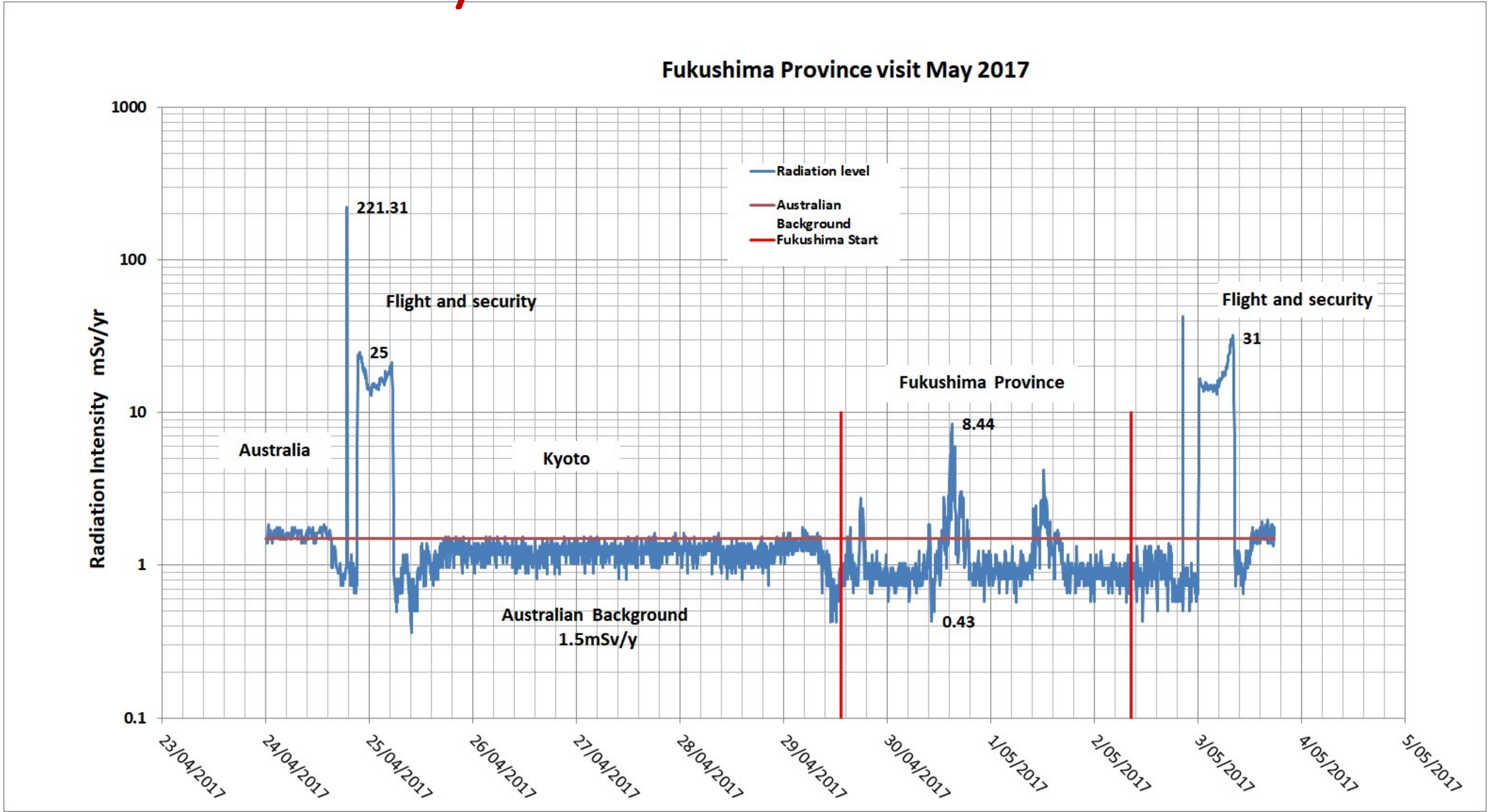
Co-location of micro-reactors with end users eliminates the need for massive, costly and unreliable infrastructure for energy storage, transmission and distribution

NEW MARKETS - U.S. EXAMPLES

Potential heat applications in the state of Washington

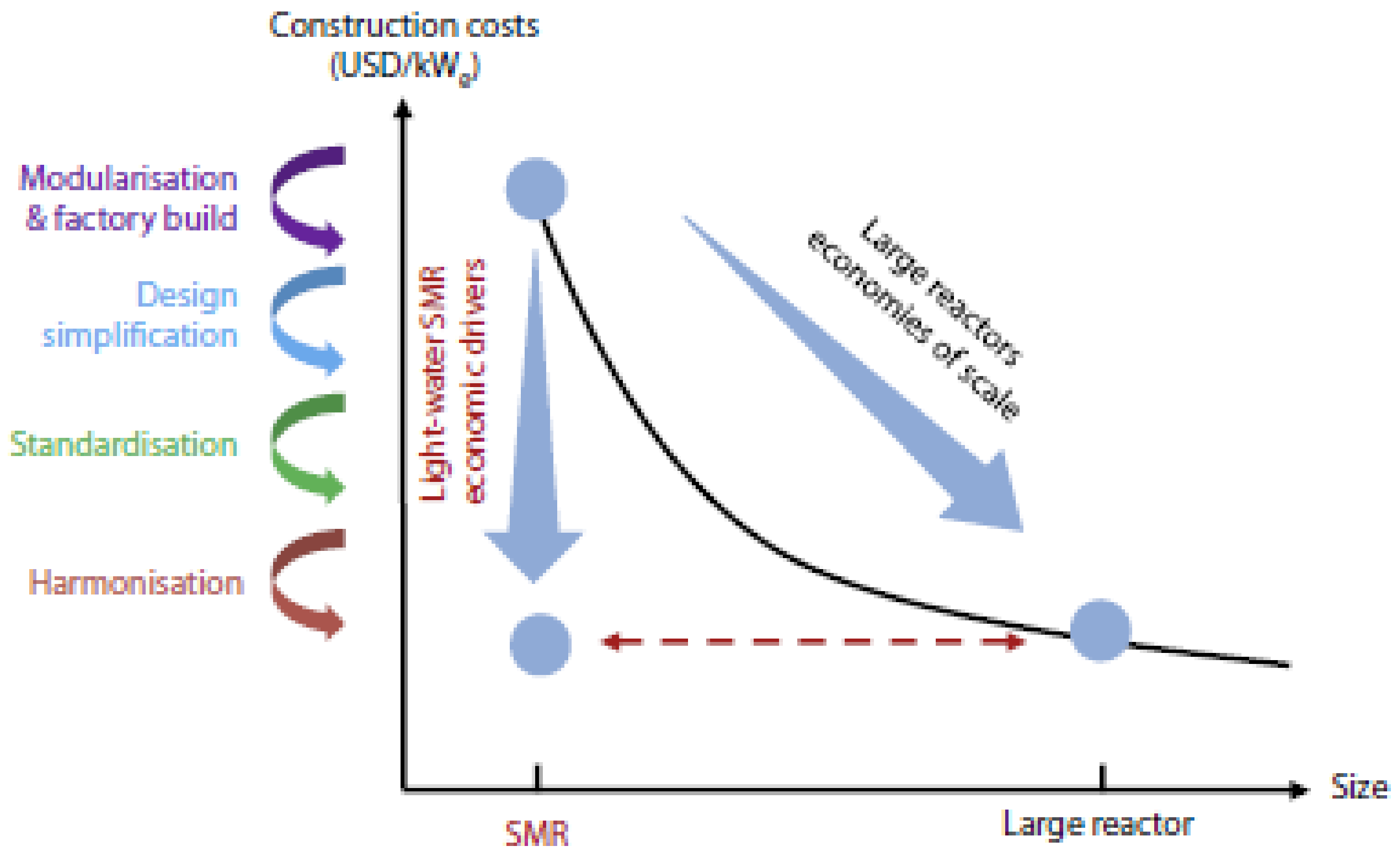
Site Name and Location	Business type	Non-biogenic CO_2 emissions (tons/year)	Average heat load (MW_t)
Darigold Sunnyside	cheese manufacturing	38,000	24
Darigold Lynden	dry, condensed, and evaporated dairy product manufacturing	17,900	11
Darigold Chehalis	dry, condensed, and evaporated dairy product manufacturing	11,800	8
J.R. Simplot Company Othello	potato processing plant	47,000	30
McCain Foods Othello	potato processing plant	37,000	23
Lamb Weston, Inc. Pasco	potato processing plant	44,000	28
Lamb Weston, Inc. Quincy	potato processing plant	32,000	20
Lamb Weston, Inc. Connell	potato processing plant	35,000	22
Lamb Weston, Inc. Richland	potato processing plant	60,000	38
Lamb Weston, Inc. Warden	potato processing plant	18,000	11
Basic American Foods Moses Lake	dried and dehydrated food manufacturing	24,000	15
Univ. of Washington Seattle	university campus	92,000*	58
Univ. of Washington Pullman	university campus	62,000	39
Univ. of Washington Ellensburg	university campus	19,000	12
CertainTeed Gypsum Seattle	gypsum products manufacturing	50,000	32
Georgia/Pacific Gypsum LLC Tacoma	gypsum products manufacturing	50,000	32
Longview Fibre Paper and Packaging, Inc. Longview Mill	paperboard mills	150,000**	95
Nippon Dynawave Longview	paperboard mills	280,000**	177
WestRock CP, LLC Tacoma	paperboard mills	122,000**	77
Boise Paper Wallula	paperboard mills	111,000**	70
Georgia/Pacific Consumer Products LLC Camas	paperboard mills	124,000**	78
Sonoco Products Company Sumner	paperboard mills	11,000**	7
North Pacific Paper Company, LLC Longview	newsprint mill	37,000	23
Inland Empire Paper Company Spokane	newsprint mill	10,000	6
Michelsen Packaging Yakima	other converted paper products	11,000	7
Cosmo Specialty Fibers Inc. Cosmopolis	sulfite mills pulp	20,000	13
Tyson Fresh Meats, Inc. Wallula	animal slaughtering	22,000	14
Darling Ingredients Inc. Tacoma	rendering and meat products	10,000	6

Radiation dose during visit to Kyoto and Fukushima



SMR's vs Large Plants

Figure 34: SMR economic drivers that help compensate for diseconomies of scale



5.3 Long-term industrial performance and design development