The Transformative Advanced Nuclear Technologies That Are Driving Rare Bi-partisanship in Washington, D.C.

Jeffrey S. Merrifield, Partner, Global Energy Section Leader

March 1, 2022 – CCIF Virtual Summit

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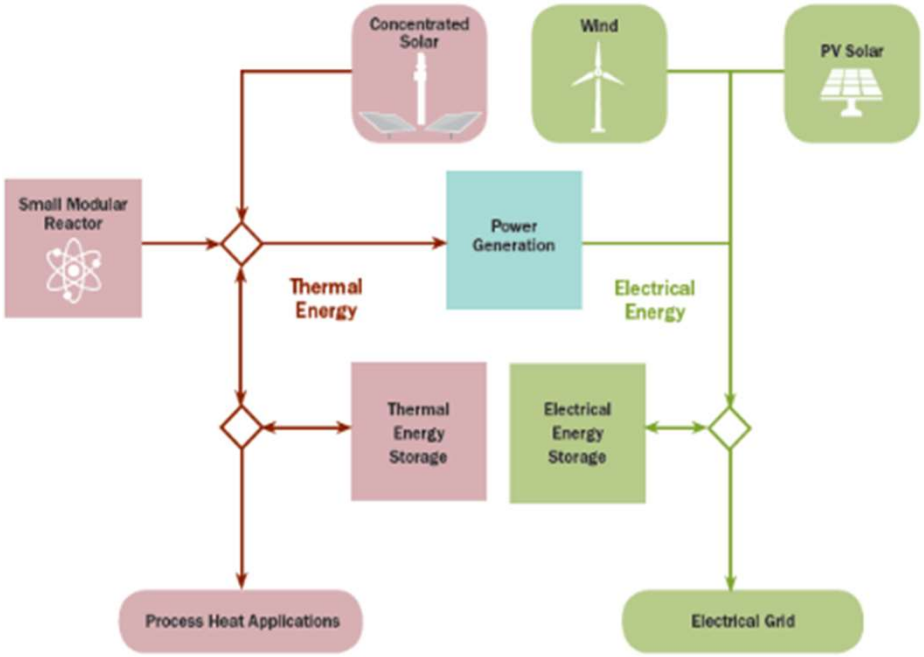
Overview

- Introduction - Jeff Merrifield and Pillsbury
- Brief overview of advanced reactor technologies
- Technical, system, climate change, and commercial benefits of and challenges for advanced nuclear
- Durable U.S. Government support for speedy commercialization
- Potential role in the hydrogen economy



Conceptual Diagram of Advanced Nuclear Integrated in a Hybrid Decarbonized Grid. (INL 2017)

Honorable Jeffrey S. (Jeff) Merrifield



- Energy Section Leader – Pillsbury Law Firm (2015-Present)
- Commissioner – Appointed by Presidents Clinton and Bush to serve as U.S. NRC Commissioner (1998-2007)
- Senior V.P. – Shaw Power Group/CBI – nuclear engineering, construction, maintenance and decommissioning (2007-2014)
- Chairman, Advanced Nuclear Task Force – Nuclear Industry Council
- Chairman – E4 Carolinas – Largest "All-in" U.S. Energy Association Outside of Washington
- Chambers Ranked Attorney

Practice Areas/Industries

- Energy
- Nuclear Energy
- Strategic Planning
- Advanced Reactors
- Decommissioning
- Nuclear Security
- Mergers and Acquisitions
- Employee Concerns

- Pillsbury Winthrop Shaw Pittman LLP
  - International, 700+ attorney firm with 21 offices in key financial, energy, technology, and government centers (New York, Washington DC, London, Los Angeles, Houston, Austin, Silicon Valley, Beijing, Taipei, Shanghai, and Tokyo)
  - The oldest dedicated nuclear law group in the world
  - First hydrogen practice of a major law firm
  - Industry-leading experience in energy and environmental regulatory and transactional law

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U.S. Energy Companies that Have Pledged to Achieve 80-100% Carbon Free Generation By 2050

Advanced Nuclear Reactors – Definition/Classification

- Advanced nuclear is categorized in terms of electrical generation capacity
  - Microreactors: <10 MWe
  - Small-scale reactors: 10MWe - <300 MWe
  - Large-scale reactors: >300 MWe
- Small-scale reactors are often characterized as small modular reactors (SMRs) to reflect method of fabrication and construction
- Further classified by type of moderator transferring heat from the fission reaction to the steam plant
  - Light water (LWRs)
  - High-temperature gas (HTGRs)
  - Liquid metal-cooled
  - Molten salt

Advanced nuclear largely represents innovative, evolutionary applications of historically proven design elements.



Shippingport: the first U.S. commercial nuclear power plant —and an SMR!

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Representative Technologies

Design	Classification	Nameplate Capacity	Licensing Status
NuScale Reactor	Light Water	77 MWe	NRC Approved Final SER on 08/28/20. $1.4 billion DOE funding for UAMPs demonstration of 6-module reactor at Idaho National Laboratory.
GE Hitachi BWRX-300	Light Water	300 MWe	Selected for potential deployment by Ontario Power Generation (OPG) and Tennessee Valley Authority (TVA). First topical report submitted to NRC.
X-Energy XE-100	High-Temp Gas (Pebble Bed)	80 MWe	Selected for ARDP - $80 million by DOE to deploy at EnergyNorthwest site in Washington State. NRC pre-application discussions.
Terrestrial Energy IMSR	Molten Salt	195 MWe	Selected for USNRC/CNSC pilot project. NRC pre-application discussions.
TerraPower Natrium Reactor	Sodium Fast Reactor with Molten Salt Storage System	345 Mwe 500 MWe (5 ½ hours) - with Molten Salt	Selected for ARDP- $80 million by DOE. Partnered with PacificCorp to construct at former coal plant in Wyoming.
Oklo Aurora	Metal	1.5 MWe	Filed a combined construction and operations license with the NRC on March 11, 2020 – licensing review suspended.
Kairos Power	Pebble Bed with Molten Salt Coolant	140 MWe	Selected for $30 million risk reduction award by DOE.
Westinghouse eVinci	Solid Core Heat Pipe	200 kWe to 5 MWe	Selected for $30 million risk reduction award by DOE



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Developments in Canada



- New Brunswick Power – Selected two technologies: Moltex (Molten Salt) and Advanced Reactor Concepts (Fast Reactor) for potential deployment at Point Lepreau
- Ontario Power Generation – Selected GE/Hitachi-BWRX-300 (LWR) for deployment at the Darlington (December 2021)
  - SaskPower and Bruce Power are collaborating with OPG on potential deployment
- Canadian National Laboratory (Chalk River) will serve as the site for the UltraSafe Microreactor
- Canadian Nuclear Safety Commission currently has 10 reactors under review in the Vendor Design Review Process
- Significant opportunities for Canadian/U.S. collaboration

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Europe

- **Poland** – GE Hitachi, BWXT and Synthos Green Energy signed an agreement in December of 2021 signed agreement to deploy up to 10 of GEH's BWRX-300 reactors in Poland by the 2030s
- **United Kingdom** – November 2021, Rolls Royce Granted $285 million by UK Government to deploy 470 MWe light water reactor technology – up to 16 units planned
- **Romania** – November 2021 – Chernavoda Utility and NuScale announcement agreement for deployment of NuScale reactor in Romania by 2028
- **Russia** – December 2019 – First commercial barge, Akademik Lomonosov connected to the grid – two 35 MWe units located in Russian Far East



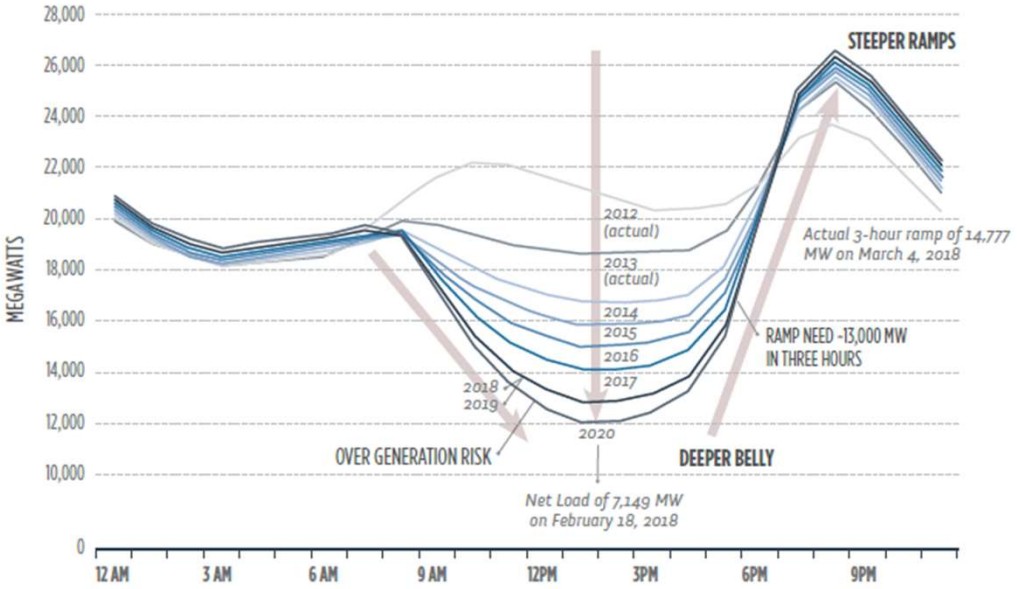
Rolls Royce SMR Rendering



Akademik Lomonosov

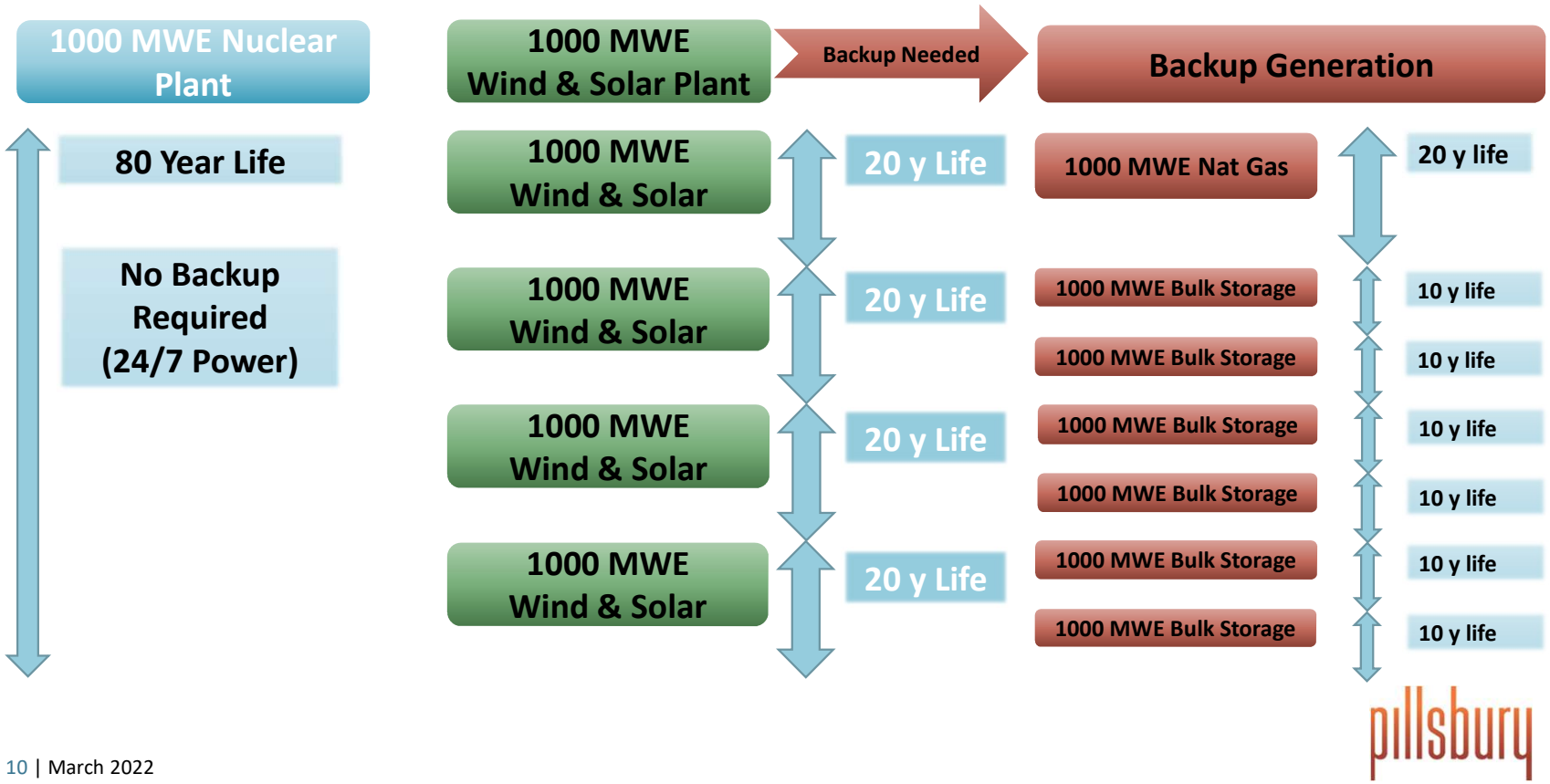
Technical Advantages

- Smaller size/modularity
- Lower accident risk from improved safety features
- Reduced emergency evacuation zone
- Emissions-free generation
- Load-following capability



The famous CAISO duck curve—illustrating the system challenges from pursuing decarbonization primarily through intermittent resources on a typical spring day (CPUC 2019, based on 2018 CAISO data)

Cost-Effective Element of a Deep Decarbonization Portfolio



Other Commercial/Regulatory Benefits

- Scalable, 24/7 power to meet incremental electric demand growth.
- Reduced overnight costs
  - Developer's target cost $3,250-$5,500 KW
- Unique resilience benefits
- Greater flexibility means more potential applications, including…
  - Repowering existing fossil fuel sites
  - Process heat for industrial applications and water purification/desalination and hydrogen production
  - Critical service applications



Oklo's Aurora reactor: construction at INL expected to start in mid-2020s. (Oklo 2019)

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Federal Action Expediting Commercialization

- Bipartisan Congressional support for advanced nuclear
  - FY2021 nuclear funding increased to $1.5 billion
  - Bipartisan nuclear legislation (NELA, etc.)
- Strong executive branch support for advanced nuclear—has been continued by incoming Biden Administration
  - FY2022 – Biden Administration Budget request of $1.86 billion
- October 2020: DOE announced first 2 Advanced Reactor Demonstration Program recipients (Terrapower and X-energy) providing in Year 1:
  (1) $160 million in DOE cost-sharing to deploy two advanced reactor demonstration projects, and
  (2) an additional $30 million (each) in DOE cost-sharing to support other five other advanced reactor designs
- U.S. NRC has directed significant resources toward adapting its licensing regime for advanced nuclear
- Development Finance Corporation announced it will provide loans and equity support for nuclear generation outside of the U.S.
- Bi-partisan infrastructure legislation appropriated $2.477 billion towards the Advanced Reactor Demonstration Program, to be managed by the new DOE Office of Clean Energy Demonstrations



THE WHITE HOUSE
WASHINGTON

DEPARTMENT OF DEFENSE
UNITED STATES OF AMERICA

DEPARTMENT OF ENERGY
UNITED STATES OF AMERICA

U.S.NRC

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Hydrogen Market - Nuclear

- <u>DOE Office Of Nuclear Energy - Advanced Nuclear Technology Development</u>
  - October 2020 issued two awards, totaling $26 million, to demonstrate high and low temperature electrolysis at existing U.S. nuclear power plants
    - XCEL (Prairie Island Plant) – high-temperature steam electrolysis process to split water for commercial grade hydrogen production and power generation
    - FuelCell Energy Inc. of Connecticut to team with Idaho National Laboratory to demonstrate a solid oxide electrolysis cell hydrogen production system for integration at existing units
  - October 2019 – Energy Harbor (Davis Besse) and Arizona Public Service (Palo Verde) received grants to demonstrate commercial level hydrogen production via low-temperature electrolysis



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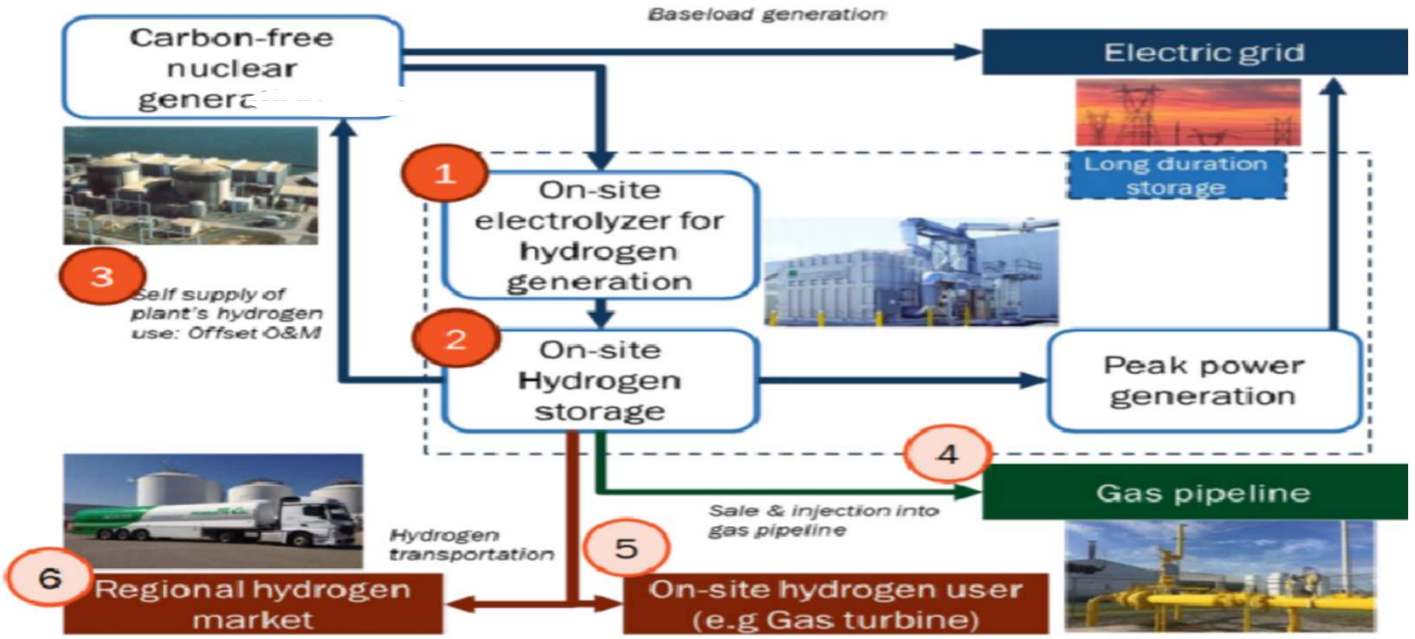
Pair Technologies to Reduce Carbon

Electrolysis + Renewables/Nuclear



Constellation Nuclear + Norwegian firm Nel – Hydrogen Process at Nine Mile Point Station – State of N.Y.

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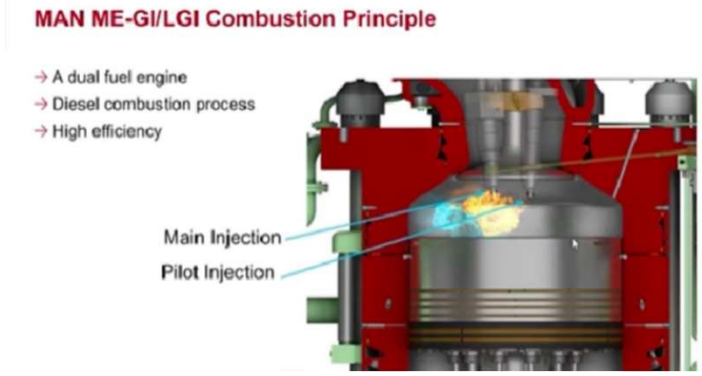
Hydrogen Market – Marine Shipping





- Marine transport responsible for 2.5% of all human-induced CO_2 emissions
  - 50% from large ships, tankers that can't be electrified
  - International Maritime Organization has a goal of reducing annual GHG emission by at least 50% by 2050 (compared to 2008 levels)
- **Ammonia as fuel:**
  - Ammonia is easier to store and transport than H2
  - H2 converted to ammonia to use as marine fuel
- **Planned Activity:**
  - By early 2024, Man Energy Solutions plans to install its ammonia-ready engine on a ship which will initially use dual fuels
  - Wärtsilä working on engine designs, field tests by 2022; developing ammonia storage/supply systems for Eidesvik Offshore's vessel Viking Energy by 2023
    - Viking Energy will be world's first carbon-free ammonia vessel

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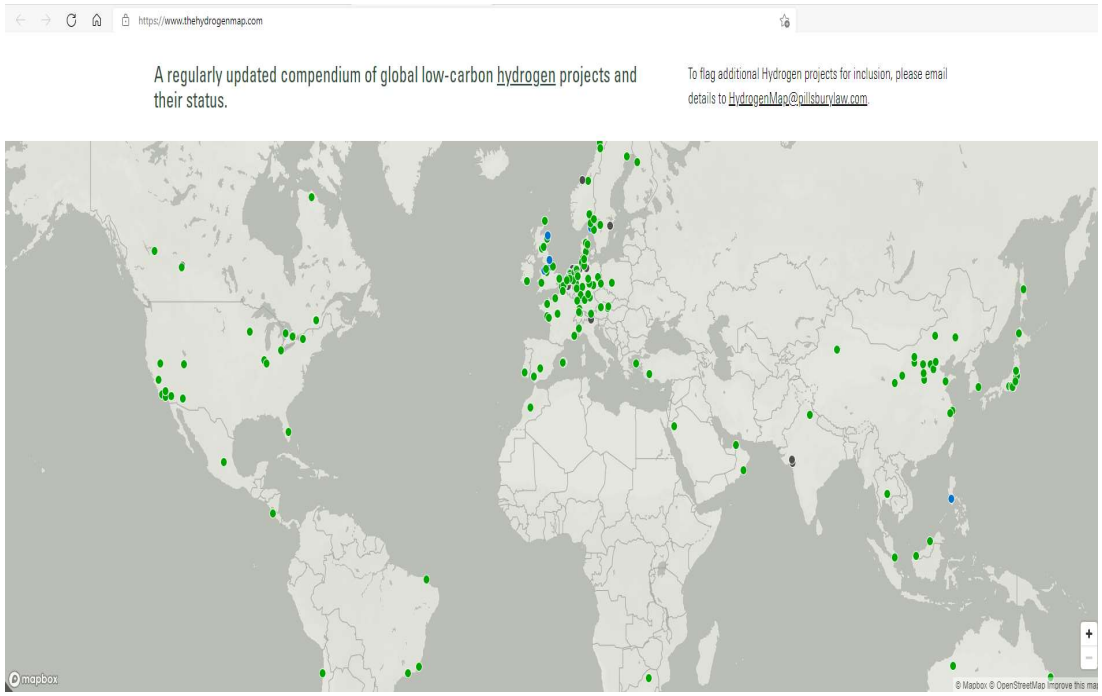
thehydrogenmap.com



- Go-to resource for those evaluating global hydrogen projects
- Pillsbury recognized as hydrogen industry leader for work related to:
  - decarbonization of transportation
  - iron and steel making using hydrogen
  - use of hydrogen as storage in renewables space
  - hydrogen generated from nuclear units



Closing Thoughts and Contact Information

Questions?

Pillsbury Winthrop Shaw Pittman
+1.202.663.8718 (office) +1.703.629.5601 (mobile)
Jeff.Merrifield@pillsburylaw.com

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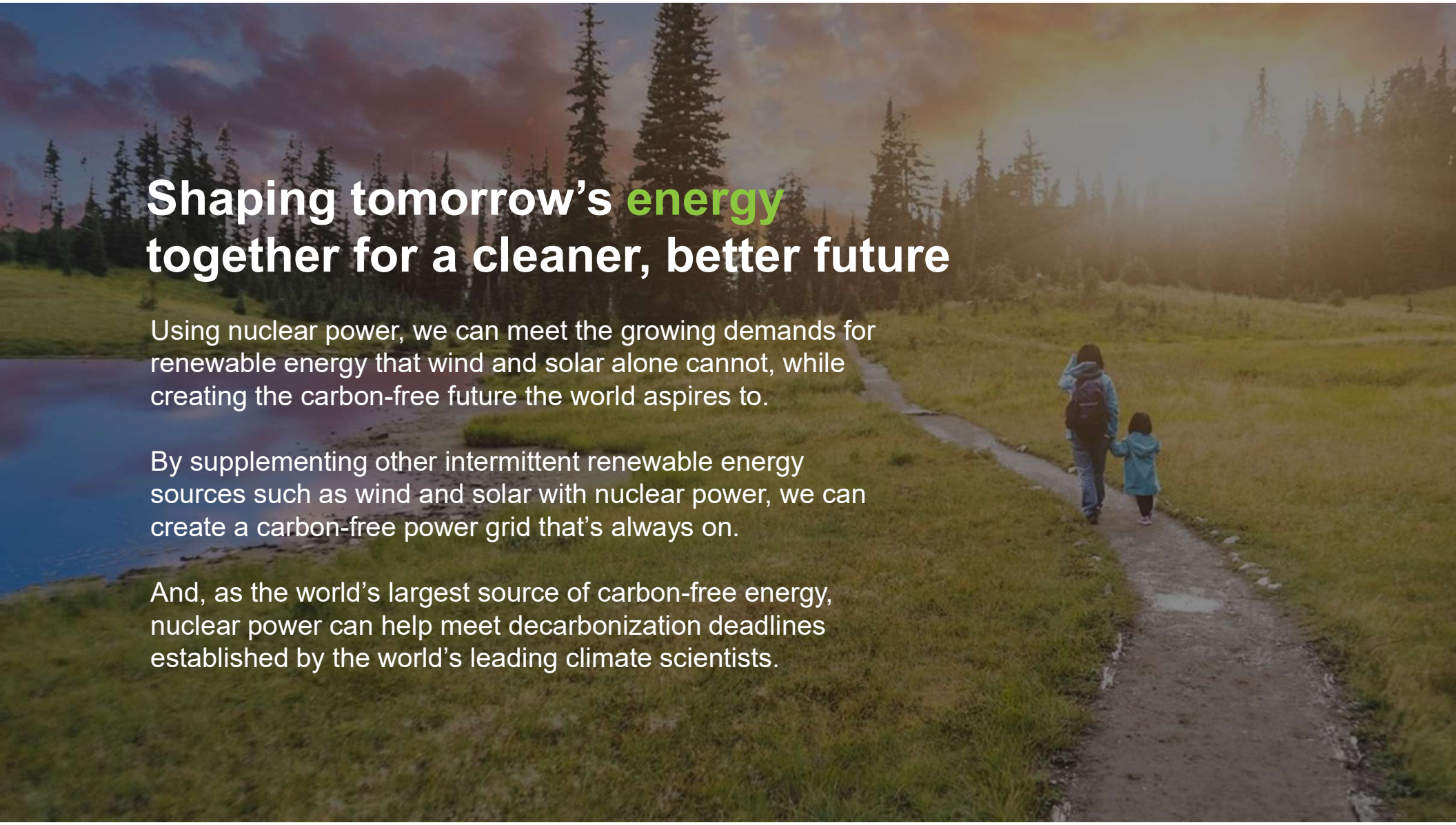
Shaping Tomorrow's
Energy
Rita Baranwal
Chief Technology Officer
March 1, 2022
Westinghouse


“Energy is central to nearly every major challenge and opportunity the world faces today.”
—The United Nations
Over the next 20 years, the world population is expected to grow 25% and, by 2030, demand for electricity will nearly double.
Finding solutions to our increased energy needs while confronting the realities of a changing climate might be the most pressing issue of our time.



Shaping tomorrow's energy together for a cleaner, better future

Using nuclear power, we can meet the growing demands for renewable energy that wind and solar alone cannot, while creating the carbon-free future the world aspires to.

By supplementing other intermittent renewable energy sources such as wind and solar with nuclear power, we can create a carbon-free power grid that's always on.

And, as the world's largest source of carbon-free energy, nuclear power can help meet decarbonization deadlines established by the world's leading climate scientists.

About **Westinghouse**

Approximately

9,000

Employees

Locations in

19

Countries

Comprised of

5

Business Units

AMERICAS OPERATING PLANT SERVICES

EMEA OPERATING PLANT SERVICES

ASIA OPERATING PLANT SERVICES

ENERGY SYSTEMS

ENVIRONMENTAL SERVICES

More Than

70

Facilities

Our Technology Generates Nearly

50%

Of the World's Nuclear Power

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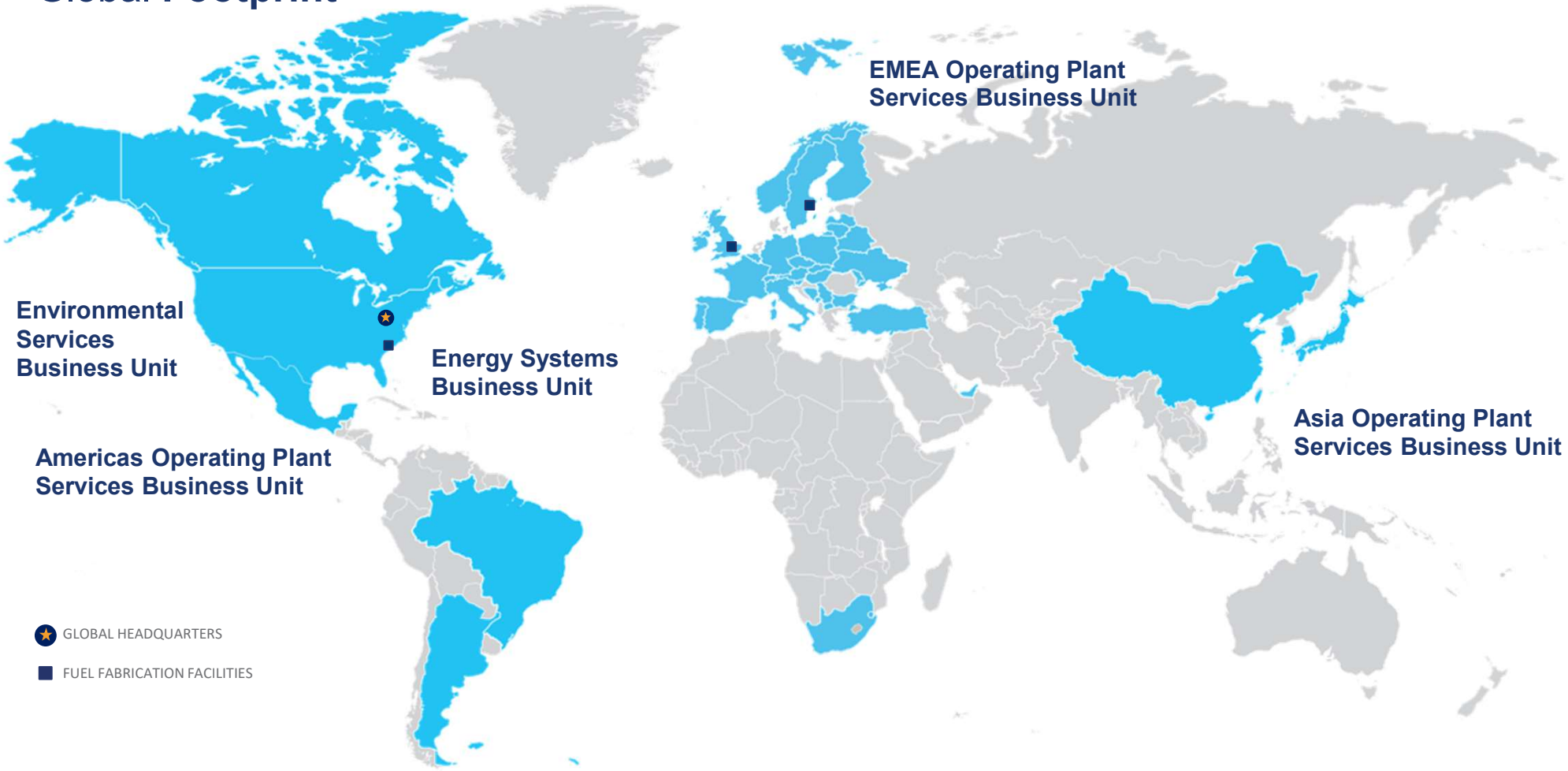
Global **Footprint**



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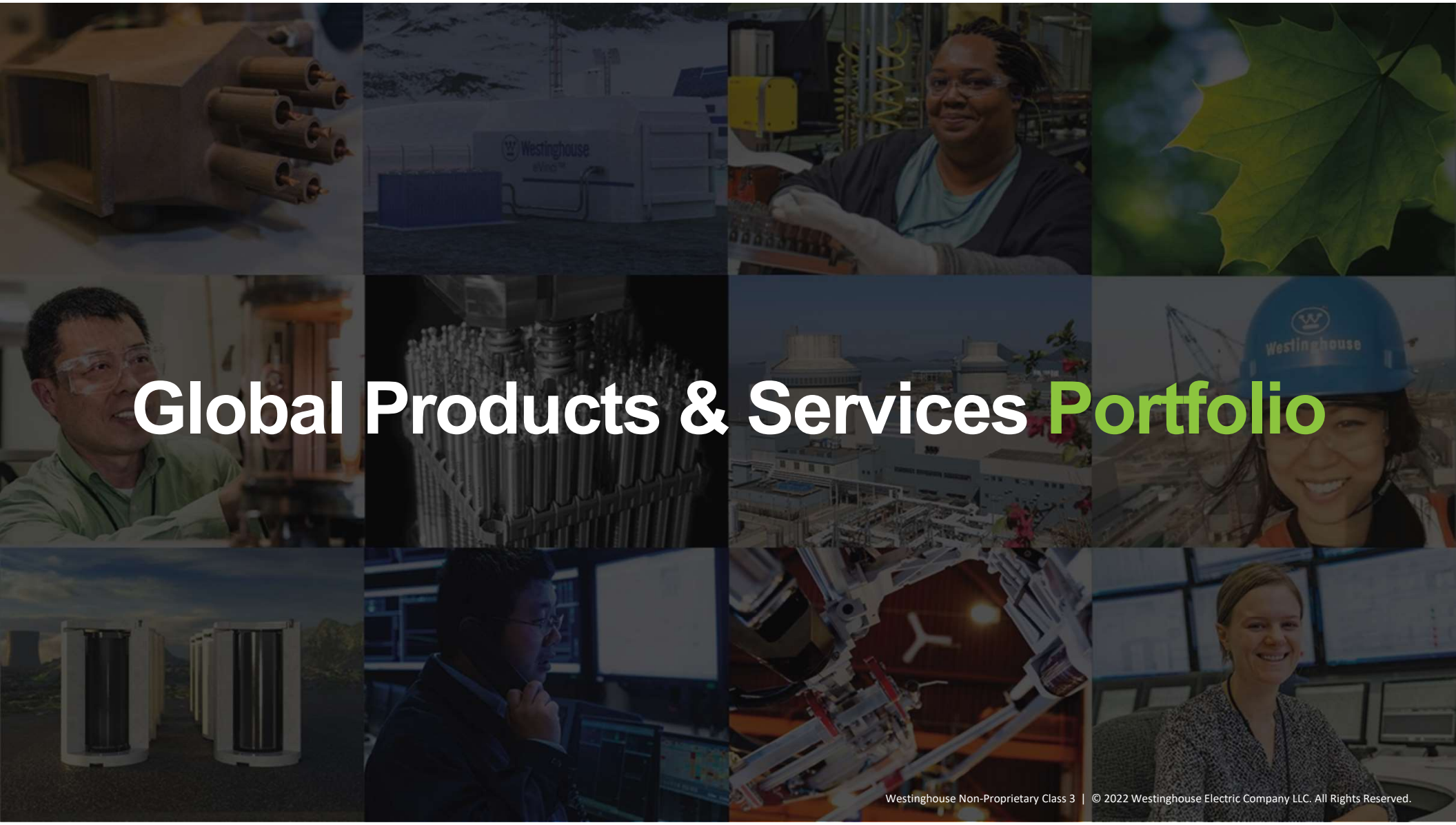

Global Products & Services Portfolio

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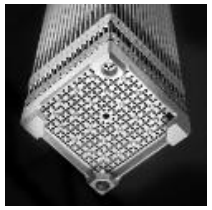
Global Products & Services **Portfolio Snapshot**



Nuclear Fuel



Instrumentation & Control



Staffing Services



Components & Manufacturing



Field Services and Plant Modifications



New Plants



Engineering Services



Decontamination & Decommissioning Solutions



Project and Engineering Services

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New Plants

The Westinghouse AP1000® plant, a Generation III+ two-loop pressurized water reactor (PWR), is considered the most advanced commercially available plant, offering an industry-leading design featuring passive safety systems.

Westinghouse provides the development, licensing, detailed engineering, project management, component manufacturing and startup support for new nuclear power plants.

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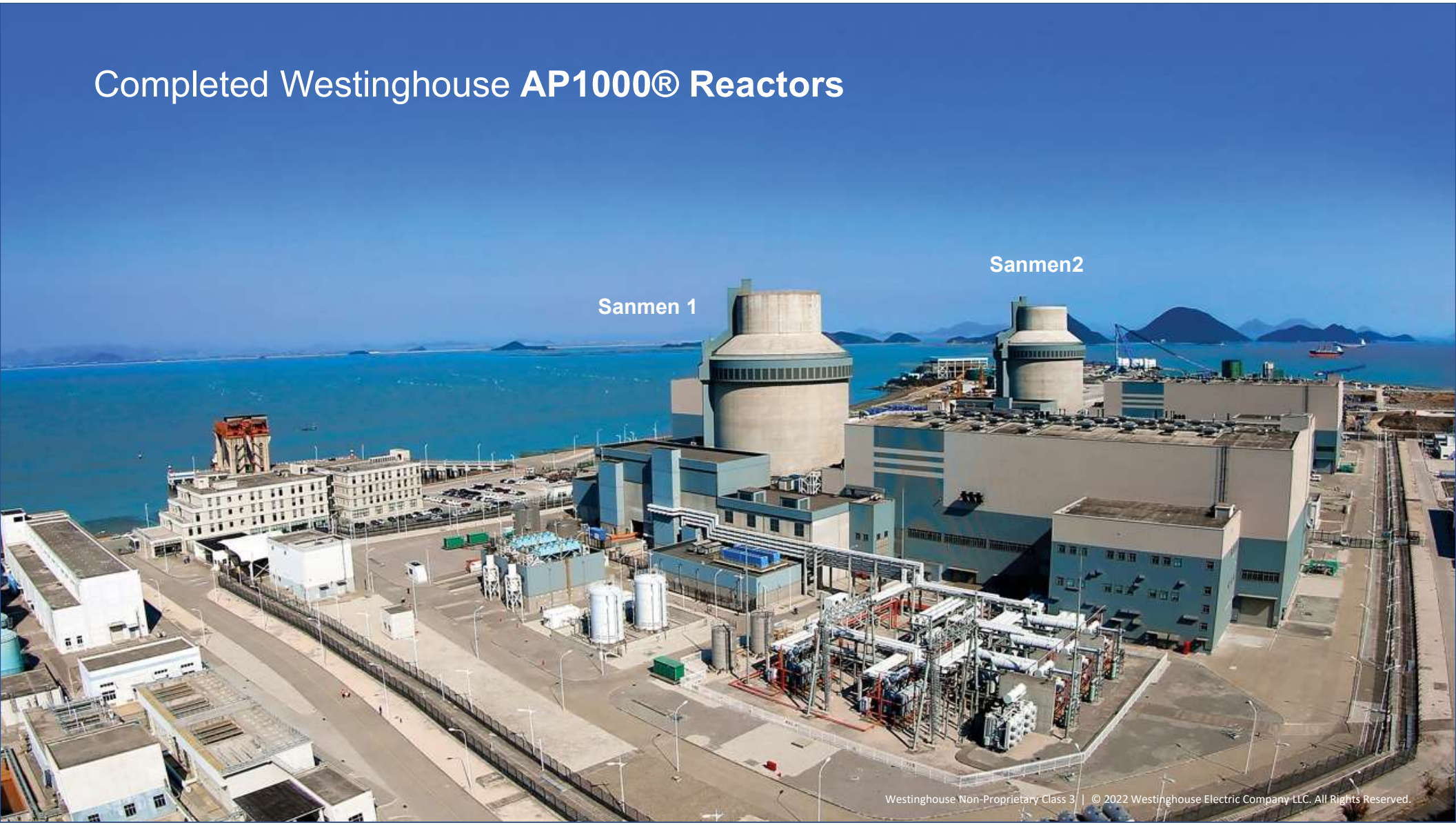
Completed Westinghouse **AP1000® Reactors**



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eVinci™ Micro Reactor

eVinci is a next-generation micro reactor for decentralized generation markets

Demonstration Strategy

2 years Electrical Demonstration Unit (EDU)

3 years Nuclear Demonstration Unit (NDU)

2019 — **2021** — **2024**

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eVinci Micro Reactor

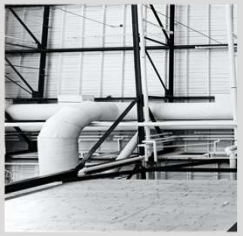
Prospective Markets/End Uses



Remote mining operations



Industrial process heat



District heating



Remote communities



Hydrogen Generation



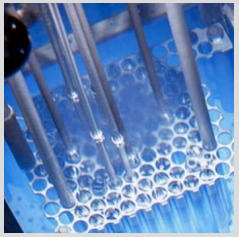
Marine Shipping



Critical Infrastructure Installations



Disaster relief



Research Reactors

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eVinci Micro Reactor Deployment

Transportability Advantages



Minimizes construction cost and labor

Installation to operation in less than 30 days

- ❑ **Entire plant delivered in four truckload size containers (40’ x 14’ x 14’)**
  - Reactor container
  - Power conversion unit
  - Instrument and controls
  - Miscellaneous support equipment

- ✓ **Weights and sizes allow for deployment in remote areas (truck/rail/barge)**
- ✓ **Allows for rapid scaling to meet demand supporting scale up, life extension and ramp down**
- ✓ **No spent fuel or waste storage on site**
- ✓ **Minimizes decommissioning**

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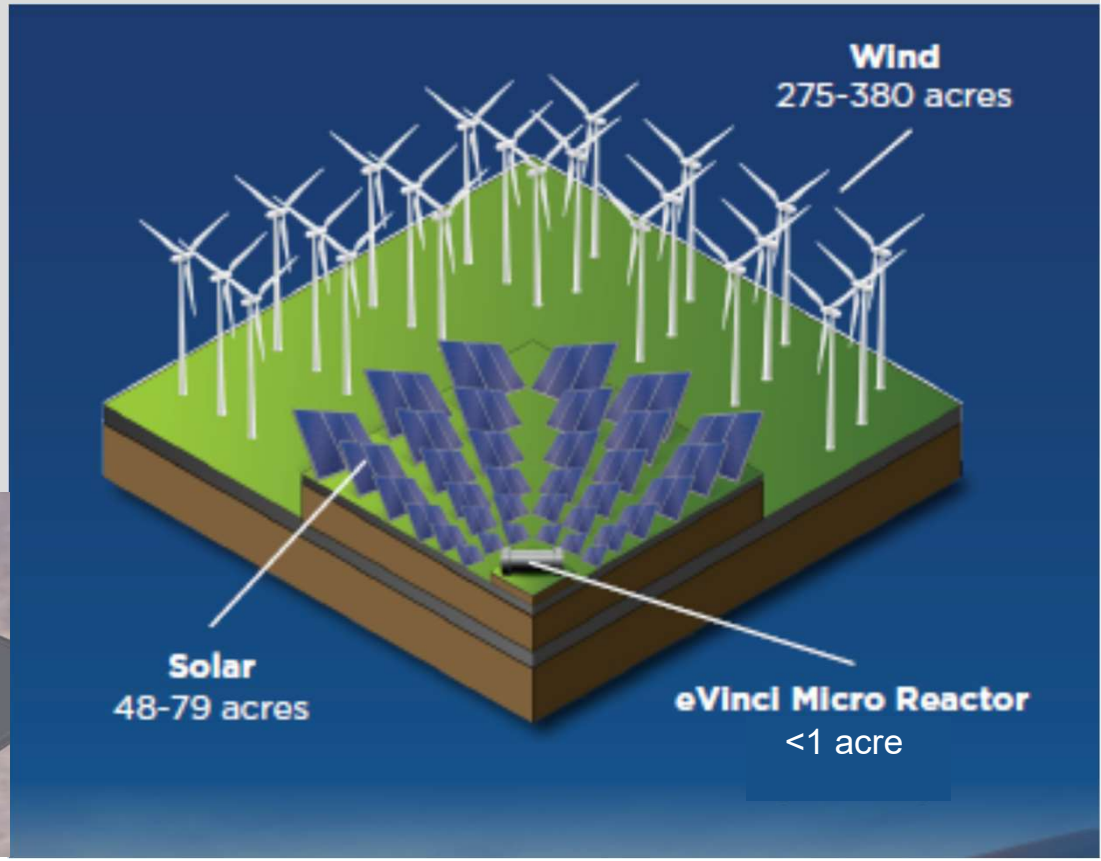
eVinci Micro Reactor
Footprint

- Near 100% capacity factor versus intermittent renewable supply
- Building shields radiation
- Emergency planning zone contained within site boundary
- All construction above ground
- Site footprint: **1.5 acre**
- Building footprint: **0.25 acre**





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